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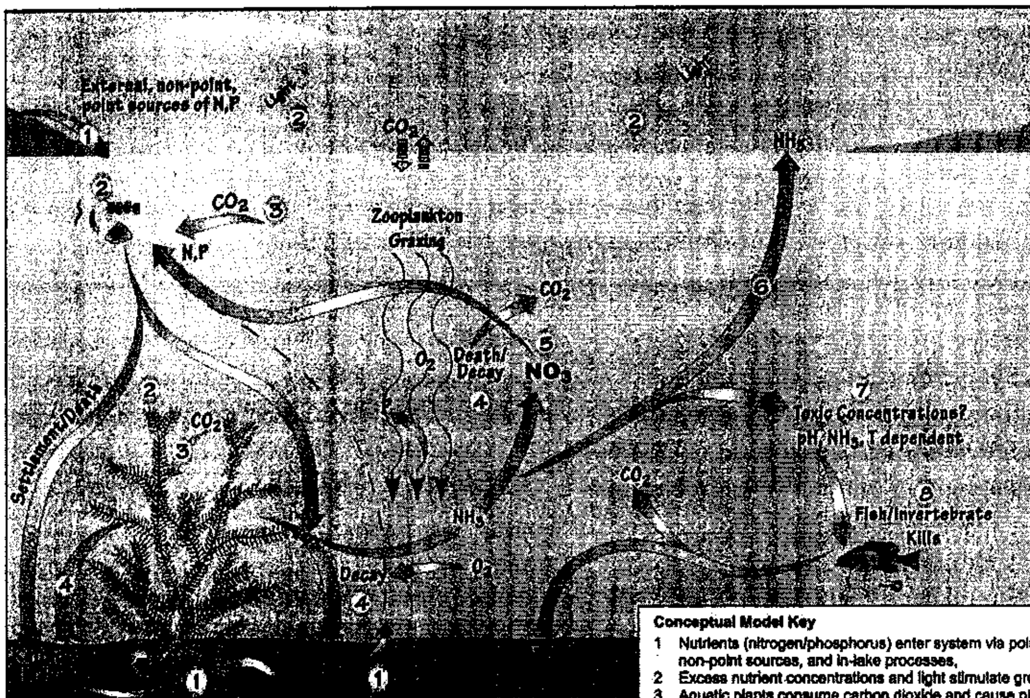
WORK PLAN

DEVELOPMENT OF NUTRIENT CRITERIA FOR ECOREGIONS WITHIN CALIFORNIA, ARIZONA, AND NEVADA



Conceptual model of potential in lake nutrient related processes.

Conceptual Model Key

1. Nutrients (nitrogen/phosphorus) enter system via point sources, non-point sources, and in-lake processes,
2. Excess nutrient concentrations and light stimulate growth,
3. Aquatic plants consume carbon dioxide and cause pH to rise,
4. Aquatic plants fragment or die releasing ammonia, phosphorus, carbon dioxide, and consume oxygen into water column or sediments,
5. Ammonia undergoes nitrification to yield nitrate. Nitrate is recycled back into system,
6. Ammonia diffuses into atmosphere,
7. Ammonia can become toxic if pH and ammonia concentrations are high enough, and
8. High concentrations of unionized ammonia can cause fish and invertebrate kills and release ammonia into the water column and consume additional dissolved oxygen.

Prepared for:
California State Regional Technical Advisory Group
EPA Region IX Regional Technical Advisory Group

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WORK PLAN

THE DEVELOPMENT OF NUTRIENT CRITERIA FOR ECOREGIONS WITHIN: CALIFORNIA, ARIZONA, AND NEVADA

INTRODUCTION

The development of nutrient criteria is being undertaken to provide water quality standards that can be used as endpoints to protect the Nation's waters from nutrient over enrichment. Nutrient criteria must be placed within the context of the Clean Water Action Plan to meet its primary goal of maintaining nutrient levels that support the health of aquatic systems and limit the excessive growth of macrophytes or phytoplankton, potentially harmful algal blooms leading to oxygen declines, imbalance of aquatic species, public health threats, and a general decline in the aquatic resource (US EPA 1998).

It is universally acknowledged that aquatic systems require some amount of nutrients to maintain their health. There is a wide range in nutrient levels found in minimally impacted aquatic systems (also called reference conditions) in EPA Region IX (Tetra Tech 2000). Even in relatively undisturbed conditions, it can be common for aquatic systems to have higher levels of nutrients and primary productivity (i.e., eutrophic systems with higher concentrations of algae and macrophytes). In addition, there are factors such as habitat degradation and flow conditions that exacerbate the effects of available nutrients and lead to nuisance conditions (e.g., excessive algal growth, low dissolved oxygen). A single numeric nutrient criterion is not appropriate for all waterbodies. The national challenge is to develop nutrient criteria, which allow decision-makers to discriminate water quality impacts that are due to nutrient over enrichment and to establish meaningful nutrient criteria, which will effectively reduce excessive algal growth, and not other contributing factors (e.g., degraded physical habitat such as riparian canopy and channel configuration).

NUMERIC WATER QUALITY CRITERIA

Water Quality Standards are composed of three elements: 1) Designated Uses, 2) Water Quality Criteria, and 3) Antidegradation policy. Designated Uses are assigned to waterbodies by States and Tribes and include uses such as cold water fishery or municipal water supply. Numeric water quality criteria are adopted to protect and support designated uses. Numeric criteria are values assigned to measurable components of water quality, such as the concentration of a specific constituent that is present in the water column. Numeric criteria provide distinct interpretations of acceptable and unacceptable conditions, form the foundation for responsible measurement of environmental quality, and reduce ambiguity for management and enforcement decisions.

Our goal in the work outlined here is to develop a rigorous, scientifically defensible approach to determine nutrient criteria in California, Arizona, and Nevada. Out of necessity this work plan will require some methods development before any nutrient criteria recommendations can be made. Regional classification units must be constructed, optimal parameters for the criteria need to be identified, and the form of the standard that best supports the decision-making process must also be described. The nutrient criteria development process will be well initiated by 2004, but is far from complete. Because of the required methods development and limited amounts of available data it is unlikely that more than a few of the many possible criteria recommendations will be completed. Work on the criteria recommendations for most of the regionalization units and waterbodies will need to continue after 2004. Good progress towards the goals and objectives described in this work plan will avert the imposition of the default 301(a) criteria by the US EPA. The approach described in this work plan will also provide a clear road map to the states for further data collection, analysis, and eventual development of a complete set of numeric nutrient criteria required by the ecoregion-based approach.

APPROACH

This work plan describes activities within the five primary task areas that are illustrated in Figure 1. The task areas include Data Collection; Categorization of Waterbodies and Development of Regionalization Units; Criteria Parameter Evaluation; Development of Criteria and Data Collection Recommendations; and Support for and Interaction with the Stakeholder Groups (EPA Region IX Regional Technical Advisory Group [RTAG] and State Regional Board Technical Advisory Group [STRTAG]). Due to ongoing data collection and interaction with the advisory groups many of the activities with the task areas will be occurring concurrently.

The strategy is to develop three lines of investigation to support the development of criteria recommendations: 1) review of in-depth long-term monitoring studies (including consultation with principal investigators); 2) empirical data analysis of existing water quality and watershed data; and 3) water quality and watershed modeling assessments. The project team will also work with the Regional Board and other collaborators to collect additional monitoring data to support the ongoing development of nutrient criteria. A brief summary of the primary task areas is provided below. Detailed task descriptions are provided in Appendix A found at the end of this document.

Data [illegible]

The technical support team will compile all available water quality data related to nutrients and nutrient impacts, along with corresponding watershed information and hydrologic data from the receiving waters. The focus of the data collection will be on waterbodies that are known to be minimally impacted by human-induced nutrient loads. This database will provide the analysis with a perspective on reference systems that are expected to span a broad range of conditions. In addition, the project team will also compile data sets of non-referenced waterbodies that will include a broader range of conditions for use in other data analysis approaches. The project team will make site visits as needed to facilitate the collection of data.

Categorization and Regionalization Units

During the initial stages of collection, the data will be grouped into major waterbody type categories. The most nutrient-sensitive beneficial uses will also be established and included in the database. Watershed and hydrologic information will be used to classify the waterbodies into different groups that are expected to behave similarly in terms of nutrient response. Delineation of classification categories (i.e., regionalization units) will require the development and application of statistical models (regression equations) and deterministic watershed models to evaluate a wide range of stratification criteria. The goal of this phase of the work plan is to separate the waterbodies into major groups that will have different nutrient criteria.

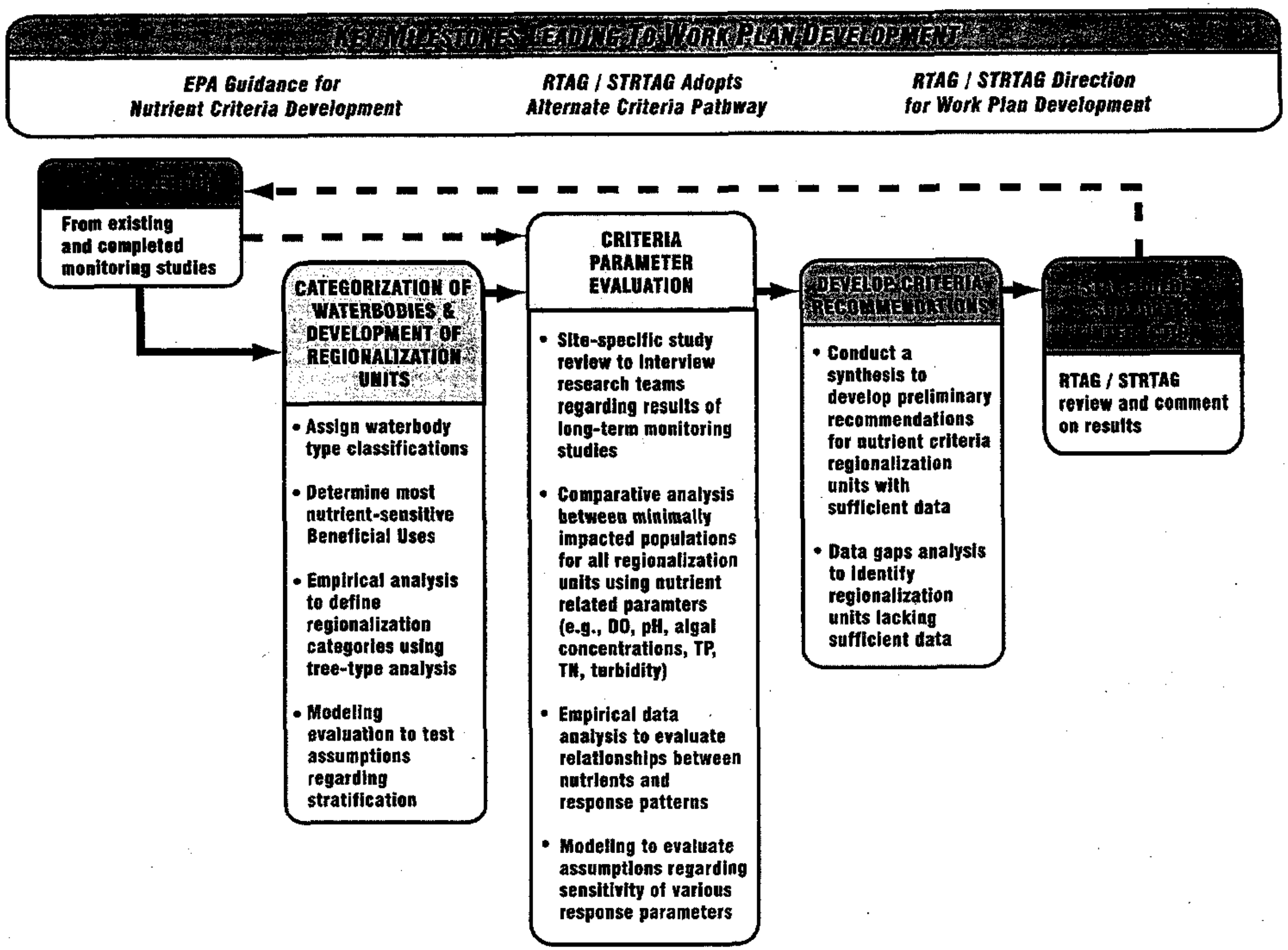
Criteria Parameter Development

A comparative analysis will initiate the development of criteria parameters through use of information compiled on minimally impacted aquatic systems and a general population represented by systems that are included within the STORET database. This analysis will illustrate the usefulness of comparing nutrients and response parameters from minimally impacted waterbodies to those within the general population of all waterbodies in a particular classification category.

This activity area will also include other forms of statistical analyses: 1) methods to separate the data into different classification categories and to evaluate which categories are most significant, 2) methods to statistically summarize the data for each category (e.g., cumulative frequency distributions), and 3) the development and application of statistical models (e.g., regression equations) to develop quantitative relations between waterbody nutrient concentrations and algal biomass, and if possible relationships between algal biomass and other relevant parameters including DO, pH, biotic diversity, flow, etc. This approach will require the development of indicators for beneficial use protection/support including targets for algal biomass and DO. These relationships will be based on waterbody type, ecoregion, stratification characteristics, and variance conditions. The relationships will also be affected by flow, substrate availability, light, and other factors. This approach is a modification of the techniques discussed in Biggs (2000) and Dodds et al. (1997). The goal of the statistical analyses is to determine the most useful classification scheme and to determine the appropriate nutrient concentrations and response parameter values in unimpaired waterbodies for each classification category. These results will provide the main foundation for the development of the nutrient criteria.

In addition to empirical data analyses, the project team will also conduct assessments using mechanistic water quality simulation models. This modeling will be performed concurrently with the statistical analyses and will be used to help establish the best classification scheme, to help fill in data gaps for categories that are not well represented in the monitoring data, and to help evaluate the sensitivity of various response parameters to nutrient impairment. Watershed, stream, and lake models will provide a mechanistic framework for assessing background nutrient

Figure 1. Flow Diagram Illustrating Process Steps for Nutrient Criteria Development



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loads from different watershed situations and regionalization units, and the corresponding nutrient responses for different waterbody types and classification categories. The models will be used to test assumptions regarding the classification categories and stratification criteria and to help determine which categories are most likely to be responsible for the largest differences in nutrient responses. Later, the models will also be used to evaluate assumptions regarding the sensitivity of various response parameters to different nutrient loading and waterbody/watershed situations. However, the monitoring data, rather than the model results, will be the major source of data for criteria development. The models are very useful for systematically exploring the effects of different factors under controlled conditions that could not be accomplished through statistical analyses of the database. Therefore, they complement and expand the capabilities of the empirical data in establishing nutrient criteria.

The team will also evaluate longer-term in-depth research projects on specific waterbodies where nutrient and algal dynamics have been assessed in conjunction with the evaluation of beneficial use attainment. Research teams will be identified, contacted, and interviewed regarding the scope and results of their monitoring programs. Synthesis of these studies will support the statistical and model analyses, providing an additional line of evidence that the proposed nutrient criteria will protect beneficial uses for waterbodies in the corresponding classification category.

As the databases, statistical analyses, and model analyses are developed; certain anomalous situations are expected to emerge where a particular waterbody does not have the expected nutrient response because of certain site-specific factors. These situations will be used to develop a preliminary list of possible variance conditions. However, full definition of the variance condition policy is not an objective of this work plan. Variances will be addressed during the implementation phase of the nutrient criteria process.

Develop Criteria Recommendations

The information from the statistical analyses, modeling, and research project reviews will be used to develop nutrient criteria recommendations for regionalization units and waterbody categories that have sufficient data available. Data gaps will be identified for those regionalization unit/waterbody categories that do not have sufficient data, and a data collection strategy to obtain the necessary data will be recommended.

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The nutrient criteria recommendations, data gaps analysis, and data collection recommendations will be sent to the RTAG/STRTAG for review and comments at the end of the study in 2004. The project team will meet with the stakeholder groups on a regular basis throughout the course of the study to present results and to receive input on the ongoing analyses. After review and

Physical Habitat as a Contributing Factor to Nuisance Conditions

The effects of the activities listed above extend to modifications of physical habitat (e.g., degraded channel conditions, reduced riparian cover, reduced flow) that fundamentally alter the manner in which aquatic systems process nutrients. The loss of physical habitat integrity contributes to the occurrence of nuisance conditions generally attributed to nutrient over enrichment such as dense algal growth, low DO, and low biological diversity (Ohio EPA 1999).

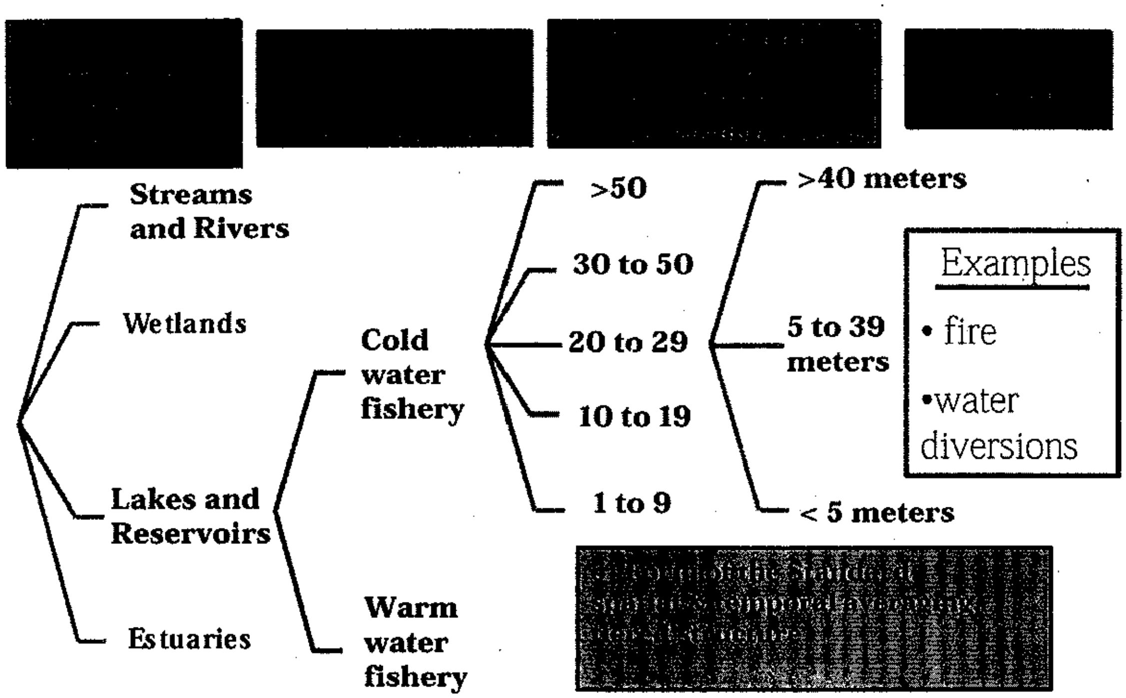
Water Transfers

Throughout the western United States, and especially in California, the effect of water transfers from one ecoregion to another confounds the regional approach to setting nutrient criteria.

DECISION FRAMEWORK COMPONENTS

It is essential to develop nutrient criteria within a decision framework that provides decision-makers with the capability to discriminate when impacts are due to cultural nutrient enrichment or to other factors. The proposed approach has five essential components that provide the capability to apply nutrient criteria in a manner that correctly indicates when a nutrient management plan is required to protect or restore an affected aquatic system. The five components of the proposed decision framework are illustrated in Figure 2 and briefly discussed below:

Figure 2. Diagram of Decision Framework



comment, the project team will reinitiate efforts to collect data and develop criteria for data-deficient categories. However it is anticipated that for some regionalization units, monitoring to collect the necessary data will continue after the current project is completed.

The administrative processes of implementing the recommended criteria are not included in the work plan process and will occur independently of the activities described here. The framework developed in this work plan will provide the methodology for additional data collection, analysis, and numeric nutrient criteria development for the missing regionalization unit/waterbody categories.

CONFOUNDING ISSUES

There are several factors that contribute to the inherent difficulty of setting nutrient criteria. These are listed below with a short discussion of each.

Few Reference Aquatic Systems

There are few reference condition streams that can be used to characterize conditions in an undisturbed setting. Throughout the region, land management activities (e.g., mining, grazing, logging, agriculture, urbanization) have resulted in pervasive legacy effects that have altered nutrient inputs from watersheds. In addition, the contribution of nutrient loading (primarily nitrogen) from atmospheric loading is also widespread.

Variability Within Minimally Impacted Aquatic Systems

RTAG sponsored a demonstration project evaluating nutrient concentrations for minimally impacted rivers and streams (Tetra Tech 2000). The study compared cumulative distributions for the general (STORET) population with the minimally impacted (or reference) population for several parameters in Ecoregion II. The populations have significant overlap (approximately 100%) with similar variance within the two populations. The RTAG response was that the results suggested that:

- The assumption used in the EPA guidance documents (US EPA 2000) regarding the relationship of the two populations could not be used as the basis for setting nutrient criteria in Region IX

- Using a range of values rather than a single point on a curve would need to be considered in criteria development

- Ecoregions were too coarse of an analysis unit and would need to be further refined using additional stratification criteria

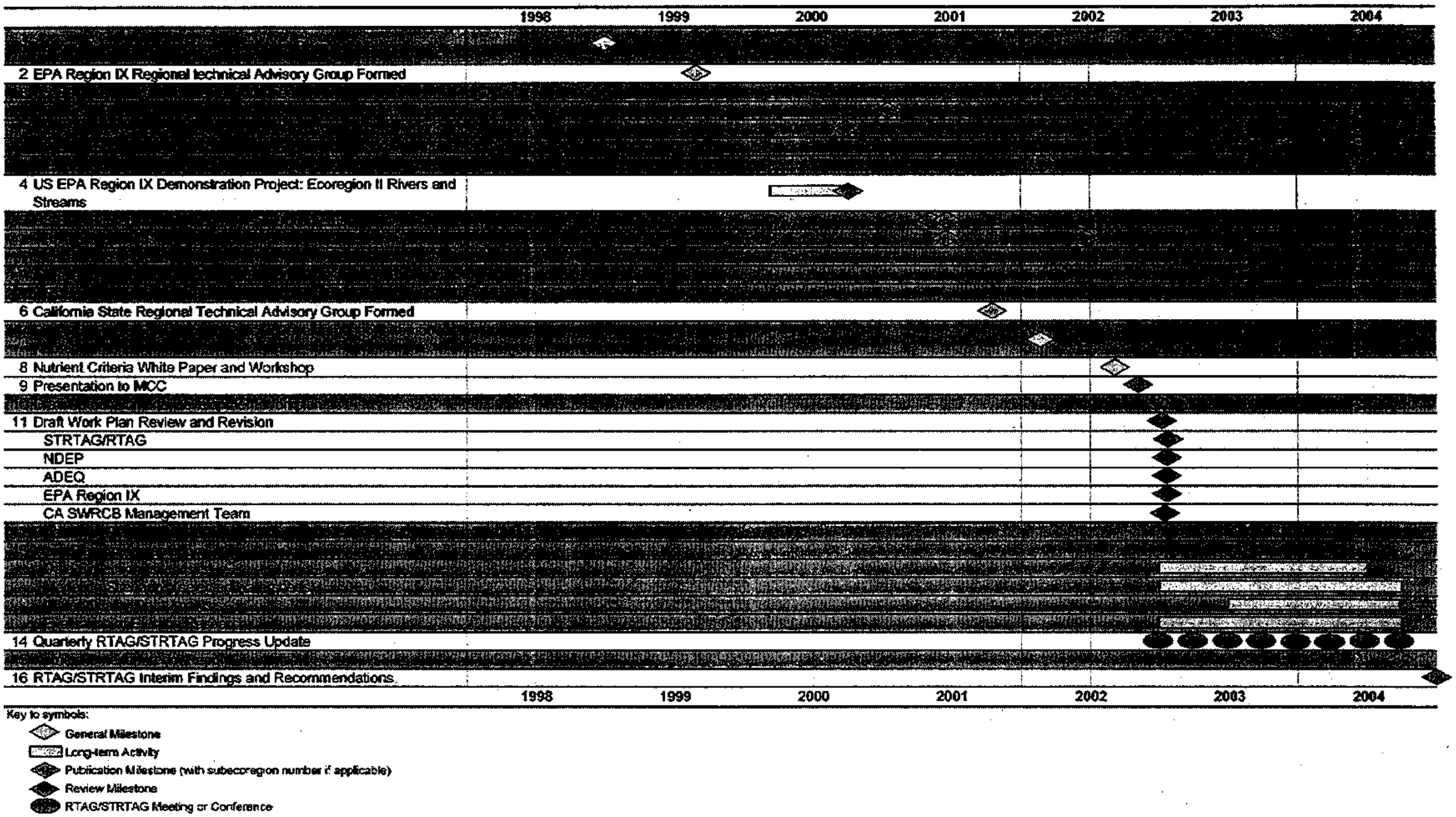
1. ***Waterbody Types:*** It is anticipated that nutrient criteria will be completed for four types of aquatic ecosystems: 1) Rivers and Streams; 2) Lakes and Reservoirs; 3) Estuaries and Near Coastal Waters; and 4) Wetlands. This work plan addresses the first two types of aquatic ecosystems: Rivers and Streams and Lakes and Reservoirs.
2. ***Designated Use Classification:*** The decision framework explicitly includes the beneficial uses for aquatic systems. The beneficial use endpoint that is most sensitive to nutrient impacts will be included in the decision framework.
3. ***Regionalization Units:*** The results of the demonstration project indicate that variability within ecoregions is too great for use as the nutrient criteria classification unit. Stratification criteria will be applied to the ecoregions to refine aquatic system categories and to reduce the variability in the causal (e.g., nutrients) and response (e.g., nuisance algae, DO) parameters for the target population. The resulting regionalization units will group waterbodies of similar characteristics that respond to nutrient inputs in a similar manner.
4. ***Variance Conditions:*** The decision framework includes a component that addresses aquatic systems that are exceptions to the classification systems and may require some form of variance to nutrient criteria. Aquatic systems that are designated to the variance category may require the development of site-specific nutrient objectives. (Refer to the end of the section describing Criteria Parameter Development.)
5. ***Form of the Standard:*** The form of the standard is critical to interpreting the ecological signal regarding aquatic system status relative to nutrients and other factors that can cause similar types of impairment. The form of the standard will account for temporal and spatial variability (e.g., seasonal variations in stream concentrations, vertical gradients in lake concentrations). In addition, the criteria will likely involve multiple parameters (both causal and response variables) to better determine the source of impairment. Criteria interpretation could also involve a tiered approach that allows for investigation that is necessary to determine potential nutrient enrichment. This includes the development and application of a translator that provides the capability to discriminate the cause of impacts on response variables (e.g., algae density).

PROJECT SCHEDULE

All activities will be carried out in close collaboration with RTAG / STRTAG. The RTAG / STRTAG will be provided with regular updates on progress and will be consulted regarding options that are developed for each aspect of the decision framework.

This work plan for criteria development is an iterative adaptive management approach that relies on input from all RTAG / STRTAG participants and the technical advisors (John Reuter and Jim Brock). It is expected that because of data availability and other factors that some regionalization units will be completed before others. Nutrient criteria recommendations will be provided as they are completed. The schedule of activities for the work plan is illustrated in Figure 3.

Figure 3. Key Milestones and Project Schedule



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APPENDIX A
TASK DESCRIPTIONS

TASK 1
WORK GROUP FACILITATION AND COMMUNICATION SUPPORT

The California State Water Resources Control Board (SWRCB) and EPA Region IX are coordinating the involvement of the Regional Boards and other stakeholders who compose the Nutrient Criteria Work Group. The RTAG will serve as the general coordinating forum for Region IX stakeholders. The STRTAG will closely collaborate with RTAG and will provide the primary direction for the development of nutrient criteria for California. Arizona will participate in the RTAG process and has its own nutrient criteria development initiative under way. Nevada will cooperate and contribute to the RTAG and STRTAG process. Hawaii is also participating in the RTAG process. However, since ecoregional guidance has yet to be developed for Hawaii, there will be no nutrient criteria developed for the state. The RTAG will continue to provide some support to Hawaii on data analysis tasks.

The technical contractor facilitates Work Group meetings and conference calls. The contractor also writes and distributes meeting summaries, technical products, and technical information of interest to the Work Group. The Work Group meeting schedule includes monthly conference calls and quarterly meetings. Key information and meeting summaries are posted on a publicly accessible website maintained by the technical contractor to facilitate public and stakeholder involvement.

University representatives are serving as technical advisors to RTAG and STRTAG. In addition, several agencies and organizations that conduct research on nutrients and their environmental impacts are participating in the process, including (but not limited to) U.S. Geological Survey (USGS), California Department of Fish and Game (CDFG), Southern California Coastal Water Research Project (SCCWRP), and individual municipalities.

TASK 2
COLLECTION OF EXISTING WATER QUALITY DATA

The development of nutrient criteria will require the use of existing data. Water quality and watershed data will be needed for each regional classification unit. The data collection task will require direct contact with agencies and entities that have collected water quality data not reported to EPA's STORET database. The technical approach requires information from minimally impacted water bodies that are fully supporting their beneficial uses.

Data will be collected using a three-tiered, hierarchical approach. These three tiers are (1) existing data, (2) data from on-going projects, and (3) data from special studies. Additionally, a Geographic Information System (GIS) will be used to acquire topographic and land cover data. GIS will be used extensively to identify those physical topographical watershed parameters (e.g., gradient) that will be used to classify and categorize the water bodies, as well as to characterize land uses, vegetation covers, and soil characteristics in the watershed.

Existing Data

The time constraints of the nutrient criteria development program dictate that the majority of the data that will be used to set nutrient criteria are already in existence. This will require technical support staff to contact federal, tribal, state, and local government sources, as well academia, environmental, and private sources for water, biological, and habitat quality data.

The process of acquiring the data will include contacting the sources via personal and phone interviews that are followed up with site visits to collect the data. Additionally, on-line database searches as well as other, as of yet, unidentified resources will be actively pursued.

Ongoing Projects

The database generated from existing data will be supplemented with data currently being collected and compiled by other agencies. This includes, but is not limited to, SWRCB's Surface Water Ambient Monitoring Program (SWAMP), CDFG's Bioassessment Program, and USGS's NAWQA program. Other ongoing projects that are collecting water, biological, and habitat quality data will be actively pursued and, if possible, their datasets incorporated into the nutrient database.

Special Studies

Data from special studies will be used to fill in critical data gaps that are identified in the database. They may include, but are not limited to, collection of specific data types (*e.g.*, benthic chlorophyll-a or percent periphyton coverage) or intense data collection from a specific waterbody type, that is under-represented in the database as a whole.

TASK 3
DATA ANALYSIS - REGIONAL UNITS AND CRITERIA PARAMETERS

Task 3 involves statistical data analysis of the existing water quality data that have been collected for each regional classification unit. The data analyses will range from simple descriptions of population characteristics to more complex evaluations of correlations among classification criteria and response parameters.

The goal of the EPA nutrient criteria development process is to find the most appropriate nutrient levels for reference conditions in water bodies. It is generally understood that reference levels of nutrients will be different for different regions of a state or EPA region as well as for different

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water body characteristics. Therefore, when numeric nutrient criteria are defined, we must also define the best regionalization and water body classification that goes with the numeric criterion.

There are two ways to select the most appropriate stratification for water bodies in a state: the first is to do it based on the scientific judgment of the RTAG members, and the second is to use a group of statistical classification techniques to select the best stratification given the nutrient data. Possibly the best approach is to combine the two approaches; that is, first obtain the stratification using different statistical techniques, and then refine the stratification based on the knowledge of experts in the RTAG.

For the purpose of this study we propose to use a method called Classification and Regression Trees (CART) that can be used with both numeric and non-numeric classification data. Thus, we can associate each sampling station and its nutrient level with various land use and geology-related parameters. A station could be identified by the watershed it is in, the geology of the watershed, the slope of the streambed, the flow rate in the stream, the season, the land-use in the watershed, and so on. Note that all of these data may not be available for the reference streams that we have studied in California, and that significant effort may have to be made to make the data set complete.

When finished, the complete data set would consist of the variable to be predicted (i.e., the nutrient species of concern), and a series of independent variables that we believe can be used to estimate the predicted variable. This is not unlike the data format that would be used for multiple regression, except that CART allows us to use a mixture of numeric and category-type variables, for example the use of descriptive terms for the geology of the watershed. When the CART algorithm is applied to the data, we can find out what values and ranges of the independent variables are best able to predict the dependent variable. The goal of the CART algorithm is to divide a large data set into smaller and smaller subsets of data, that are more similar to each other than the full data set, and that can be associated with certain ranges of the independent variables. To consider a hypothetical example, high phosphorus levels in reference streams may be associated with a certain type of geology, steep slope, and the absence of forest cover. Such stratification does not replace the professional expertise of the RTAG members, but is intended to enhance the interpretations and analyses being performed.

The statistical analyses of the existing water quality data will also help determine the appropriate form of the nutrient standards. This task will consist of determining the parameters that will be measured and how often and in what location they will be measured to determine compliance. The term location refers to sampling within the stream channel or lake-depth profile rather than another location downstream that is not proximate to the discharge. Although it is generally understood that nutrient criteria will be defined in terms of chemical concentrations, it need not necessarily be so. For the purpose of defining nutrient criteria, we will broaden the potential metrics to include, in addition to various chemical species of nitrogen and phosphorus, dissolved oxygen, turbidity, chlorophyll *a*, and indices of biological integrity. All of these metrics will exhibit gradients in water bodies due to uptake and cycling by biota and also due to transport and dilution. These gradients may be both spatial and temporal. Because algae and macrophytes in surface waters take up nutrients as they grow, they will exert an influence on measured concentrations. There are two temporal cycles of interest, diurnal and seasonal, and the definition may need to consider both cycles.

Numeric Parameters in Criteria

What metric or combination of metrics should be used to define the numeric criteria for water bodies? These metrics could include chemical parameters such as phosphorus (soluble reactive phosphorus and total phosphorus) and nitrogen species (total nitrogen, total organic nitrogen, nitrate, ammonia), and also direct and indirect biological parameters such as dissolved oxygen, chlorophyll *a*, secchi depth, and turbidity. A locally specified index of biological integrity could also be part of the standard, particularly, where it can be more closely related to the designated use of the water body. There are advantages and disadvantages to using each of the metrics listed here. Perhaps the most significant constraint is that much of the historical data available for water bodies is limited to chemical concentrations, i.e., the different nitrogen and phosphorus species. Thus, if we need to define a baseline reference condition from existing historical data, we are limited to the constituents that are most commonly measured. However, if we use only chemical parameters to define nutrient criteria, we may not always capture conditions that are most likely to cause impairment. As we work toward developing nutrient criteria, the RTAG must balance the advantages of using the historical database against coming up with a new metric (or combination of metrics) that may not have been measured in the past, but one which scientists think is a more accurate reflection of nutrient-related impairment.

Spatial Averaging

Because of the existence of spatial gradients in nutrient levels (and also other surrogate metrics), where we make measurements will influence the values we observe. Typically, we need to obtain samples at several locations to obtain a representative picture of nutrient levels across a water body. It is recommended that the specification of the spatial averaging to be undertaken should be part of the standard. This list must be supplemented by consideration of other factors that are responsible for generating spatial gradients in nutrient levels in water bodies.

Temporal Averaging

Because of diurnal and seasonal cycles in the growth and uptake of nutrients by biota, nutrient concentrations and other surrogate parameters are influenced by the time of sampling. Algae, macrophytes, and the biota that feed on them grow most rapidly in the spring and summer months, and grow only slightly in fall and winter. Over the course of a day, plants consume oxygen at night and produce it during the day as they photosynthesize. Nutrient uptake is greatest during photosynthesis. As with spatial averaging above, the approach will consider under what conditions specification of the time of sampling should be included as part of the numerical nutrient criteria. This list must be supplemented by consideration of other factors that are responsible for causing temporal gradients in nutrient levels in water bodies.

Determination of Numeric Criterion

Once several measurements of nutrient levels in a water body have been made, it still remains to be determined what numerical level we will define as an exceedance of the nutrient criterion. There are several approaches to be considered. (If a numeric value chosen for the criterion required a minimum value rather than a maximum value, this argument would be reversed.)

⇒ **Compare the annual arithmetic mean or the geometric mean to the numeric criterion, and consider any mean value greater than the criterion to be an exceedance.** Selection of the arithmetic mean versus the geometric mean should be based on the distribution of data. For log-normally distributed data, a geometric mean is preferred; for normal distributions, an arithmetic mean should be used. This test could be performed once each year or with a rolling 12-month mean every month. It is important to note that we are more likely to observe exceedances if we sample and compare with the standard more often. Therefore, to compare all water bodies in a similar way, we need to use approximately the same frequency for sampling and comparing against the standard. In the event that different water bodies of necessity are sampled at different frequencies (for example to control costs in a water monitoring program), we must apply corrections to the data that account for the greater incidence of false negatives.

⇒ **Allow a certain percentage of exceedances (e.g., 5% or 10%) over the criterion, that would still have the water body in compliance.** Thus, if 95% or 90% of the measured values were below the criterion, the waterbody may still not be in violation. This is generally appropriate for nutrients, as compared with toxins, because nutrients do not normally have acute, irreversible effects at specific threshold concentrations. This excludes particular chemical species that may be toxic at specific threshold levels (e.g., ammonia) which must be treated separately, and for which more rigorous exceedance criteria may be established. However, phosphorous can accumulate in sediments and over time flux from the sediments, becoming a significant source of impairment long after the allowed discharge. As a result, any increase over the criterion will need to be evaluated for the potential to create a future sediment source of nutrients to the aquatic system.

⇒ **Consider the allowance of seasonal climatic factors in the standard.** The work plan includes provisions to evaluate seasonal adjustments to the criterion.

⇒ **Consider a tiered approach for the criterion.** Because it is possible that all water bodies cannot be monitored at the same level of intensity, whether due to the different levels of importance or due to finite monitoring resources, a tiered approach may be used to evaluate the exceedance of nutrient criteria. This means that water bodies will be sampled at a certain frequency, and, if there are indications that there may be nutrient-related impairment in the water body, the monitoring is intensified so that a better understanding of the problem may be obtained. For the purpose of this standard, an indication of nutrient related impairment could include one or more of the following: 1) occasional values of nutrients in excess of the numeric criteria, although on average the water body is within compliance and 2) observation of nutrient-related secondary impacts, such as low dissolved oxygen, or negative effects on fish and other biota, even though numeric concentrations of nutrients are within acceptable levels. Other factors that the RTAG believes to be indications of potential over-enrichment could be added to this list that would put a water body under a higher level of monitoring and study. Following this higher level of monitoring, it could be determined if the water body was genuinely out of compliance using the tests described above.

⇒ **Classify the water body before applying the criterion.** The type of water body, and the chemical and physical characteristics of its surroundings (e.g., slope, climate, water body size and watershed area, geology, and land use) has a fundamental effect on the levels of nutrients that may be considered natural and that may cause observable negative impacts. For this reason, it is vital to develop standards by classifying water bodies into certain major categories, and calculate different nutrient criteria for different classifications. In previous studies, this classification has been performed at the ecoregion level for California, however, further classification along the physical characteristics of waterbodies is needed. A major limitation of developing a finer classification is the paucity of data at appropriate scales and resolutions. In the event that the RTAG has an influence on the future level of monitoring to be performed across California, an effort should be made to ensure that data are obtained from representative waterbodies along the principal classification criteria. These classification criteria should be communicated to the entity responsible for monitoring.

TASK 4
MODELING SCENARIOS TO DEFINE NUTRIENT CLASSIFICATION CATEGORIES

Computer simulation models will be used to evaluate the nutrient responses of streams and lakes to the key variables in the classification hierarchy. This will be conducted in two tasks (Tasks 4 and 5).

In Task 4, the models will be used to help evaluate the potential classification categories and to determine which categories appear to have the most promise for separating water bodies according to nutrient response. This task will be performed at the same time as the data collection and statistical analysis tasks, and the results will be used to help focus the statistical analyses. The modeling will allow us to systematically explore the effects of varying one lake or stream characteristic at a time while everything else remains constant. This will help determine which classification parameters have the most impact on nutrient and algal conditions, and how far the nutrient response can be expected to change with variations in the classification parameters. The effects of key watershed characteristics will also be evaluated with the models.

Two general approaches can be used in the model analyses: (1) generic modeling in which the models are set up for hypothetical watersheds, streams, and lakes representing each classification category; and (2) setting up the models for a few real streams and lakes (and their associated watersheds) that cover a few of the most important classification categories (e.g., ecoregions). These models can then be modified to evaluate the effects of some of the key classification parameters.

The generic approach relies heavily on default model parameters and does not require a great deal of calibration. The advantage of default parameters is that they have been developed to represent average conditions in many water bodies. Calibration efforts are minimized since it is not necessary to compare the model results with actual field data. Generic models are also much easier to set up since it is not necessary to compile extensive information for a real water body, and then parameterize the model to reflect those data. Because calibration and set up efforts are minimized, generic modeling allows many different scenarios to be evaluated.

The second approach, setting up models for a few real streams and lakes, has the advantage of basing the initial analyses on real water bodies. The additional effort expended in setting up and calibrating the models gives more confidence that the models represent real systems. However, there are also several drawbacks. First, the extensive effort required to set up and calibrate the models will leave fewer resources available for evaluating alternative scenarios, limiting the number of classification parameters that can be evaluated. Second, since real water bodies have several site-specific factors that influence their nutrient responses, the analyses will be biased by these factors and may not be as representative of other water bodies (as generic models would be). Third, once the models are modified to reflect variations in important classification parameters, they may no longer accurately represent the original water bodies.

The generic model approach is preferred for this study since many more scenarios can be evaluated, and the results will not be biased by site-specific factors. Three types of models will be used in the model analysis tasks: watershed models, stream models, and lake models.

Watershed Modeling

Watershed models will be used to estimate background nutrient loads to the streams and lakes. The models will be used to establish baseline nutrient loading conditions for several different watershed scenarios. The scenarios may include any of the following:

- Average representative conditions for each ecoregion
- Keystone watersheds in each ecoregion
- Watersheds dominated by single land uses and vegetation covers

- Watersheds of different size
- Climatic effects on watershed nutrient response
- Variations in key watershed characteristics including topography, soils, geology, vegetation, and land use

Most of the modeling analyses will focus on assessing nutrient loading conditions in unimpacted areas so that natural background conditions can be evaluated. A few analyses may also be conducted to estimate typical nutrient loads in urbanized areas so that urban lakes and streams can be assessed. Two general approaches can be used in the watershed modeling: (1) generic watersheds; and (2) real keystone watersheds representing each category.

For generic modeling, a typical watershed scenario would be established for each ecoregion using a GIS. This involves determining the average distribution of land uses, vegetation covers, soil characteristics, topography, climates, and background nutrient concentrations so that a hypothetical watershed scenario could be defined. These conditions would then be modeled using as many default parameters as possible. Calibration would be minimal since the models results could not be compared with data from an actual watershed. However, the results would be checked with available data from the region to make sure they are consistent with data from real watersheds.

Modeling of keystone watersheds involves setting up and calibrating the model for real watersheds, and then removing all unnatural point and nonpoint sources from the model in order to estimate background conditions (those without human influence). For this type of modeling, much more effort is required to compile and analyze the site-specific data necessary to set up and calibrate the model. Calibration is also a major effort, especially with the more complex models. Many model process parameters will have to be adjusted to reflect the site-specific conditions, and many model iterations and parameter adjustments will be required to match the field data. A significant effort will also be required to define the point and nonpoint sources of nutrients in the watershed.

Most keystone watersheds represent major lakes and streams that have been relatively well studied or monitored, but are usually heavily influenced by human activities with significant nonpoint source loads. These nonpoint loads typically dominate the model calibration and field data. Therefore, the model calibration may not be sensitive to background nutrient loads, which makes it difficult to determine if the background load estimates are accurate. Since determination of background nutrient loads from unimpaired watersheds is the main purpose of the watershed modeling, the use of keystone watersheds is probably not appropriate.

Generic watershed modeling is preferred over the modeling of keystone watersheds since more watershed scenarios can be evaluated and the results will not be biased by site-specific factors. Furthermore, default parameters can be used to estimate background nutrient loads without having to subtract the effects of major nonpoint sources. Additional modeling scenarios will be defined for each ecoregion to represent the typical range of watershed conditions that can be expected. For example, scenarios may be developed for different sizes of watersheds, different land uses, and to evaluate the differences between upland watersheds with low order streams and larger watersheds feeding downstream higher order streams.

Watershed models can range from simple empirical methods such as export coefficients to very complex simulation models with detailed process formulations and extensive data and calibration requirements. Several approaches will be evaluated for this study.

A watershed modeling strategy will be selected after an assessment of the available data and the number and types of scenarios to be evaluated. The modeling approach may involve simple empirical methods, mid-range models, detailed models, or some combination of these techniques. The recommended mid-level model is GWLF, and the recommended detailed model is SWAT. Both of these models are applicable to both rural undeveloped areas and urban areas, and both include a fairly extensive set of default parameters that makes them useful for generic analyses. A GIS model based on runoff coefficients and nutrient EMCs for different land uses and vegetation types will also be considered.

Stream Modeling

Since watershed models predict nutrient loads and concentrations in the stream outlets at the downstream end of the watershed, separate models are often not necessary for estimating stream nutrient concentrations. Nutrient concentrations in different reaches of a river network can be evaluated by dividing the overall watershed into several subwatersheds and calculating the results separately. However, stream models are useful for addressing specific issues such as periphyton growth and diurnal dissolved oxygen variations that are not typically included in watershed models. They are also useful for predicting instream nutrient losses (e.g., algal uptake) and nutrient transformations (e.g., nitrification).

Dynamic stream models can be used for predicting seasonal periphyton dynamics, diurnal dissolved oxygen fluctuations, nutrient transformations, biological uptake and cycling, and sediment nutrient exchange along stream systems. These models typically require site-specific data and calibration since periphyton and dissolved oxygen depend on site-specific factors such as substrate, channel morphometry, and flow regime (in addition to nutrients, light, and temperature). Therefore, dynamic stream models are more difficult to use for generic analyses than other simpler types of models. However, they could be set up and run for generic streams using typical stream and flow conditions for a particular ecoregion (or other region), and using as many default model parameters as possible to parameterize the stream. Models applied in this way would have minimal calibration since the stream would be hypothetical and therefore would not have real field data. Alternatively, the model could be set up for several real streams representing different ecoregions or other major stream categories. This approach would require more effort since site-specific data would have to be collected and the model would have to be calibrated.

With either the generic stream or the real stream modeling approach, numerous scenarios will be run with the models to assess the stream nutrient, periphyton, and oxygen responses to variations in the key stream classification parameters. Several stream models will be evaluated for their potential applicability to evaluating these effects, and the most appropriate model or set of models will be selected.

Realistic representations of periphyton are only available in a few models. These include the periphyton model developed by Jim Brock and his colleagues as part of the Dynamic Stream Simulation and Assessment Model (DSSAMt), the addition of periphyton to the WASP5 model by John Warwick based on Jim Brock's model, and recent periphyton enhancements to the AQUATOX model developed by Richard Park. Statistically based models using regression analysis and other techniques have also been developed to predict periphyton abundance from nutrient concentrations and other stream and watershed characteristics. These include the models of Heiskary and Markus (2001), Niewenhuyse and Jones (1996), Biggs (2000), Dodds et al. (1997), and Welch et al. (1989). These and any other appropriate models will be evaluated for their potential use in the stream analyses.

Lake Modeling

The steady-state model BATHTUB will be used for the lake modeling. A steady-state modeling approach was selected since dynamic lake models require extensive time series of monitoring data, are difficult to calibrate, and are not really appropriate for generic analyses. Steady-state models are much more appropriate for generic analyses of many different lake classification parameters. Steady-state models predict seasonal or annual average nutrient and phytoplankton concentrations. Seasonal or annual averages are more useful for evaluating lake nutrient responses and establishing nutrient criteria than the daily values predicted by dynamic models. Steady-state models are also much easier to apply than dynamic models, which will allow many more lake classification scenarios to be evaluated. Steady-state lake models are also compatible with any type of watershed modeling approach, while dynamic models are best suited for complex watershed modeling approaches.

BATHTUB is the most comprehensive of the available steady-state lake models. The model simulates phosphorus, nitrogen, phytoplankton chlorophyll a, Secchi depth, and hypolimnetic oxygen consumption. It uses more mechanistic formulations for some of the modeled processes than other models. It considers both phosphorus and nitrogen as limiting nutrients, and includes several options for estimating nutrient sedimentation from the water column, nutrient release from sediments and macrophytes, and nutrient availability in inflows. BATHTUB also includes many default values for the nutrient sedimentation and algal parameters. These defaults are based on the statistical analysis of data from many different lakes from EPA's National Eutrophication Survey and from Corps of Engineers reservoirs. The default parameters allow the generic analysis of many different lakes with different size and hydrologic characteristics without requiring site-specific calibration to a real lake. However, the model can also be calibrated to real lakes if that type of modeling approach is adopted. Spatial segmentation and hydraulic transport processes can also be incorporated, if appropriate.

BATHTUB will be used to predict lake nutrient and phytoplankton responses to each load scenario established from the watershed modeling. These analyses will be repeated for lakes of different size, shape, and hydrology using the classification variables derived from the database. These results will show how the nutrient and phytoplankton levels can be expected to vary with lake size, hydrology, and watershed characteristics in each ecoregion.

TASK 5
MODELING SCENARIOS TO CONDUCT RESPONSE PARAMETER SENSITIVITY ANALYSES

In Task 5, the watershed, stream, and lake models described above will be used to conduct sensitivity analyses on the various response parameters selected for the establishment of the nutrient criteria. The models are not being used to generate primary data. Rather they are being used to dynamically test our best understanding of various response hypotheses. The modeling will be used to verify the results of the statistical analyses, and also to fill in data gaps and extend the analyses to a full range of conditions that may not be fully represented in the database. The purpose of these modeling scenarios is to evaluate response parameters that have been identified by the Work Group as candidates for use in the nutrient criteria. Models will be used to evaluate response parameters under various nutrient conditions, watershed classifications, and specific water body characteristics (e.g., stream gradient, lake depth).

TASK 6
REVIEW AND SYNTHESIS OF EXISTING WATER QUALITY STUDIES

A synthesis of detailed and comprehensive site-specific studies is needed to support the modeling scenarios and empirical data analyses. The site-specific studies will confirm that beneficial uses are protected within the recommended nutrient criteria ranges. This task will require identifying long-term studies and reviewing study results. Direct contact with primary researchers will be the preferred approach, since they will have the most knowledge of nutrient and algal dynamics in the water bodies, as well as knowledge of whether or not the designated beneficial uses are attained.

Data from site-specific studies will be used to provide detailed information to supplement the distribution information. This type of data will provide a sense of "ground truth" by answering questions such as "Given this range of potential nutrient criteria, can we be certain that beneficial uses would be supported?" A synthesis of several site-specific studies that compare causal and response variables to their impact on beneficial uses is provided in Appendix E of the document entitled, "*White Paper: The Development of Nutrient Criteria for Ecoregions within California, Arizona, and Nevada*"(March 2002). This summary includes site-specific data for water bodies both within and outside of EPA Region IX. This task will work toward supplementing this table with data from special studies performed on water bodies inside EPA Region IX.

There are several sources of site-specific data available to us. These include, but are not limited to, completed and ongoing nutrient TMDLs, university studies, sanitary surveys, studies performed by local interest groups (e.g., Friends of the River), SWAMP's reference water study, and the California Bioassessment program.

Technical advisors will be used as resources to identify potential site-specific studies, as well as providing technical guidance in developing the data synthesis.

TASK 7
DRAFT RECOMMENDATIONS REPORT

The draft recommendations report will describe the progress made on every facet of the work plan for the development of nutrient criteria. The results of the study will be presented in a final report in 2004 and an annual progress report in 2003. Recommendations in the final report at the end of the study will include the selected classification hierarchy, recommended response parameters for establishing nutrient criteria, and ranges for nutrient criteria parameters for selected regional classification units where sufficient data are available. The data compilation, statistical analyses, and model analyses used to support the recommendations will be fully documented. However, it will not be possible to make nutrient criteria recommendations for most of the regional classification units upon completion of the first year of the work plan. The recommendations in the annual progress report after the first year will describe the status of each regional classification unit and make recommendations for future efforts.

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