generally concur with that recommendation. More detailed descriptions of this multimetric index development can be found in Karr and Chu (1999), Barbour et al. (1999), and Hill et al. (2000)

ASSESSING NUTRIENT-ALGAL RELATIONSHIPS USING EXPERIMENTAL PROCEDURES

Management of nutrients to ensure high stream quality is greatly strengthened by examining relationships between the limiting nutrient and maximum algal biomass (i.e., potential) that will occur if/when other factors are optimum. Relationships between ambient nutrient content and existing biomass may not adequately predict maximum biomass potential for any single stream because other factors, such as light, high-flow scouring, and grazing often limit biomass accrual in natural streams. Experimental procedures are valuable for determining the maximum biomass potential of a system. However, physical constraints imposed in experimental setups are often unrealistic. Thus, the value of extrapolating results from laboratory experiments to natural conditions is often uncertain. There are many more experimental results reported to determine which nutrient (N, P, or carbon) limits algal growth, than to determine nutrient-biomass relationships. Experimental procedures to determine the limiting nutrient/s for algal growth are discussed earlier in this section (see Defining the Limiting Nutrient).

As indicated previously, biomass levels up to 1000 mg/m^2 chl *a* were accrued on stones of in-stream channels receiving as little as 10 mg/L SRP (Walton et al. 1995). Although *Cladophora* has not been grown in channels, other filamentous green algae (FGA) (*Mougeotia*, *Stigeoclonium*, *Ulothrix*) have dominated in such experiments. In contrast, bottle tests with unattached *Cladophora* have shown that growth/biomass is not saturated at such low SRP concentrations (Pitcairn and Hawkes 1973), indicating results from flowing-water channel experiments more closely represent natural systems. Nevertheless, Bothwell (1989) did show added accrual of diatom films from about 250 mg/m^2 chl *a* at an SRP of 5 μg/L, increasing to 350 mg/m^2 at about 50 μg/L.

There may be problems with achieving a species assemblage in channel experiments that is representative of the natural stream(s) in question. In fact, accurate prediction or even chatacterization of ambient assemblages in dynamic systems may be challenging. *Cladophora* has been difficult, if not impossible, to establish in such systems, and other FGA have not established on Styrofoam substrata (used by Bothwell 1985), even when abundant in the source stream. Diatoms are usually first to establish, with more time required for FGA to colonize due to their more complex reproduction requirements. Natural stones seem to be the most effective substratum for colonizing either diatoms or FGA in these systems, but resulting dominant taxa in channels may not replicate exactly as in natural streams, even though channels are inoculated from stream rocks. Moreover, diatoms may, in fact, dominate the biomass in channels even though FGA establishes and appears most abundant to the eye. Correctly predicting community composition in future stages of succession is very difficult, even in simple systems. Given the complexity inherent in dynamic ecosystems, only excessively broad predictions may be possible. Data gathered from channel experiments may be little better at characterizing process than a grab sample is at characterizing water chemistry. Only simple extrapolations can be made employing data gathered from simple systems.

Caution is recommended in applying nutrient-biomass relationships developed in channel experiments to natural streams, primarily for two reasons: (1) TP and TN content required to produce a maximum biomass will probably be higher in natural streams than in channels, as previously discussed, because more detrital TP and TN will accumulate in enriched natural streams than in short-detention time channels. Hence, the yield (i.e., slope of regression line) of chl *a*/TP or TN in channels will be greater. (2) The more or less continual input of soluble nutrients from groundwater to the natural stream is usually unknown, so inflow soluble nutrient-maximum biomass relations from short-detention time channels may not be applicable to natural streams where in-stream soluble nutrients are low as a result of algal uptake during long travel times, yet may have a relatively high inflow concentration of soluble nutrients.

OTHER ISSUES TO KEEP IN MIND

Changes in certain physical factors including: (1) riparian vegetation; (2) total suspended solids (TSS); (3) reduced flow following scouring-flood conditions; (4) greatly reduced summer flow due to prolonged drought (somewhat common); or (5) reduced grazing may cause nuisance algal growths in stream systems. Identifying the controlling physical constraint(s), should be rather straightforward. If the stream is shaded, available light at the streambed should be measured to determine the extent to which photosynthesis is inhibited (Jasper and Bothwell 1986; Boston and Hill 1991). Shading can substantially reduce production (Welch et al. 1992), even though photosynthesis of periphyton is usually saturated at relatively low intensities (<25% full sunlight; Boston and Hill 1991). Turbidity can inhibit periphyton at relatively low levels (>10 NTU) (Quinn et al. 1992).

Biggs (1996) argued that flood disturbance is “perhaps the fundamental factor” determining the physical suitability for algal accrual in unshaded streams. Floods act as a “reset” mechanism, initiating a new cycle of accrual, succession, and loss due to grazing. Post-flood (scour) accrual rates are related to enrichment level (Lohman et al. 1992). The role of scouring high flow should be readily discernible from flow records and the seasonal pattern of periphyton accrual (Biggs 1996).

Flow can also regulate biomass. For example, *Cladophora* was observed to reach high biomass followed by senescence and detachment from substrata in enriched, unregulated northern California rivers, which experienced winter flooding and scour (Power 1992). In regulated rivers, where the flood, scour, and re-growth phenomenon did not occur, low biomass levels of *Cladophora* were maintained through grazing.

6.3 STATISTICAL ANALYSES

Statistical analyses are used to identify variability in data and to elucidate relationships among sampling parameters. Several statistical approaches for analyzing data are mentioned here. We advocate simple descriptive statistics for initial data analyses, i.e., calculating the mean, median, mode, ranges and standard deviation for each parameter in the system of interest. The National Nutrients Database discussed in Chapter 5 will calculate simple descriptive statistics for queried data. Creating a histogram or frequency distribution of the data for the class of streams of concern can identify the nutrient condition continuum for that class of streams. Specific recommendations for setting criteria using frequency distributions are discussed in Chapter 7, although the basis for the analysis is discussed here. Methods of statistical analyses are included in Appendix C to provide relevant references for the investigator if additional analyses are needed to understand and interpret data for criteria derivation.

FREQUENCY DISTRIBUTION

Frequency distributions can be used to aid in the setting of criteria. Frequency distributions do not require prior knowledge of individual stream condition prior to setting criteria. Criteria are based on and, in a sense, developed relative to the population of stream systems in the Region, State, or Tribe.

Data plotted on a scale of mean nutrient concentration versus frequency of occurrence in a specific stream class produces a frequency distribution of mean nutrient concentration. Plots of frequency distributions of mean TP, mean TN, mean chl *a*, and turbidity for the index period (discussed in Chapter 4) should be examined to determine the normalcy of the data in the distribution and to locate patterns for the class of streams being investigated. A sample size of thirty streams within a stream class is recommended for developing nutrient criteria. Smaller sample sizes will require more reference streams, more complete knowledge of the stream systems being investigated, more in-depth statistical analyses, and/or modeling to complete criteria derivation. Sample sizes smaller than thirty may be highly affected by extreme values in the dataset. Data that are not normally distributed are often transformed into a distribution more approximating the normal distribution by taking the logarithm of each value. Analysis of outliers may assist in explaining variability in small data sets. Additional analysis can be conducted to identify the statistical significance of population differences.

CORRELATION AND REGRESSION ANALYSES

The relationship between two variables may be of use in analyzing data for criteria derivation. Correlation and regression analyses allow the relationship to be defined in statistical terms. A correlation coefficient, usually identified as r, can be calculated to quantitatively express the relationship between two variables. The appropriate correlation coefficient is dependent on the scale of measurement in which each variable is expressed (whether the distribution of data is continuous or discrete) and, whether there is a linear or non-linear relationship. Results of correlation analyses may be represented by indicating the correlation coefficient, and represented graphically as a scatter diagram which plots all of the collected data, not just a measure of central tendency. The statistical significance of a calculated correlation coefficient can be determined with the t test. The t test is used to determine if there is a true relationship between two variables. Therefore, the null hypothesis states that there is no correlation between the data variables measured within the population. A critical α value is chosen as a criterion for determining whether to reject the null hypothesis. If the null hypothesis is rejected, the alternate hypothesis states that the correlation at the calculated r value between the two variables is significant.

Regression analyses provides a means of defining a mathematical relationship between two variables that permits prediction of one variable if the value of the other variable is known. In contrast to correlation analyses, there should be a true independent variable (a variable under the control of the experimenter) in regression analyses. Regression analyses establishes a relationship between two variables that allows prediction of the dependent variable (predicted variable) for a given value of an independent variable (predictor variable). However, scientists (other than statisticians) apply regression analyses to field data when a relationship is known to exist, even when there is no true independent variable (e.g., cell counts of algae and chlorophyll concentration; nutrient concentrations and chlorophyll concentration) (Ott 1988, 1995; Campbell 1989; Atlas and Bartha 1993).

TESTS OF SIGNIFICANCE

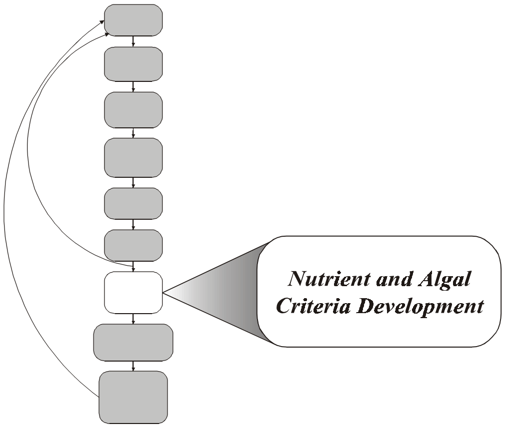
Various statistical tests are used to assess the hypotheses being tested. Statistical tests of significance differ in their applicability to the dataset of interest, and the power of the test (the ability of the test to detect a false null hypothesis). A parametric test of significance assumes a normal distibution of the population. Non-parametric analyses are valid for any type of distribution (normal, log-normal, etc.) and can be used if the data distribution is not normal or unknown. A parametric test has more power than a non-parametric test when its assumptions are satisfied. Two types of errors can be made when testing hypotheses: Type I–where a correct null hypothesis is mistakenly rejected, and Type II–when there is a failure to reject a false null hypothesis. The parametric test is less likely to make a Type II error, when the assumptions are met, than a non-parametric test. Therefore, if given a choice, the parametric test should be used rather than the non-parametric test when the assumptions of the parametric test are fulfilled. Less powerful, non-parametric tests of significance must be used in cases where the data do not fit the assumption of a normal distribution (Ott 1988; Campbell 1989; Atlas and Bartha 1993). Parametric tests include: the student *t* test, analysis of variance, multivariate analysis of variance, and multiple range tests. Non-parametric tests include: chi square, Mann Whitney U test; and the Kruskal - Wallis test (Ott 1988; Campbell 1989; Atlas and Bartha 1993) Detailed descriptions of these and other relevant statistical tests can be found in Appendix C.

6.4 USING MODELS AS MANAGEMENT TOOLS

Computer simulation modeling and probability testing can be used to predict responses to candidate criteria (i.e., numeric nutrient concentrations). Models that have been calibrated and verified can be used to extrapolate to a projected nutrient condition where existing data are either insufficient or unavailable. Data from the same system that is far removed from the present can be used if parameters can be adjusted to the present conditions. The model output can be compared to data from a similar stream system of the same class and in the same ecoregion for validation. Data from a similar system may also be used to extrapolate the nutrient condition when data for the system of interest are unavailable. In both cases, data are complemented by a set of clearly stated assumptions developed from data representing one point in time to estimate conditions in the future. In some instances, surrogate information such as turbidity and chl *a* concentration can be used to estimate nutrient concentrations.

Site-specific simulation models can also be developed for a system of interest, although this is frequently a time-consuming, expensive process. Site-specific computer simulation models should be solicited from the regional academic community, because they are more accurate for predicting specific waterbody concentrations and loadings. This section will not discuss site-specific model development, although several ecological and water quality modeling texts and articles can assist the investigator in developing such a model (see Fry [1993] and McIntire et al. [1996]). Appendix C provides information on several relevant stream water quality models.

Chapter 7. Nutrient and Algal Criteria Development



7.1 INTRODUCTION

This chapter addresses the details of developing scientifically defensible criteria for nutrients and algae. Three approaches are presented that water quality managers can use to derive numeric criteria for streams in their State/Tribal ecoregions. The approaches that are presented include: (1) the use of reference streams, (2) applying predictive relationships to select nutrient concentrations that will result in appropriate levels of algal biomass, and (3) developing criteria from thresholds established in the literature. Considerations are also presented for deriving criteria based on the potential for effects to downstream receiving waters (i.e., the lake, reservoir, or estuary to which the stream drains). The chapter concludes with the process for evaluating proposed criteria including the role of the Regional Technical Assistance Group (RTAG) in reviewing criteria, guidance for interpreting and applying criteria, considerations for sampling for comparison to criteria, potential revision of criteria, and final implementation of criteria into water quality standards.

The most rational approach for deriving criteria is to determine nutrient values in the absence of non-nutrient related factors that influence growth of algal biomass (e.g., light availability, flow). Then, refinements and exceptions to the criteria can be made based on the extent to which non-nutrient related factors are present for specific streams in an ecoregion or subecoregion. Thus, for both periphyton- and plankton-dominated systems, criteria should be set with the goal of reaching an acceptable algal biomass in streams with little or no light limitation, during periods of stable, post-flood/runoff, and moderate numbers of grazing invertebrates. For periphyton-dominated streams, substrata for attachment is assumed to be adequate and stable.

Expert evaluations are important throughout the criteria development process. The data upon which criteria are based and the analyses performed to arrive at criteria must be assessed for veracity and applicability. The EPA RTAGs are responsible for these assessments. The RTAG is composed of State, Tribal, and Regional specialists that will help the Agency and States/Tribes establish nutrient criteria for adoption into State/Tribal water quality standards. The RTAG is tasked with conducting an objective and exhaustive evaluation of regional nutrient information to establish protective nutrient criteria for the ecoregional waterbodies located in their EPA Region.

7.2 METHODS FOR ESTABLISHING NUTRIENT AND ALGAL CRITERIA

The following discussions focus on three methods that can be used in developing nutrient and algal criteria ranges. The first method requires identification of reference reaches for each established stream class based on either best professional judgement (BPJ) or percentile selections of data plotted as frequency distributions. The second method advocates refinement of trophic classification systems, use of models, and/or examination of system biological attributes to assess the relationships among nutrient and algal variables. The two methods described above should be based on data for the selected index period (see Chapter 4). Finally, the third method provides several published nutrient/algal thresholds that may be used (or modified for use) as criteria. A weight of evidence approach that combines one or more of the three approaches described below will produce criteria of greater scientific validity. This section also discusses how to develop criteria for streams that feed into standing receiving waters.

USING REFERENCE REACHES TO ESTABLISH CRITERIA

One approach that may be used in developing criteria is the reference reach approach. Reference reaches are relatively undisturbed stream segments that can serve as examples of the natural biological integrity of a region. There are three ways of using reference reaches to establish criteria.

1. Characterize reference reaches for each stream class within a region using best professional judgement and use these reference conditions to develop criteria.

2. Identify the 75th percentile of the frequency distribution of reference streams for a class of streams and use this percentile to develop the criteria (see Figure 8 and the Tennessee case study, Appendix A).

3. Calculate the 5th to 25th percentile of the frequency distribution of the general population of a class of streams and use the selected percentile to develop the criteria (Figure 8).

Identification of reference streams allows the investigator to arrange the streams within a class in order of nutrient condition (i.e., trophic state) from reference, to at risk, to impaired. Defining the nutrient condition of streams within a stream class allows the manager to identify protective criteria and determine priorities for management action. Criteria developed using reference reach approaches may require comparisons to similar systems in States or Tribes that share the ecoregion so that criteria can be validated, particularly when minimally-disturbed systems are rare.

Best professional judgement-based reference reaches may be identified for each class of streams within a State or Tribal ecoregion and then characterized with respect to algal biomass levels, algal community composition, and associated environmental conditions (including factors that affect algal levels such as nutrients, light, and substrate). The streams classified as reference quality by best professional judgement may be verified by comparing the data from the reference systems to general population data for each stream class. Reference systems should be minimally disturbed and should have primary parameter (i.e., TN, TP, chl *a*, and turbidity) values that reflect this condition. Factors that are affected by algae, such as DO and pH, should also be characterized. At least three minimally impaired reference systems should be identified for each stream class (see Chapter 2). Highest priority should be given to identifying reference streams for stream types considered to be at the greatest risk from impact by nutrients and algae, such as those with open canopy cover, good substrata, etc. [Conditions at the reference reach (e.g., algal biomass, nutrient concentrations) can be used in the development of criteria that are protective of high quality, beneficial uses for similar streams in the ecoregion.]

Alternatively, a reference condition for a stream class may be selected using either of two frequency distribution approaches. In both of the following approaches, an optimal reference condition value is selected from the distribution of an available set of stream data for a given stream class.

In the first frequency distribution approach, a percentile is selected (EPA generally recommends the 75th percentile) from the distribution of primary variables of known reference systems (i.e., highest quality or least impacted streams for that stream class within a region). As discussed in Chapter 3, primary variables are TP, TN, chl *a*, and turbidity or TSS. It is reasonable to select a higher percentile (i.e., 75th percentile) as the reference condition, because reference streams are already acknowledged to be in an approximately ideal state for a particular class of streams (Figure 8).

The second frequency distribution approach involves selecting a percentile of (1) all streams in the class (reference and non-reference) or (2) a random sample distribution of all streams within a particular class. Due to the random selection process, an upper percentile should be selected because the sample distribution is expected to contain some degraded systems. This option is most useful in regions where the number of legitimate "natural" reference water bodies is usually very small, such as highly developed land use areas (e.g., the agricultural lands of the Midwest and the urbanized east or west coasts). The EPA recommendation in this case is usually the 5th to 25th percentile depending upon the number of "natural" reference streams available. If almost all reference streams are impaired to some extent, then the 5th percentile is recommended.

Both the 75th percentile for reference streams and the 5th to 25th percentile from a representative sample distribution are only recommendations. The actual distribution of the observations should be the major determinant of the threshold point chosen. Figure 8 shows both options and illustrates the presumption that these two alternative methods should approach a common reference condition along a continuum of data points. In this illustration, the 75th percentile of the reference stream data distribution produces a TP reference condition of 20 µg/L. The 25th percentile of the random sample distribution produces a value of 25 µg/L. Because there is little distinction in this case, the Agency may select either 20 µg/L, 25 µg/L, or the intermediate 23 µg/L value as illustrated in Figure 8.

Each State or Tribe should similarly calculate its reference condition initially using both approaches to determine which method is most protective. The more conservative approach is recommended for subsequent reference condition calculations. A State or Tribe may choose to draw one single line vertically through the data distribution to set their criterion (the equivalent of the line drawn at the 23µg/L TP concentration shown in Figure 8). The obvious difficulty is choosing where the line is drawn. If drawn to the left of the central tendency point, most streams are in unacceptable condition and significant restoration management should occur. If the line is drawn to the right of the central tendency point, then most streams would be in acceptable condition and far less effort would be needed for

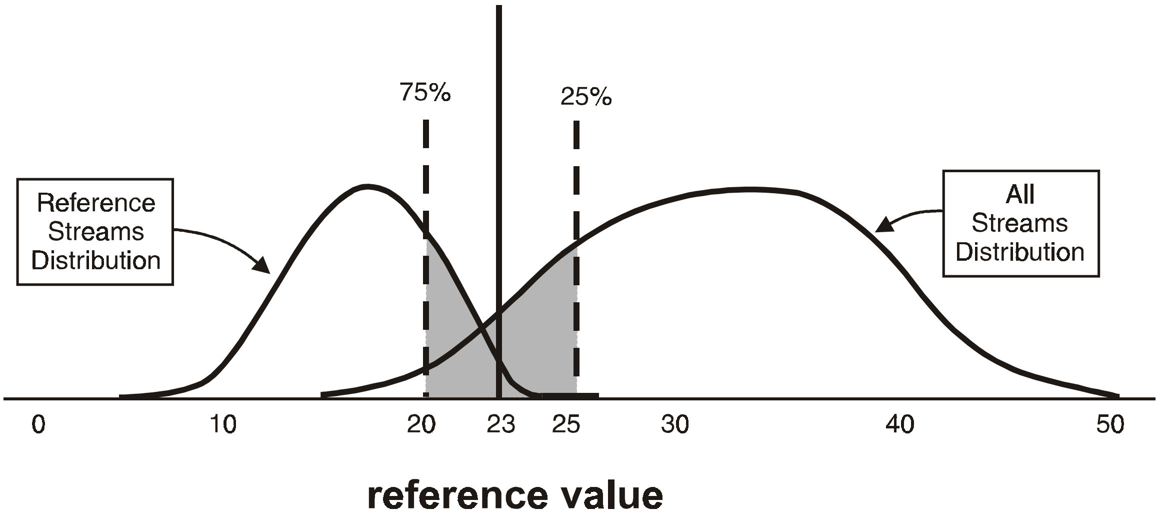


Figure 8. Selecting reference values for total phosphorus concentration (μg/L) using percentiles from reference streams and total stream populations.

restoration. The establishment of a reference condition helps to set the position of the line as objectively as possible.

It is important to understand that any line drawn through the data has certain ramifications; streams in unacceptable condition (on the right) should be dealt with through restoration. The streams to the left of the line are in acceptable condition, and should not be allowed to increase their nutrient concentrations. These streams should be protected according to the State's or Tribe's approved antidegradation policy, and through continued monitoring to assure that no future degradation occurs.

If a State or Tribe desires greater flexibility in setting their criteria, the frequency distribution can be divided into more than two segments (Figure 9). Using this approach, a criterion range is created and a greater number of stream systems fall within the criterion range. This approach divides systems into those that are of reference quality, currently in acceptable condition, or impaired. In this case, emphasis may be shifted from managing stream systems based on a central tendency (as shown above when a single line is drawn through the frequency distribution) to managing systems based on the level of impairment. This approach will also aid in prioritizing systems for protection and restoration. Stream data plotted to the right represent an increasingly degraded condition. Use of this approach requires that subsequent management efforts focus on improving stream conditions so that, over time, stream data plots shift to the left of their initial position.

State or Tribal water quality managers may also consider analyzing stream data based on designated use classifications. Using this approach, frequency distributions for specific designated uses could be examined and criteria proposed based on maintenance of high quality systems that are representative of each designated use.

In summary, frequency distributions can be used to aid in setting criteria. The number of divisions used has significant implications with respect to system management. A single criterion forces the manager to make decisions about the number of streams that will be in unacceptable condition, with considerable ramifications from that decision. If the distribution is divided into three segments, the majority of streams will be in acceptable condition (assuming that these streams are meeting their specified designated uses and do not contribute to downstream degradation of water quality), which will minimize management requirements. The method that is used may depend on the goals of the individual State or Tribe; some may wish to set criteria that encourage all State/Tribal stream systems to be preserved or restored to reference conditions. Other managers may consider additional options, such as developing criteria specific to protect the designated uses established for local streams.

USING PREDICTIVE RELATIONSHIPS TO ESTABLISH CRITERIA

The following section provides several options that can be used to evaluate nutrient and algal relationships in stream systems. These options include use of trophic state classifications, models, and biocriteria.

Trophic State Classification

One challenge associated with setting criteria is defining the relative trophic state of a stream. It is difficult to determine whether a stream is excessively eutrophic if its trophic state is not known relative

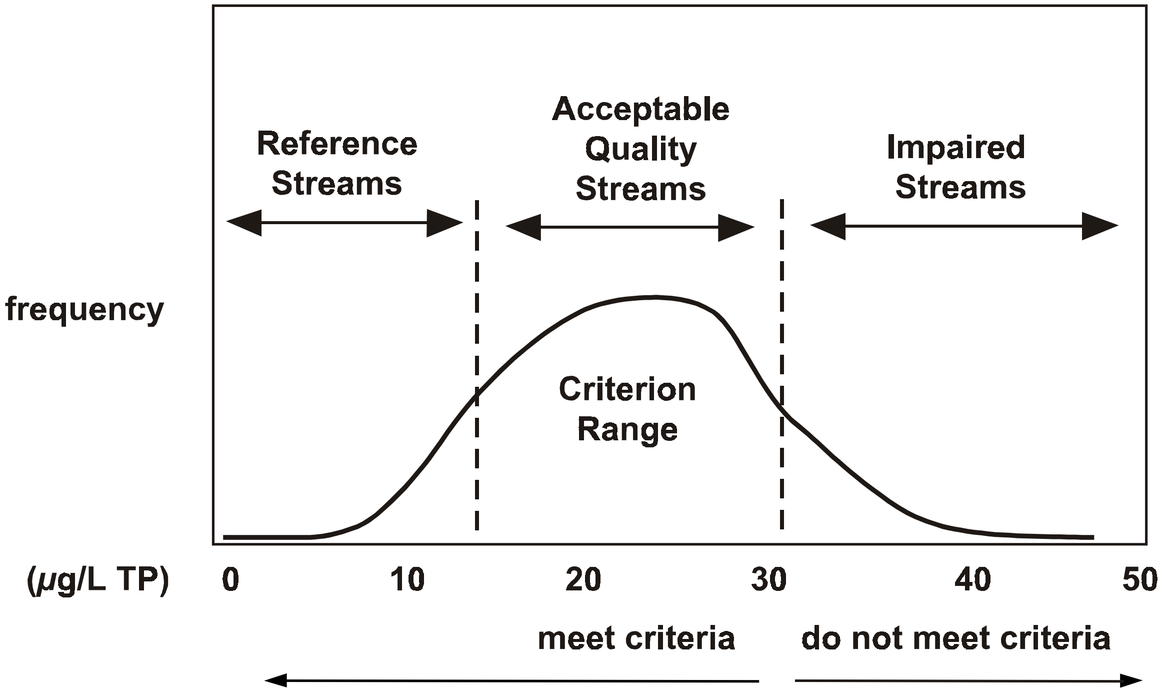


Figure 9. Frequency distribution divided into three segments that represent (from left to right) high-quality reference streams, acceptable quality streams, and impaired streams.

to other streams. There is no generally accepted system for classifying the trophic states of streams (Dodds et al. 1998). The only proposed system divides data plotted as cumulative frequency diagrams into oligotrophic (lower third), mesotrophic (middle third), and eutrophic (upper third) categories (see Chapter 2) (Dodds et al. 1998). This approach is similar to the reference reach method described in the previous section. More data are necessary to determine the applicability of such a classification scheme to streams from different ecoregions.

Models

A few models establish correlations between TN/TP and benthic algal biomass in streams (e.g., Lohman et al. 1992; Dodds et al. 1997; Bourassa and Cattaneo 1998; Chételat et al. 1999; Biggs 2000). Such models estimate algal biomass as a function of water column nutrients (as has often been done for lakes and reservoirs).

A regression model linking TP to river phytoplankton has been published (Van Nieuwenhuyse and Jones 1996). This model can be used to set TP criteria. The TP levels can in turn be used to calculate corresponding TN concentrations using the Redfield ratio (Harris 1986). This model captures additional variance when watershed area is considered (as discussed in Chapter 6).

Finally, it is necessary to relate instream TN and TP concentrations to nonpoint and point sources of nutrients. Models allowing prediction of nutrient loading in streams are needed. A method for determining instream TN and TP concentrations based on loading from point sources has been developed for use in the Clark Fork River (Dodds et al. 1997). Simple correlation techniques using data available from various regions may yield a nutrient and chlorophyll relationship that can be used to predict what management strategies are necessary to bring nutrients from point sources, and consequently algal biomass, to target levels.

Biocriteria

Biocriteria involve the use of biological parameters to establish nutrient impairment in streams. There are two ways to use biocriteria to establish water quality criteria. The first approach involves the protection and restoration of ecosystem services, which is almost exclusively related to biological features and functions in aquatic ecosystems. Although it is recognized that chemical and physical factors play a critical role in the algal-nutrient relationship, it is felt that the effect of nutrients on algae and other components of aquatic ecosystems is critical. This is why ecoregional and waterbody-specific nutrient criteria are recommended and chl *a* and Secchi depth/turbidity, arguably biocriteria, are required. The second approach is based on the concept that attributes of biological assemblages vary less in space and time than most physical and chemical characteristics. Thus, fewer mistakes in assessment may occur if biocriteria are employed in addition to physical and chemical criteria.

Multimetric indices are a special form of biocriteria in which many metrics are used to summarize and communicate in one number the state of a complex ecological system. Multimetric indices for macroinvertebrates and fish are used successfully as biocriteria in many States. A multimetric index of trophic status could be developed to complement N, P, and chl *a* criteria (see Section 6.2, Developing Multimetric Indices to Complement Nutrient Criteria).

The same approaches used to establish nutrient and algal criteria could be employed to establish criteria for other biological attributes, such as a Diatom Index of Trophic State (DITS). Frequency distributions of reference conditions or a random sample of streams would provide a target for management and restoration efforts. Alternatively, dose-response relations (predictive models) between biocriteria and nutrients could be used to set nutrient and biocriteria, based on a desired level of biotic integrity or other valued ecosystem component.

A fourth approach is also possible when characterizing the responses of many biological attributes to nutrients. Some of these factors change linearly with increasing nutrient concentrations, for a number of reasons, and some factors change non-linearly. Non-linear changes in metrics indicate thresholds along environmental gradients where small changes in environmental conditions cause relatively great changes in a biological attribute. These thresholds are valuable for setting nutrient criteria, but changes in these metrics are not necessarily the best indicators of biotic integrity. They can for example, remain relatively constant as human disturbance increases until a stress threshold is reached. Alternatively, during restoration, they may not respond to remediation until a lower threshold is reached. Thus, metrics or indices that change linearly (typically higher-level community attributes such as diversity or a multimetric index) provide better variables for establishing biocriteria because they respond to environmental change along the entire gradient of human disturbance. However, parameters changing non-linearly along environmental gradients are valuable for determining where along the environmental gradient the physical and chemical criteria should be set and, correspondingly, where to establish other biocriteria.

USING PUBLISHED NUTRIENT THRESHOLDS OR RECOMMENDED ALGAL LIMITS

In addition to using the ‘reference reach’ concept or applying predictive relationships to establish criteria for trophic state variables, other methods to consider include using thresholds and criteria already recommended in the literature. These approaches might be used as limits if identifying reference reaches proves difficult or as temporary measures until reference reaches can be adequately described. The following text describes potential criteria for several nutrient-related variables. Because most of the following threshold concentrations were derived primarily for northern to mid-temperate cobble-bottom streams, caution should be exercised when applying them to streams found in other geographic areas such as southern temperate and subtropical regions. The nutrient/algal relationships described below may not be valid for sandy streams of the southeast and southwest and should be tested on intermittent and effluent-dominated systems. Literature values may be used as criteria if a strong rationale is presented that demonstrates the suitability of the threshold value to the stream of interest (i.e., the system of interest should share characteristics with the systems used to derive the threshold, published values).

Nutrients

Criteria for nutrients in streams have been set or suggested by various agencies and investigators (Table 4). However, in contrast to lake management schemes, there is much less agreement on whether to use total nutrient concentrations, soluble nutrient concentrations, or nutrient concentrations that might produce a given biomass level or an undesirable effect in gravel-bed streams. Although much of the total nutrient concentrations in the water column of streams is not immediately available (due to a high fraction of detritus, as discussed previously), total concentrations probably have more general applicability than soluble fractions. While soluble fractions are more available, they also may be held at low levels during high-biomass periods due to uptake (Dodds et al. 1997). Nevertheless, some investigators have had considerable success relating soluble nutrients to algal biomass if annual mean or seasonal values are used for nutrient concentrations. Using the Bow River as an example, mean TDP during summer was more useful than TP (Table 4).

Table 4. Nutrient (µg/L) and algal biomass criteria limits recommended to prevent nuisance conditions and water quality degradation in streams based either on nutrient-chlorophyll *a* relationships or preventing risks to stream impairment as indicated.

PERIPHYTON Maximum in mg/m^2						
TN	**TP**	**DIN**	**SRP**	**Chlorophyll *a***	**Impairment Risk**	**Source**
				100-200	nuisance growth	Welch et al. 1988, 1989
275-650	38-90			100-200	nuisance growth	Dodds et al. 1997
1500	75			200	eutrophy	Dodds et al. 1998
300	20			150	nuisance growth	Clark Fork River Tri-State Council, MT
	20				*Cladophora* nuisance growth	Chetelat et al. 1999
	10-20				*Cladophora* nuisance growth	Stevenson unpubl. data
		430	60		eutrophy	UK Environ. Agency 1988
		100[1]	10[1]	200	nuisance growth	Biggs 2000
		25	3	100	reduced invertebrate diversity	Nordin 1985
			15	100	nuisance growth	Quinn 1991
		1000	10[2]	~100	eutrophy	Sosiak pers. comm.
PLANKTON Mean in µg/L						
TN	**TP**	**DIN**	**SRP**	**Chlorophyll *a***	**Impairment Risk**	**Source**
300[3]	42			8	eutrophy	Van Nieuwenhuyse and Jones 1996
	70			15	chlorophyll action level	OAR 2000
250[3]	35			8	eutrophy	OECD 1992 (for lakes)

[1] 30-day biomass accrual time

[2] Total Dissolved P

[3] Based on Redfield ratio of 7.2N:1P (Smith et al. 1997)

Notwithstanding the sparse set of cases, there is an indication of some consistency for total and soluble P criteria (Table 4). In two separate data sets, the tendency for *Cladophora* to begin dominating the periphyton was observed at TP concentrations of 10-20 µg/L (Chetelat et al. 1999; Stevenson pers. comm.). This general range was also selected by the Clark Fork Tri-State Council to limit maximum biomass to levels below 150 mg chl *a*/m^2. Setting a criterion equivalent to 'no filamentous green algae', even if chl *a* levels exceed 150 mg/m^2, would protect aesthetic use and still may not limit fisheries production.

Using a criterion for periphytic or planktonic biomass to initially judge if nutrient concentrations are excessive, may have a practical management and enforcement appeal. Advantages are several: (1) there is general agreement among some investigators and agencies on a biomass level that minimizes risk to recreational and aquatic life uses (see Table 4), (2) problems of algal control that result in poor dose-response relationships of nutrients versus biomass (due to shading by riparian canopies or suspended sediment and grazing) are averted, and (3) TMDLs and resultant controls would be required only for situations in which biomass criteria were exceeded. However, criteria for nutrients (specifically TN and TP) will ultimately be required for all stream classes within an ecoregion.

Algal Biomass

Criteria for levels of periphyton algal biomass that present a nuisance condition in streams and impact aesthetic use have been recommended by several investigators. There is surprising consistency in these values, with a maximum of about 150 mg/m^2 chl *a* being a generally agreed upon criterion (Table 4). As objective support for that criterion, percent coverage by filamentous forms was less than 20 percent, but increased with increased biomass and noticeably affected aesthetic quality (Welch et al. 1988). At this level, there were no apparent effects on DO, pH, or benthic invertebrates, which, as described earlier, occur at higher biomass levels.

Furthermore, a literature review of 19 cases indicated biomass levels greater than 150 mg/m^2 tended to occur with enrichment and when filamentous forms were more prevalent (Horner et al. 1983). As noted earlier, Lohman et al. (1992) observed that biomass rapidly recovered following flood-scour events in 12 Ozark streams when biomass exceeded the 150 mg/m^2 level at moderately to highly enriched sites. Pre-disturbance biomass did not recover as rapidly when initial levels did not exceed approximately 75 mg/m^2 at unenriched sites.

A provisional guideline of a maximum 100 mg/m^2 chl *a* and 40 percent coverage of filamentous forms was proposed for New Zealand streams to "protect contact recreation". There was insufficient evidence for protection of other uses that require specific DO and pH thresholds, which in turn vary due to atmospheric exchange (area:volume ratio) and buffering capacity (Quinn 1991).

While the 150 mg/m^2 level cannot be supported as an absolute threshold above which adverse effects on water quality and benthic habitat readily occur, it nonetheless is a level below which an aesthetic quality use will probably not be appreciably degraded by filamentous mats or any other of the adverse effects attributed to dense mats of filamentous algae (e.g., objectionable taste and odors in water supplies and fish flesh, impediment of water movement, clogging of water intakes, restriction of intra-gravel water flow and DO replenishment, DO/pH flux in the water column, or degradation of benthic habitat) (Welch 1992). Avoidance of these problems in many stream systems may be achieved with a maximum 150 mg/m^2 chl *a* criterion. As an example, control strategies were developed for the Clark Fork River, Montana, using a 100-150 mg/m^2 maximum as a criterion (see Appendix A case studies) (Watson and Gestring 1996; Dodds et al. 1997).

CONSIDERATIONS FOR DOWNSTREAM RECEIVING WATERS

More stringent nutrient criteria may be required for streams that feed into lentic or standing waters. For example, it is proposed that 35 μg/L TP concentration and a mean concentration of 8 μg/L chl *a* constitute the dividing line between eutrophic and mesotrophic lakes (OECD 1982). In contrast, data from Dodds et al. (1997) suggest that seasonal mean chlorophyll *a* values within stream systems of 100 mg/m^2 are likely at concentrations of 221 μg/L TP. Thus, unacceptable levels of chlorophyll may occur in lakes at much lower nutrient concentrations compared to streams (Dodds and Welch 2000).

7.3 EVALUATION OF PROPOSED CRITERIA

During criteria derivation, the RTAG will provide expert assessment of any proposed criteria or criteria ranges and their applicability to all streams within the class of interest. Criteria will need to be verified in many cases by comparing criteria values for a stream class within an ecoregion across State and Tribal boundaries. In addition, prior to recommending any proposed criterion, the RTAG must consider the potential for the proposed criterion to cause degradation of downstream receiving waters. In developing criteria, States/Tribes must consider the designated uses and standards of downstream waters and ensure that their water quality standards provide for the attainment and maintenance of water quality standards in downstream waters. Criteria recommended by the RTAG can be adopted by the State or Tribe as approved by EPA if there is documented evidence that no adverse effects will result downstream. However, if downstream waters are not adequately protected at the concentration level associated with the proposed criteria, then the criteria should be adjusted accordingly. Load estimating models, such as those recommended by EPA (USEPA 1999), can assist in this determination (see Section 4.2, Nutrient Load Attenuation). Water quality managers responsible for downstream receiving waters should also be consulted.

GUIDANCE FOR INTERPRETING AND APPLYING CRITERIA

After evaluating criteria proposed for each stream class, determining streams condition in comparison with nutrient criteria can be made by following the steps:

1. Calculate duration and frequency of criteria violations as well as associated consequences. This can be done using modeling techniques or correlational analysis of existing data.

2. Develop and test hypothesis to determine agreement with criteria. Analyze for alpha and beta (Type I and II) errors (see Appendix C).

3. Reaffirm appropriateness of criteria for protecting designated uses and meeting water quality standards.

The goal is to identify protective criteria and standards. Criteria should be based on ecologically significant changes as well as statistically significant differences in compiled data. Although criteria are developed exclusively on scientifically defensible methods, assignation of designated uses requires consideration of social, political, and economic factors. Thus, it is imperative that some thought be given during the criteria development process of how realistically the criteria can be implemented into standards that are accepted by the local public.

SAMPLING FOR COMPARISON TO CRITERIA

Once criteria have been selected for each indicator variable, a procedural rule to assess stream concurrence with criteria should be established. The four primary criteria variables include two causal variables (TN and TP) and two response variables (chl *a* and Secchi depth or a similar indicator of turbidity). Failure to meet either of the causal criteria should be sufficient to require remediation and typically the biological response, as measured by chl *a* and turbidity, will follow the nutrient trend. Should the causal criteria be met, but some combination of response criteria are not met, then a decisionmaking protocol should be in place to resolve the issue of whether the stream in question meets the proposed nutrient criteria.

Sampling to evaluate agreement with the standards implemented from nutrient and algal criteria will have to be carefully defined to ensure that State or Tribal sampling is compatible with the procedures used to establish the criteria. If State or Tribal observations are averaged over the year, balanced sampling is essential and the average should not exceed the criterion. In addition, no more than ten percent of the observations contributing to that average value should exceed the criterion.

A load estimating model (e.g., BASINS [see Appendix C]) may be applied to a watershed to back-calculate the criteria concentration for an individual stream from its load allocation. This approach to criteria determination may also be applied on a seasonal basis and should help States/Tribes relate their stream reach criteria with their lake or estuarine criteria. It may also be particularly important for criteria developed for streams and rivers that cross State/Tribal boundaries.

Algal Sampling for Comparison to Criteria

Once criteria for algal biomass have been established, certain sampling considerations must be addressed to obtain meaningful samples. This section discusses some of the more relevant considerations, using several questions as the basis for determining stream condition with respect to nutrients and algae.

1. How can algal criteria be applied to samples that come from only certain depths of the stream? Aesthetic criteria should be applied to the wadeable portion of large rivers, as has been done in British Columbia (Nordin 1985; see Table 4). The level necessary to protect aquatic life is likely to be system-specific and is best evaluated by determining how algal biomass affects DO, pH, and aquatic communities.

2. How large an area must exceed an algal criterion (e.g., 150 mg chl *a*/m^2) to be considered unacceptable? The area must be large enough to interfere with aesthetics and recreation or to cause undesirable water quality changes. Obviously, regional and site-specific testing of criteria will be necessary. The related sampling question is: how large an area should be characterized when assessing whether a reach exceeds a quantitative criterion? To ensure that a reasonably representative portion of a reach is sampled, replicate samples should be distributed over a reach at least 100 m long. Before selecting a point for sampling, a walk upstream and downstream a few hundred meters should be conducted to ensure that the preferred sampling point is not atypical of the reach being characterized.

Low altitude aerial photos taken on a sunny day in mid-to-late growing season can be used to determine the longitudinal extent of conditions similar to those at the sampling site. Floating the stream by boat can serve a similar purpose.

3. For how long must algal biomass exceed criteria to be considered unacceptable?
Attached algal biomass does not change as rapidly as water column parameters. Hence, one sample a month(from June to September) may be adequate to assess algal biomass, though weekly or bi-weekly sampling is ideal. If only two samplings can be afforded, the likely period containing the highest biomass levels should be bracketed. However, such a sampling scheme may be regarded as unacceptable if both sample values exceed aesthetic criteria. If algal biomass is high enough to cause excessive DO and pH fluctuations that violate water quality standards or that release toxins at unacceptable levels, then the time frames for those water quality violations should be used to judge the acceptability of algal biomass levels. As an example, some States or Tribes might regard the exceedance of algal biomass criteria once in 10 years (i.e., only during the 10-year low-flow) as acceptable, but more frequent exceedances may be deemed unacceptable.

4. How many replicate samples at a site are needed to obtain acceptable precision of data in order to detect differences between sites and changes over time? This depends on the variability in algal biomass in the particular system. The Kendall test with Sen slope estimate (Hirsch et al. 1982) allows the determination of the number of replicate samples needed to detect a certain percent change in annual means of a variable or a certain percent trend over a period such as 10 years (see Clark Fork River case study, Appendix A).

CRITERIA MODIFICATIONS

There may be specific cases identified by States or Tribes that require modification of established criteria, either due to unique stream system characteristics or specific designated uses approved for a stream or stream reach. Two examples of acceptable criteria modifications are presented below.

Site Specific Criteria

If a State/Tribe has additional information and data which indicate a different value or set of values is more appropriate for specific stream systems than ecoregionally-derived criteria, a scientifically defensible argument should be prepared that a “site specific” criteria modification is required. Once approved by EPA, this value can be incorporated into State or Tribal water quality standards. If no action is taken by the State or Tribe involved, EPA may propose to promulgate criteria based on the regional values and best available supporting science at the time.

Designated Use Approaches

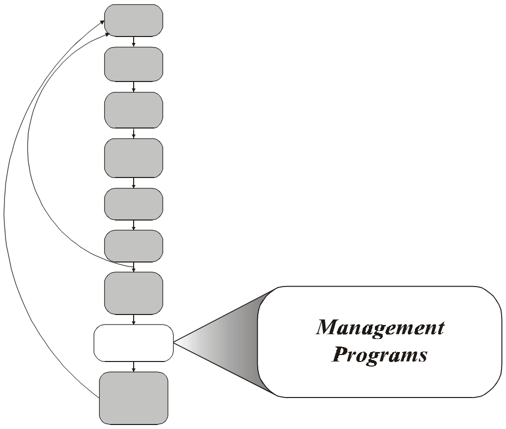
Once a regional criterion has been established, it is subject to periodic review and calibration. Any State or Tribe in the region may elect to use the criterion as the basis for developing its own criteria to protect designated uses for specific stream classes. This is entirely appropriate as long as the criteria are as protective as the basic EPA criterion for that region. This ecoregional criterion represents EPA’s “304(a)” recommendation for protection of an aquatic life use.

The Clean Water Act as amended (Pub. L. 92-500 (1972), 33 U.S.C. 1251, *et seq.*) requires all States to establish designated uses for their waters (Section 303[c]). Designated uses are set by the State. EPA’s interpretation of the Clean Water Act requires that wherever attainable, standards should provide for the protection and propagation of fish, shellfish, and wildlife and provide for recreation in and on the water (Section 101[a]). Other uses identified in the Act include industrial, agricultural, and public water supply. However, no waters may be designated for use as repositories for pollutants (see 40 CFR 131.10[a]). Each water body must have legally applicable criteria or measures of appropriate water quality that protect and maintain the designated use of that water. It is therefore proper for States and Tribes to set nutrient criteria appropriate to each of their designated uses in so far as they are as protective as the regional nutrient criteria established for those classes of waters.

IMPLEMENTATION OF NUTRIENT CRITERIA INTO WATER QUALITY STANDARDS

Criteria, once developed and adopted into water quality standards by a State or Tribe, are submitted to EPA for review and approval (see 40 CFR 131). EPA reviews the criteria (40 CFR 131.5) for consistency with the requirements of the Clean Water Act and 40 CFR 131.6, which requires that water quality criteria be sufficient to protect the designated use (40 CFR 131.6[c] and 40 CFR 131.11). The procedures for State/Tribal review and revision of water quality standards, EPA review and approval of water quality standards, and EPA promulgation of water quality standards (upon disapproval of State/Tribal water quality standards) are found at 40 CFR 131.20 -22 (see Figure 1, Chapter 1). The Water Quality Standards Handbook (EPA 1994) provides guidance for the implementation of these regulations.

Chapter 8. Management Programs



8.1 INTRODUCTION

This chapter provides information on regulatory and non-regulatory programs that may utilize or be affected by nutrient criteria, as well as management solutions for problems associated with varying streamflow conditions. This chapter is intended to inform resource managers and foster potential links among regulatory and non-regulatory programs to best manage watersheds. Information about other agency programs that may assist in implementing criteria and maintaining water quality is also included.

The information provided by nutrient surveys of stream systems in a region will permit the resource manager to rank stream systems by trophic state; i.e., the manager should be able to classify systems according to the degree of nutrient enrichment. Stream systems can be selected for priority attention for management action. Documented stream nutrient and algal conditions and an understanding of regional public preferences regarding limits of productivity can be used to establish three categories of streams:

1. Systems with algal and/or nutrient problems. The most severely degraded waterbodies requiring extensive, expensive restoration.

2. Systems with a strong potential for developing algal problems (factors other than nutrients are unlikely to be limiting). The intermediate streams in need of remedial management to improve conditions requiring various levels of expense and manpower depending on the characteristics and problems identified in each case.

3. Systems with a low potential for developing algal problems that do not contribute to degraded nutrient conditions in downstream waterbodies. The systems in excellent condition requiring no restoration and for which management is essentially the protection of this resource through careful watershed land use planning and diligent observation of conditions. This is usually a relatively low cost option allowing for the protection of many such waterbodies with little expenditure of budget or personnel.

Systems with high nutrient loading but low potential for developing algal problems due to other limiting factors should be prioritized based on the potential for degradation of downstream receiving waters. The management strategies required for nutrient reduction within streams and those for lakes and estuaries are not different, so these processes should be linked when management plans are being formulated.

The next logical action is the design of management plans to enhance collective water body resources. The initial categorization helps set priorities for the best use of limited personnel and funds by selecting some optimal combination of many low cost but effective projects combined with some important restoration projects, and perhaps long range planning to begin to address major restoration of one or two important stream systems on an incremental basis.

This chapter is separated into discussions of point source and nonpoint source programs. Each program is discussed and a list of source information or contacts is provided. This chapter is intended to aid the resource manager in identifying programs that may assist in implementation of nutrient criteria. These programs include regulatory and non-regulatory programs that address both point and nonpoint sources of nutrients. Consultation with these programs is recommended for watershed and development planning activities. Linking with other programs may allow maximization of resources for addressing water quality concerns.

8.2 MANAGING STREAMFLOW CONDITIONS

LOW FLOWS

Maintaining flow is often essential to habitat protection. In many regions of the United States, stream segments periodically lose water due to irrigation, industrial and municipal withdrawals; and/or diversion for hydroelectric power; evaporation; and groundwater infiltration. Additionally, during low-flow conditions, impacts from point source discharges of chemical stressors are typically greatest, because effluent constitutes a larger percentage of (or sometimes all) stream water at low flow, with increased pollutant concentration. National Pollutant Discharge Elimination System (NPDES) permits based on low flow conditions (e.g., 7Q10) often cannot antic-ipate various combinations of climatic conditions and water demand that lead to exceedingly low flows.

Impacts attributable to low flows caused by human actions can be mitigated by several in-stream restoration techniques, including:

- Reducing channelization,
- Restoring wetlands for conservation and storage purposes thereby restoring natural hydrologic regimes,
- Controlling evaporation through restoration of the riparian canopy,
- Replacing exotic riparian plant species that have high evapotranspiration rates with native species that have lower transpiration rates,
- Constructing drop structures to create pools that provide protection for aquatic life during low-flow periods,

- Increasing channel depth and undercut banks to provide protective areas for fish and other species during periods of low flow, and
- Increasing groundwater recharge to streams through increased infiltration (e.g., reduced imperviousness in recharge areas).

Minimum flows can also be addressed by applying techniques in the surrounding watershed, such as managing watershed land use to prevent excessive dewatering. Restoration practices to mitigate low velocity/low-flow conditions often require close collaboration with other resource management agencies (e.g., USDA Forest Service), zoning authorities (e.g., county governments), and agricultural extension agencies. Several agricultural activities contribute to low velocity/low flow conditions. Agricultural extension agencies have developed specific techniques to modify the practices that result in low-flow impact to streams. For example, irrigation plans can be optimized to reduce the demand for water that is diverted directly from the stream. Changing crop rotations and using less water-intensive crop alternatives are other tools that have been used effectively to address low velocity/low-flow situations. Source: [http://www.epa.gov/owowwtr1/NPS/Ecology/chap3.html]

HIGH FLOWS

High-energy flows can erode substrate and bank materials, destabilize the physical structure of aquatic habitats, eradicate resident aquatic organisms, and destroy eggs located in the benthic environment. Seasonal cycles of high-energy flow events (e.g., spring floods) are typical in most aquatic systems. Habitat alteration and degradation, however, may exacerbate impacts of high-energy flows and contribute to impairment of designated uses. For instance, in a channelized stream with minimal riparian vegetation, flow velocity and volume will likely be much greater than would be expected in a "natural stream," thereby increasing its erosive potential.

Two aspects of flooding are considered here. It has recently been recognized that water retention structures remove the natural flooding that is part of a normal stream ecosystem (the flood pulse concept). Such floods are known to reduce levels of algae and macrophytes and may be beneficial to stream communities otherwise. The floods appear destructive on the short term, but most stream organisms are adapted to some level of flooding.

Alternatively, channel alteration and watershed modification can lead to abnormally high water velocities through the stream channel and amplify the effects of floods. For example, channelization can reduce the amount of refugia used by stream organisms to escape floods. Removal of riparian vegetation, urbanization, and deforestation of watersheds can lead to much greater peak flows during floods for a given amount of rain. Watershed disturbance can also lead to increases in sedimentation, which will scour away excessive algal biomass and, if deposited, make it difficult for periphyton to become established. However, such sediment will compromise the ecological integrity by harming fish and invertebrates in the stream channels.

In-stream and riparian techniques that can mitigate high flow impacts include:

- Restoring natural stream meander and channel complexity;
- Increasing substrate roughness;
- Promoting growth of riparian vegetation, which serves as a drag on flows;

- Modifying land use along buffers and other source areas; and
- Creating plunge pools and flow baffles to decrease the high energy of discharged waters.

These in-stream practices may need to be accompanied by techniques applied in the surrounding watershed, such as upland revegetation or the establishment of nonpoint source best management practices (BMPs).

Resource management agencies, for example, can encourage or allow beavers to colonize stream segments; beaver dams create wetlands and retain water that supplements low flow during dry periods. Restored wetlands can have the same effect as a beaver dam. In areas below dams where flow is very stable and excessive growths of macrophytes and periphyton are common, water releases to mimic natural floods may be considered. Local zoning authorities have also begun to encourage impervious area reduction in watersheds through land-use ordinances. Increased infiltration and reduced peak flows from rapid runoff contributes to a more sustained base flow to the stream from groundwater discharge. Source: [http://www.epa.gov/owowwtr1/watershed/wacademy/acad2000/river/]

8.3 MANAGING POINT SOURCE POLLUTION

The term "point source" means any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agricultural storm water discharges and return flows from irrigated agriculture. This section describes some of the regulatory programs that permit point source discharges into rivers and streams. The regulatory programs discussed here apply to federal requirements of the Clean Water Act (Section 303). State, Tribal, and local governments frequently have regulatory programs that operate on agency specific requirements. These agencies should be considered in management planning activities.

WATER QUALITY STANDARDS

Anti-degradation

Water quality standards include an anti-degradation policy and methods through which the State or Tribe implements the anti-degradation policy. Anti-degradation is a policy required in State water quality standards to protect waters from degradation. At a minimum, States must maintain and protect the quality of waters to support existing uses. Anti-degradation was originally based on the spirit, intent, and goals of the Clean Water Act, especially the clause “...restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (USEPA 1994). The water quality standards regulation sets out a three-tiered anti-degradation approach for the protection of water quality.

Tier 1

Maintains and protects existing uses and the water quality necessary to protect these uses (40 CFR 131.12[a][1]). An existing use can be established by demonstrating that fishing, swimming, or other uses have actually occurred since November 28, 1975, or that the water quality is suitable to allow such uses to occur, whether or not such uses are designated uses for the water body in question.

Tier 2

Protects the water quality in waters whose quality is better than that necessary to protect "fishable/swimmable" uses of the water body (40 CFR 131.12[a][2]). The water quality standards regulation requires that certain procedures be followed and certain showings be made (an "anti-degradation review") before lowering water quality in high quality waters. In no case may water quality for a tier 2 water body be lowered to a level at which existing uses are impaired.

Tier 3

Preserves outstanding national resource waters (ONRWs), which are provided the highest level of protection under the anti-degradation policy (40 CFR 131.12[a][3]). ONRWs generally include the highest quality waters of the United States. However, the ONRW anti-degradation classification also offers special protection for waters of "exceptional ecological significance," i.e., those water bodies which are important, unique, or sensitive ecologically, but whose water quality, as measured by the traditional parameters such as dissolved oxygen or pH, may not be particularly high. Waters of exceptional ecological significance also include waters whose characteristics cannot adequately be described by traditional parameters (such as wetlands and estuaries).

Anti-degradation implementation procedures address the measures used by States and Tribes to ensure that permits and control programs meet water quality standards and anti-degradation requirements.

General Policies

The water quality standards regulation allows States and Tribes to include implementation in their standards policies and provisions, such as mixing zones, variances, and low-flow exemptions. Such policies are subject to EPA review and approval. These policies and provisions should be specified in the State or Tribe's water quality standards document. The rationale and supporting documentation should be submitted to EPA for review during the water quality standards review and approval process.

Mixing Zones

States and Tribes may, at their discretion, allow mixing zones for dischargers. The water quality standards should describe the methodology for determining the location, size, shape, outfall design, and in-zone quality of mixing zones. Careful consideration must be given to the appropriateness of a mixing zone where a substance discharged is bioaccumulative, persistent, carcinogenic, mutagenic, or teratogenic.

Low-Flow Provisions

State and Tribal water quality standards should protect water quality for the designated and existing uses in critical low-flow situations. States and Tribes may, however, designate a critical low-flow below which numerical water quality criteria do not apply. When reviewing standards, States and Tribes should review their low-flow provisions for conformance with EPA guidance.

Water Quality Standards Variances

As an alternative to removing a designated use, a State or Tribe may wish to include a variance as part of a water quality standard, rather than changing the entire standard, especially if the State or Tribe believes that it can ultimately be attained. By maintaining the standard rather than changing it, the State or Tribe will assure that further progress is made in improving water quality and attaining the standard. Variances are temporary, subject to review every three years, and may be extended upon expiration. If a variance specifies an interim criterion applicable for the duration of the variance for a particular pollutant, a long-term underlying goal criterion is also specified that is adequate to protect the designated use. EPA has approved variances in the past and will continue to do so if:

- The variance is included as part of the water quality standard;
- The variance is subjected to the same public review as other changes in water quality standards;
- The variance is granted based on a demonstration that meeting the standard is not feasible due to the presence of any of the same conditions as if a designated use were being removed (these conditions are listed in section 131.10(g) of the water quality standards regulation); and
- Existing uses will be fully protected.

For additional information, see http://www.epa.gov:80/ostwater/econ/chaptr5.pdf.

NPDES PERMITS

The Clean Water Act requires wastewater dischargers to have a permit establishing pollution limits, and specifying monitoring and reporting requirements. More than 200,000 sources are regulated by the NPDES permits nationwide. These permits regulate household and industrial wastes that are collected in sewers and treated at municipal wastewater treatment plants. Permits also regulate industrial point sources and concentrated animal feeding operations that discharge into other wastewater collection systems or that have the potential to discharge directly into receiving waters. Permits regulate discharges with the goals of 1) protecting public health and aquatic life, and 2) assuring that every facility treats wastewater. Typical pollutants regulated by NPDES are “conventional pollutants” such as fecal coliforms or oil and grease from the sanitary wastes of households, businesses, and industries and “toxic pollutants” including pesticides, solvents, polychlorinated biphenyls (PCBs), dioxins, and heavy metals that are particularly harmful to animal or plant life. “Non-conventional pollutants” are any additional substances that are not conventional or toxic that may require regulation, including nutrients such as N and P. [Source: http://www.epa.gov/owm/gen2.htm].

Discharge monitoring data for pollutants limited and/or monitored pursuant to NPDES permits issued by States, Tribes, or EPA are required to be stored in the central EPA Permit Compliance System (PCS). The assessment of point source loadings is not a simple process of assessing PCS data, even though PCS is an important data source. The PCS database does not provide complete information for important N sources. Most PCS N data is generated by water quality-based permit limitations on ammonia, often applied in discharges to smaller streams. Few data exist in PCS on other forms of N, or TN; and data for TP is not frequently found in PCS. This situation exists largely because most permits do not include limits and/or monitoring requirements for N or P. The lack of nutrient limits and/or monitoring requirements in permits is due to a general lack of State water quality standards for these parameters. [Source: http://www.epa.gov/msbasin/protocol.html]

The NPDES Storm Water Permitting Program

Storm water runoff is one of the remaining causes of contaminated lakes, streams, rivers, and estuaries throughout the country. Pollution in storm water runoff is responsible for closing beaches and shellfish harvesting areas, contaminating fish, and reducing populations of water plants and other aquatic life. High flows of storm water runoff cause flooding, property damage, erosion and heavy siltation. The