Section B1. Sampling Process Design (Experimental Design)

This section provides detailed background on the monitoring objectives that are designed to address the protection and enhancement of beneficial uses of the state's surface waters. These objectives are utilized by RWQCB's in the specific designing of their monitoring approach and rationale each year in their annual RWQCB SWAMP Work Plans **(Appendix B)**. The lengthy detail provided in this section is necessary in order to provide the basis for the sampling process design used by the RWQCB's in their Work Plans, since there is no one unified, routine type of monitoring design that occurs in SWAMP, as it is currently designed.

NOTE: Because of the budget constraints during 2001-02, and continuing with the 2002-03 budget, the SWRCB and RWQCB's began implementing SWAMP by primarily focusing on **site-specific monitoring** to better characterize problem sites or clean locations (reference sites) to meet each RWQCB's needs for 303(d) listing, TMDL development, and other core regulatory programs. Another major component of SWAMP– the overall status and trends of the state's surface water quality–will be implemented in the future as additional funds are made available. Until then, RWQCB's will continue to use SWAMP resources to address high priority water quality issues in each region, while following SWAMP protocols to ensure statewide data comparability. But, currently, the need for "site-specific" studies in each region is the highest priority for use of SWAMP funds. The sections which follow below provide a summary of both programmatic components--**site specific monitoring** currently being done in SWAMP focusing on regional priorities, questions, and needs; and **regional status and trends monitoring** of all of the state's waters, which may be implemented in future years if funding allows.

Summary/Overview of the Overall Experimental Design Approach Used in the Surface Water Ambient Monitoring Program

The 11/2000 Legislative Report proposal calls for a combination of (1) regional monitoring to provide a picture of the status and trends in water quality and (2) site-specific monitoring to better characterize problem and clean locations. This approach balances these two important monitoring needs of the SWRCB and serves as a unifying framework for the monitoring activities being conducted by the SWRCB and RWQCB'. The coordinated SWRCB and RWQCB involvement in study design and sampling is critical to providing a comprehensive, effective monitoring program that results in identifying degrading and improving conditions in waterways.

The regional component with the rotating basin design and, for some water bodies, the probability-based design will allow the SWRCB and RWQCB's to complete comprehensive monitoring required to satisfy CWA Section 305(b) requirements and will contribute to the

achievement of the State's various water quality programs. These types of programs allow the State and USEPA to track trends in water quality. This in turn could be used as measures to track the effectiveness of the SWRCB and RWQCB water quality control programs.
The regional monitoring component complements the site-specific monitoring effort in two ways. It provides additional data that can be used to put the data from targeted sites into a broader regional context. Equally important, the regional component would serve as a periodic screening mechanism for identifying new problem areas that were not previously known.

The site-specific monitoring provides flexibility for RWQCB's to focus monitoring resources toward specific problems and waters that may be clean. This might involve verifying problems identified in the statewide surveys, other areas suspected of having water quality problems, or locations that represent background or clean conditions. This documentation and verification of a site's water quality status should be a key component of the Section 303(d) listing process.

Regional Monitoring (not currently being conducted; implementing in the future is a goal)
The overall goal of this activity of SWAMP is to develop a statewide and region-wide picture of the status and trends of the quality of California's surface water resources. It is intended that this portion of SWAMP will be implemented in each hydrologic unit (including coastal waters) of the State at least once every five years. This portion of SWAMP is focused on collecting information on water bodies for which the State presently has little information and to determine the effects of diffuse sources of pollution, and the baseline conditions of potentially clean areas. For inland waters (watersheds), the program will implement a rotating basin framework where each Region will be divided into five areas consisting of one or more hydrologic units. The major watercourses and tributaries in one of these areas would be monitored for a one-year period at least once every five years. In coastal waters, a smaller amount of probabilistic monitoring will be completed. See Regional Monitoring section below for further details.

Site-Specific Monitoring (this is the focus of all current SWAMP-funded work)
The overall goal of this activity of SWAMP is to develop site-specific information on sites that are (1) known or suspected to have water quality problems and (2) known or suspected to be clean. It is intended that this portion of SWAMP will be targeted at specific locations in each region. The RWQCB's are given significant flexibility to select the specific locations to be monitored. The
RWQCB's may, at their discretion, perform monitoring at clean sites to determine baseline conditions (for assessments related to anti-degradation requirements) or if this information is needed to place problem sites into perspective with cleaner sites in the Region. See Site-Specific Monitoring section below for further details.

REGIONAL MONITORING (future programmatic goal; not currently done)

The overall goal of this activity of SWAMP will be to develop statewide and region-wide picture of the status and trends of the quality of California's surface water resources. It is intended that this portion of SWAMP, once funded, will be implemented in each hydrologic unit (including coastal waters) of the State at least one time every five years. This portion of SWAMP would focus on collecting information on water bodies for which the State presently has little information and to determine the effects of diffuse sources of pollution and the baseline conditions of potentially clean areas.

For inland waters (watersheds), the program would implement a rotating basin framework where each Region will be divided into five areas consisting of one or more hydrologic units. The major watercourses and tributaries in one of these areas would be monitored for a one-year period at least once every five years. In coastal waters, a smaller amount of probabilistic monitoring would be completed.

Need for Regional Monitoring
Monitoring is needed that defines the larger scale condition of beneficial uses. This regional monitoring can determine if known local impacts can be observed over large distances and allows the assessment of region-wide or statewide water resource conditions. The results of regional monitoring will help the SWRCB and RWQCB's to determine clearly the effectiveness of the State's water quality control program.

The California Legislature is also very interested in establishing a closer link between budgeted water quality program activities and the impact those activities have on protecting and improving water quality. The Supplemental Report Language to the 1999 Budget Act directed the SWRCB to "… develop performance measures for its core regulatory programs …. that relate directly to water quality outcomes ….". While the SWRCB and RWQCBs have established performance measures to manage many activities, the ability to relate directly the performance of their programs to water quality outcomes has been hampered by limited data management capabilities and fragmented and incomplete water quality monitoring data collection, evaluation, and management.

Since 1995, the SWRCB has used several performance objectives and measures for its programs. The measures are generally output related and designed to measure program efficiency and timeliness (such as percent of total inspections completed versus the number of permitted sites, number of Cleanup and Abatement Orders (CAO's); median time required to issue new NPDES permits and WDR's).

Regional monitoring, when funded and implemented, will provide the SWRCB and RWQCB's with a better picture of the water quality outcome of their programs. The information needed to assess program performance and support CWA Section 305(b) reporting focuses on the area or percentages of the area of the State's surface water that fully or partially support the associated beneficial uses.

Monitoring Objectives

In developing the SWAMP monitoring objectives, the SWRCB used a modified version of the model proposed by Bernstein et al. (1993) for developing clear monitoring objectives. The model makes explicit the assumptions and/or expectations that are often embedded in less detailed statements of objectives such as those presented in the SWRCB Report to the Legislature on comprehensive monitoring submitted in February 2000 (SWRCB, 2000). This section is organized by each major question posed in the January 2000 report.

- **Is it safe to swim?**

Beneficial Use: Water Contact Recreation

1. Throughout water bodies that are used for swimming, estimate the concentration of pathogenic contaminants above and below screening values, health standards, or adopted water quality objectives.
2. Estimate the percent of beach area that poses potential health risks of exposure to pathogens in streams, rivers, lakes, nearshore waters, enclosed bays, and estuaries using several critical threshold values of potential human impact (pathogen indicators).
3. Throughout water bodies that are used for swimming, estimate the concentration of bacterial contaminants from month-to-month above and below screening values, health standards, or adopted water quality objectives.

- **Is it safe to drink the water?**

Beneficial Use: Municipal and Domestic Water Supply

4. Throughout water bodies, estimate the area of lakes, rivers, and streams that are sources of drinking water where the concentration of microbial or chemical contaminants are above and below screening values, drinking water standards, or adopted water quality objectives used to protect drinking water quality.
5. Throughout water bodies that are used as a source of drinking water, estimate the concentration of microbial or chemical contaminants from month-to-month above and below screening values, drinking water standards, or adopted water quality objectives used to protect drinking water quality.

- **Is it safe to eat fish and other aquatic resources?**

Beneficial Uses: Commercial and Sport Fishing, Shellfish Harvesting

6. Estimate the area of streams, rivers, lakes, nearshore waters, enclosed bays, and estuaries where the concentration of chemical contaminants in edible fish or shellfish tissue exceeds several critical threshold values of potential human impact (screening values or action levels).
7. Assess the geographic extent of chemical contaminants in selected size classes of commonly consumed target species that exceed several critical threshold values of potential human impact (screening values or action levels) (Adapted from USEPA, 1995).
8. Throughout water bodies (streams, rivers, lakes, nearshore waters, enclosed bays, and estuaries), estimate the concentration of chemical contaminants in fish and aquatic resources from year to year using several critical threshold values of potential human impact (advisory or action levels).
9. Throughout water bodies that are used for shellfish harvesting, estimate the concentration of bacterial contaminants from month to month above and below health standards or adopted water quality objectives.
10. Throughout water bodies that are used for shellfish harvesting, estimate the concentration of bacterial contaminants above and below health standards or adopted water quality objectives.

o Are aquatic populations, communities, and habitats protected?

Beneficial Uses: Cold Freshwater Habitat; Estuarine Habitat; Inland Saline Water Habitats; Marine Habitat; Preservation of Biological Habitats; Rare, Threatened or Endangered Species; Warm Freshwater Habitat; Wildlife Habitat
11. Estimate the percent of degraded water area in lakes, nearshore waters, enclosed bays, and estuaries using several critical threshold values of toxicity, water or benthic community analysis, habitat condition, and chemical concentration.
12. Estimate the percent of degraded sediment area in rivers, lakes, nearshore waters, enclosed bays, and estuaries using several critical threshold values of toxicity, benthic community analysis, habitat condition, and chemical concentration.
13. Identify the areal extent of degraded sediment locations in rivers, lakes, nearshore waters, enclosed bays, and estuaries using several critical threshold values of toxicity, benthic community analysis, habitat condition, and chemical concentration.
14. Estimate the percent of degraded sediment area from year to year in rivers, lakes, nearshore waters, enclosed bays, and estuaries using several critical threshold values of toxicity, benthic community analysis, habitat condition, and chemical concentration.
15. Estimate the percent of degraded water area from year to year in rivers, lakes, nearshore waters, enclosed bays, and estuaries using several critical threshold values of toxicity, water column or benthic community analysis, habitat condition, and chemical concentration.

Beneficial Use: Spawning, Reproduction and/or Early Development
16. Estimate the area of degraded spawning locations and water or sediment toxicity associated with toxic pollutants in rivers, lakes, nearshore waters, enclosed bays, and estuaries using critical threshold values of early life-stage toxicity, chemical concentration, and physical characteristics

17. Estimate the area degraded spawning locations and water or sediment toxicity associated with toxic pollutants from year to year in rivers, lakes, nearshore waters, enclosed bays, and estuaries using critical threshold values of early lifestage toxicity, chemical concentration, and physical characteristics.

- **Is water flow sufficient to protect fisheries?**

Beneficial Use: Migration of Aquatic Organisms; Rare, Threatened or Endangered Species; Wildlife Habitat
18. Throughout water bodies, estimate the area with the conditions necessary for the migration of aquatic organisms, such as anadromous fish, using measures of habitat condition including water flow, watercourse geomorphology, sedimentation, temperature, and biological communities.
19. Throughout water bodies, estimate the area with the conditions from month to month necessary for the migration of aquatic organisms, such as anadromous fish, using measures of habitat condition including water flow, watercourse geomorphology, sedimentation, temperature, and biological communities.

- **Is water safe for agricultural use?**

Beneficial Use: Agricultural supply
20. Throughout water bodies, estimate the area of lakes, rivers and streams that are used for agricultural purposes where the concentration of chemical pollutants are above or below screening values or adopted water quality objectives used to protect agricultural uses.
21. Throughout waterbodies that are used for agricultural purposes, estimate the concentration of chemical pollutants from year-to-year above or below screening values or adopted water quality objectives used to protect agricultural uses.

- **Is water safe for industrial use?**

Beneficial Use: Industrial Process Supply; Industrial Service Supply
22. Throughout water bodies, estimate the area of coastal waters, enclosed bays, estuaries, lakes, rivers and streams that are used for industrial purposes where the concentration of chemical pollutants are above or below screening values or adopted water quality objectives used to protect industrial uses.
23. Throughout water bodies that are used for industrial purposes, estimate the concentration of chemical pollutants from year to year above or below screening values or adopted water quality objectives used to protect industrial uses.

- **Are aesthetic conditions of the water protected?**

Beneficial Use: Non-Contact Water Recreation
24. Throughout water bodies, estimate the area of coastal waters, enclosed bays, estuaries, lakes, rivers and streams where the aesthetic conditions are above or below screening values or adopted water quality objectives used to protect noncontact water recreation.
25. Throughout water bodies, estimate the aesthetic condition from year-to-year above or below screening values or adopted water quality objectives used to protect non-contact water recreation.

Overall Sampling Design for Regional Monitoring, when funded and implemented
As discussed elsewhere, each year the SWRCB, in coordination with the RWQCBs, would prepare a detailed Work Plan that is consistent with the SWAMP goals, objectives, study design, indicators, and quality assurance requirements. The specific study design would be incorporated into contracts or task orders to implement the monitoring program.

While this effort will be coordinated by the SWRCB, the RWQCBs will make any needed region-specific decisions. The steps to establish the specific sampling design are:

1. RWQCBs will divide the Region into five areas consisting of one or more hydrologic units.

2. Identify all major watercourses, tributaries and lakes to sample. Monitoring will be completed in all hydrologic units without bias to known impairments.

3. Select monitoring objectives based on applicable beneficial uses of the water bodies selected. Applicable beneficial uses are uses that are listed in the RWQCB's basin plan, or potential beneficial uses for the water body that are included in the scope of SWAMP.

4. Review available information. The RWQCB will compile all available information including data reports as part of compliance monitoring programs, State monitoring efforts, other agency monitoring, citizen monitoring efforts, or research efforts. Depending on the water body, the RWQCBs and SWRCB will include information produced by the Southern California Bight Projects; the San Francisco Regional Monitoring Program; the USEPA Environmental Monitoring and Assessment Program (EMAP) efforts in the State's enclosed bays, estuaries, coastal streams, and rivers; U.S. Forest Service efforts (Harrington, personal communication, October 2000); NOAA's Status and Trends Program; any information produced as a result of the Unified Federal Policy for a Watershed Approach to Federal Land and Resource Management (U.S. Department of Agriculture et al., 2000); and other federal, State, or local programs that would augment the State's monitoring efforts.

5. Evaluate quality and applicability of available information and then make a determination on the need for new monitoring. Considerations in this evaluation include temporal variability, spatial variability, and critical conditions (such as drought, flood, stream flow, and El Nino).

6. For inland waters (watersheds), the RWQCBs will select long-term, fixed/permanent sites in each perennial lake, major watercourse and tributary.

It is assumed that each of these sites will represent upstream water quality conditions or, for lakes, the water body condition. In selecting sites to monitor, the RWQCBs will consider the existing information or model predictions for the following characteristics:

- Seasonal variation in the water bodies or watersheds including precipitation information;
- Spatial variation in the watershed (the range of physical characteristics in the watersheds) including, but not limited to, land use patterns, topography, and soil characteristics;
- The release of water to support groundwater recharge or surface water diversions;
- Sample representativeness under different flow conditions.

7. For enclosed bays, estuaries, and ocean waters, the SWRCB and RWQCB's, will select sites using probability-based approach. The approach may be either random or stratified random (i.e., strata can correspond to a subpopulation of interest such as land use patterns) with a mechanism for systematically separating samples (Stevens, 1997; SCCWRP, 1998). It is necessary that an adequate number of samples is selected to represent the stratum with adequate precision. Thirty sites should be allocated to each stratum to provide a 90 percent confidence interval of no larger than roughly ±10 percent of the area in the subpopulation (this assumes a binomial probability distribution and p=0.2). Fewer or more sites may be selected if smaller or larger confidence intervals are needed.

8. Select necessary water quality indicators and target species. RWQCB's will select indicators based on the beneficial uses of the water body. For example, if a water body is not a source of drinking water, it is not necessary to implement monitoring focused on drinking water uses. RWQCB's may select alternative indicators if they meet the selection criteria presented in Table 4 at the end of this section.

In all monitoring efforts, the indicators will be selected from the biological response, pollutant, and habitat indicator categories presented in Table 5 at the end of this section. Further, indicators representing each category should be collected synoptically. For biological resources, it is important that a triad of measurements (biological, pollutant, and habitat) be collected concurrently. If more than one medium is being monitored, all samples should be synoptically collected, to the extent possible. The most sensitive and waterbody appropriate indicators should be selected for use.

SITE-SPECIFIC MONITORING (this is what is being conducted currently)

The overall goal of this activity of SWAMP is to develop site-specific information on sites that are (1) known or suspected to have water quality problems and (2) known or suspected to be clean. It is intended that this portion of SWAMP will be targeted at specific locations in each region. This portion of SWAMP is focused on collecting information from sites in water bodies of the State that could be potentially listed or de-listed under CWA Section 303(d). The RWQCB's are given significant flexibility to select the specific locations to be monitored.

The RWQCBs at their discretion may perform monitoring at clean sites to determine baseline conditions (for assessments related to antidegradation requirements) or if this information is needed to place problem sites into perspective with cleaner sites in the Region.

Objectives for Site-Specific Monitoring

In developing the SWAMP monitoring objectives, the SWRCB used a modified version of the model for developing clear monitoring objectives proposed by Bernstein et al. (1993). The model makes explicit the assumptions and/or expectations that are often embedded in less detailed statements of objectives (as presented in SWRCB, 2000). This section is organized by each major question posed in the SWRCB report to the Legislature on comprehensive monitoring (SWRCB, 2000).

- **Is it safe to swim?**

Beneficial Use: Water Contact Recreation

1. At sites influenced by point sources (e.g., storm drains, publicly owned treatment works, etc.) or nonpoint sources of pathogenic contaminants, estimate the concentration of bacteria or pathogens above screening values, health standards, or adopted water quality objectives.

- **Is it safe to drink the water?**

Beneficial Use: Municipal and Domestic Water Supply

2. At specific locations in lakes, rivers and streams that are sources of drinking water and suspected to be contaminated, estimate the concentration of microbial and chemical contaminants above screening values, drinking water standards, or adopted water quality objectives used to protect drinking water quality.
3. At specific locations in lakes, rivers and streams that are sources of drinking water and suspected to be contaminated, verify previous estimates of the concentration of microbial and chemical contaminants above screening values, drinking water standards, or adopted water quality objectives used to protect drinking water quality.

- **Is it safe to eat fish and other aquatic resources?**

Beneficial Uses: Commercial and Sport Fishing, Shellfish Harvesting
4. At specific sites influenced by sources of bacterial contaminants, estimate the concentration of bacterial contaminants above health standards or adopted water quality objectives to protect shellfish harvesting areas.
5. At specific sites influenced by sources of chemical contaminants, estimate the concentration of chemical contaminants in edible aquatic life tissues above advisory levels and critical thresholds of potential human health risk.
6. At frequently fished sites, estimate the concentration of chemical contaminants in commonly consumed fish and shellfish target species above advisory levels and critical thresholds of potential human health risk (Adapted from USEPA, 1995).
7. At frequently fished sites, verify previous estimates of the concentration of chemical contaminants in commonly consumed fish and shellfish target species above advisory levels and critical thresholds of potential human health risk (Adapted from USEPA, 1995).
8. Throughout water bodies (streams, rivers, lakes, nearshore waters, enclosed bays and estuaries), estimate the concentration of chemical contaminants in fish and aquatic resources from year to year using several critical threshold values of potential human impact (advisory or action levels).

- **Are aquatic populations, communities, and habitats protected?**

Beneficial Uses: Cold Freshwater Habitat; Estuarine Habitat; Inland Saline Water Habitats; Marine Habitat; Preservation of Biological Habitats; Rare, Threatened or Endangered Species; Warm Freshwater Habitat; Wildlife Habitat
9. At sites influenced by point sources (e.g., storm drains, publicly owned treatment works, etc.) or nonpoint sources of pollutants, identify specific locations of degraded water or sediments in rivers, lakes, nearshore waters, enclosed bays, or estuaries using several critical threshold values of toxicity, water column or epibenthic community analysis, habitat condition, and chemical concentration.
10. At sites influenced by point sources (e.g., storm drains, publicly owned treatment works, etc.) or nonpoint sources of pollutants, identify specific locations of degraded sediment in rivers, lakes, nearshore waters, enclosed bays, or estuaries using several critical threshold values of toxicity, benthic community analysis, habitat condition, and chemical concentration.
11. Identify the areal extent of degraded sediment locations in rivers, lakes, nearshore waters, enclosed bays, and estuaries using several critical threshold values of toxicity, benthic community analysis, habitat condition, and chemical concentration.

- **Beneficial Use: Spawning, Reproduction and/or Early Development**

12. At sites influenced by point sources (e.g., storm drains, publicly owned treatment works, etc.) or nonpoint sources of pollutants, identify specific locations of degraded water or sediment in rivers, lakes, nearshore waters, enclosed bays, and estuaries using several critical threshold values of early life-stage toxicity, chemical concentration, and physical characteristics.
13. At sites influenced by point sources (e.g., storm drains, publicly owned treatment works, etc.) or nonpoint sources of pollutants, verify previous measurements identifying specific locations of degraded water or sediment in rivers, lakes, nearshore waters, enclosed bays, and estuaries using several critical threshold values of early life-stage toxicity, chemical concentration, and physical characteristics.

o Is water flow sufficient to protect fisheries?

Beneficial Use: Migration of Aquatic Organisms; Rare, Threatened or Endangered Species; Wildlife Habitat

14. At specific sites influenced by pollution, estimate the presence of conditions necessary for the migration and survival of aquatic organisms, such as anadromous fish, using measures of habitat condition including water flow, watercourse geomorphology, sedimentation, temperature, and biological communities.
15. At specific sites influenced by pollution, verify previous estimates of the presence of conditions necessary for the migration and survival of aquatic organisms, such as anadromous fish, using measures of habitat condition including water flow, watercourse geomorphology, sedimentation, temperature, and biological communities.

o Is water safe for agricultural use?

Beneficial Use: Agricultural supply

16. At specific locations in lakes, rivers and streams that are used for agricultural purposes, estimate the concentration of chemical pollutants above screening values or adopted water quality objectives used to protect agricultural use.
17. At specific locations in lakes, rivers and streams that are used for agricultural purposes, verify previous estimates of the concentration of chemical pollutants above screening values or adopted water quality objectives used to protect agricultural uses.

o Is water safe for industrial use?

Beneficial Use: Industrial Source Supply; Industrial Process Supply

18. At specific locations in coastal waters, enclosed bays, estuaries, lakes, rivers and streams that are used for industrial purposes, estimate the concentration of chemical pollutants above screening values or adopted water quality objectives used to protect industrial use.
19. At specific locations in coastal waters, enclosed bays, estuaries, lakes, rivers and streams that are used for industrial purposes, verify previous estimates of the concentration of chemical

pollutants above screening values or adopted water quality objectives used to protect industrial uses.

o Are aesthetic conditions of the water protected?

Beneficial Use: Non-Contact Water Recreation

20. At specific locations in coastal waters, enclosed bays, estuaries, lakes, rivers and streams, estimate the aesthetic condition above screening values or adopted water quality objectives used to protect non-contact water recreation.
21. At specific locations in coastal waters, enclosed bays, estuaries, lakes, rivers and streams, verify previous estimates of the aesthetic condition above screening values or adopted water quality objectives used to protect non-contact water recreation.

Overall Sampling Design for Site-Specific Monitoring

As discussed elsewhere, each year the RWQCB's will prepare a detailed SWAMP Work Plan for ambient surface water monitoring which is consistent with the SWAMP goals, objectives, overall study design, indicators, and quality assurance requirements. Specific study design will be incorporated into contracts or task orders to implement the monitoring program.

While this effort will be coordinated by SWRCB, the RWQCB’s will make the region-specific decisions. The steps to establish the specific sampling design are:

1. Identify site-specific problem(s), potential problem(s), or clean water locations to be monitored.
2. Select monitoring objective(s).
3. Review available information. The RWQCB shall consider all available information including data reported as part of compliance monitoring programs, State monitoring efforts, other agency monitoring, citizen monitoring efforts, and research efforts. To the extent possible, the RWQCB's will solicit new information from interested parties.
4. Evaluate the quality and applicability of available information and then make determination on the need for new monitoring. Considerations in this evaluation include temporal variability, spatial variability, and critical conditions (such as drought, flood, stream flow, and El Nino).
5. Select sites using investigator pre-selection (i.e., point estimates) or a probability-based approach. The approach depends on the RWQCB’s needs. If a stratified random sampling approach is used, ensure adequate numbers of samples are selected to represent the stratum with adequate precision (specific guidance is available to determine the discussion of the number of samples needed).

The RWQCB’s may select monitoring sites in water bodies considered to be clean (unpolluted or unimpacted). These sites may be needed to assess baseline conditions or, if the sites are needed as reference sites, to place other monitoring efforts into perspective, or to make assessments related to anti-degradation requirements.

In developing the design of the site-specific monitoring efforts, the RWQCB's will consider the existing information or model predictions for the following characteristics:
• Seasonal variation in the water body or watershed including precipitation information;
• Spatial variation in the watershed (the range of physical characteristics in the watershed) including, but not limited to, land use patterns, topography, and soil characteristics;
• The release of water to support groundwater recharge and surface water diversions;
• Sample representativeness under different flow conditions; and
• Variation in the magnitude, duration, and frequency of the suspected water quality problem or unpolluted baseline conditions.

6. Select appropriate water quality indicators and target species, if appropriate. RWQCB's will select indicators based on the potential for impacts on specific beneficial uses of the water body. For example, if a suspected problem is related to potential aquatic life impacts near or at storm drains, the RWQCB's should focus on this specific concern.

In all monitoring efforts, the indicators will be selected from each of the biological response, pollutant, and habitat indicator categories described in Tables 4 and 5 at the end of this section. RWQCB's may select fewer indicators if the needed monitoring information is available and comparable to the data to be collected.

Further, indicators representing each category should be synoptically collected. For biological resources, it is important that a triad of measurements (biological, pollutant, and habitat) be collected concurrently. If more than one medium is being monitored, all samples should be synoptically collected, to the extent possible. The most sensitive and water body-appropriate indicators should be selected for use.

WATER QUALITY INDICATORS

One of the most important steps in the development of an ambient monitoring program is the selection and use of indicators of water quality. Indicators are the tools used to assess and measure water quality. This section describes the characteristics of indicators, provides supporting rationale for their use, and lists some of the indicators that will be used in SWAMP.

What is an indicator?

An indicator is a "... measurable feature or features that provide managerially and scientifically useful evidence of environmental and ecosystem quality or reliable evidence of trends in quality" (ITFM, 1995). Indicators must be measurable with available technology, scientifically valid for assessing or documenting ecosystem quality, and useful for providing information for management decision making. Environmental indicators include tools for assessment of chemical, physical, and biological conditions and processes.

Selection of Appropriate Indicators
One of the hardest tasks for development of an ambient monitoring program is the selection of meaningful indicators of water quality. General criteria are needed to help shape the monitoring efforts so the results are useful in the decision making process. The use of criteria streamlines the indicator selection process, potentially reduces costs, prevents the use of indicators that will not allow program effectiveness to be assessed, and provides consistency.

Table 4 lists several criteria for selecting environmental indicators based on scientific, practical, and programmatic considerations. Scientific validity is the foundation for determining whether data can be compared with reference conditions or other sites. An indicator must not only be scientifically valid, but its application must be practical (i.e., not too costly or too technically complex) when placed within the constraints of a monitoring program. Of primary importance is that the indicator must be able to address the questions posed by the ambient monitoring program.

Scientific Validity
Measurements of environmental indicators should produce data that allow comparisons on temporal and spatial levels. This is particularly important for comparisons with the reference conditions. Indicators should be sensitive and provide resolution sufficient to detect important environmental change and to indicate the presence of a problem. The indicator methodology should be reproducible and provide the same level of sensitivity regardless of geographic location.

Practical Considerations
The success of a monitoring program is dependent on the ability to collect consistent data. The practical considerations include monitoring costs, availability of experienced personnel, and the practical application of the technology.

A cost-effective procedure should provide a large amount of information in comparison to cost and effort. It is significant to acknowledge that not every quantitative characteristic needs to be measured unless it is required to answer specific questions.

Cost effectiveness may be dependent on the availability of experienced personnel and the ability to find or detect the indicating parameters at all locations, as well as overall geographic extent.

Water Quality Programmatic Considerations

Stated objectives of a monitoring program are an important factor in selecting indicators. Sampling and analysis programs should be structured around questions to be addressed. The term "programmatic considerations" simply means that the program should be evaluated to confirm that the original objectives would be met once the data have come together. If the design and the data being produced by a monitoring program do not meet the questions posed by the monitoring objective(s) within the context of scientific validity and resource availability, then the selected indicators should be reevaluated.

Another important consideration is the ease with which the information obtained can be communicated to the public. Although it is essential to present information for the SWRCB and RWQCB's, scientists, or other specialized audiences, information should also be responsive to public interests and needs.

Table 4. Environmental Indicator Selection Criteria (ITFM, 1995).

Criteria	Definition(s)
	Scientific validity (technical considerations)
Measurable/quantitative	Feature of environmental measurable over time; has defined numerical scale and can be quantified simply.
Sensitivity	Responds to broad range of conditions or perturbations within an appropriate time frame and geographic scale; sensitive to potential impacts being evaluated.
Resolution/discriminatory power	Ability to discriminate meaningful differences in environmental condition with a high degree of resolution.
Integrates effects/exposure	Integrates effects or exposure over time and space.
Validity/accuracy	Parameter is true measure of some environmental conditions within constraints of existing science. Related or linked unambiguously to an endpoint in an assessment process.
Reproducible	Reproducible within defined and acceptable limits for data collection over time and space.
Representative	Changes in parameter/species indicate trends in other parameters they are selected to represent.
Scope/applicability	Responds to changes on a geographic and temporal scale appropriate to the goal or issue.
Reference value	Has reference condition or benchmark against which to measure progress.
Data comparability	Can be compared to existing data sets/past conditions.
Anticipatory	Provides an early warning of changes.
	Practical considerations
Cost/cost effective	Information is available or can be obtained with reasonable cost/effort. Must consider geographic scale when examining cost effectiveness. High information return (of good quality data) per cost.
Level of difficulty	Ability to obtain expertise to monitor. Ability to find, identify, and interpret chemical parameters, biological species, or habitat parameter. Easily detected. Generally accepted method available. Sampling produces minimal environmental impact.
	Programmatic considerations
Relevance	Relevant to desired goal, issue, or agency mission; for example, fish fillets for consumption advisories; species of recreational or commercial value.
Program coverage	Program uses suite of indicators that encompass major components of the ecosystem over the range of environmental conditions that can be expected.
Understandable	Indicator is or can be transformed into a format that target audience can understand; for example, non-technical for public.

List of Indicators

Monitoring programs sponsored by the SWRCB and the RWQCBs have used a variety of environmental indicators. Indicators that have been used in ambient monitoring efforts and meet the requirements of the general criteria are presented in Table 5. These indicators are considered a starting point for the indicators which should be used in the State's ambient monitoring efforts.

Table 5: List of Indicators for Site-Specific and Regional Monitoring

Beneficial Use	Monitoring Objectives[1]		Category	Indicator
	Site-Specific	Regional		
Water Contact	1	1, 2, and 3	Contaminant exposure	Total coliform bacteria Fecal coliform bacteria Enterococcus bacteria Enteric viruses
Drinking Water	2 and 3	4 and 5	Contaminant exposure	Inorganic water chemistry Nutrients Organic water chemistry Total coliform bacteria Cryptosporidum Giardia
Fish and Shellfish Contamin-ation	4, 5, 6, 7, and 8	6, 7, 8, 9 and 10	Contaminant exposure	Fish tissue chemistry Shellfish tissue chemistry Coliform bacteria in shellfish Fecal coliform bacteria in water

1 The number refers to the monitoring objective discussed previously under site-specific and regional monitoring approaches.

Beneficial Use	Monitoring Objectives[1]		Category	Indicator
	Site-Specific	Regional		
Aquatic Life	9, 10, 11, 12, and 13	11, 12, 13, 14, 15, 16, and 17	Biological response[2]	Phytoplankton Chlorophyll-a Benthic infauna (Animals that live in sediment.) Fish assemblage Fish pathology Recruitment of sensitive life stages Interstitial water toxicity Macroinvertebrate assemblage Periphyton Sediment toxicity Water toxicity
			Pollutant exposure	Acid volatile sulfides/simultaneously extracted metals Debris Interstitial water metal chemistry Reporter Gene System (RGS 450) Organic and inorganic sediment chemistry Total organic carbon Shellfish or fish tissue chemistry Nutrients Turbidity Inorganic and organic water chemistry

2 While the assessment of invasive species is not a focus of SWAMP, these organisms will very likely be identified when biological community measurements are made.

Beneficial Use	Monitoring Objectives[1]		Category	Indicator
	Site-Specific	Regional		
			Habitat	Dissolved oxygen Sediment grain size Sediment organic carbon Water flow Water temperature Channel morphology Residual pool volume Instream structure Substrate composition Wetland vegetation Riparian vegetation Electrical conductivity Salinity Hydrogen sulfide Ammonia
Sufficient Flow	14 and 15	18 and 19	Habitat	Water flow Suspended solids Channel morphology Water temperature
			Biological response	Fish assemblage and populations Macroinvertebrate assemblage and populations Periphyton Wetland habitat Riparian habitat
Agricultural Supply	16 and 17	20 and 21	Pollutant Exposure	Organic and inorganic chemistry
Industrial Supply	18 and 19	22 and 23	Pollutant Exposure	Organic and inorganic chemistry Total organic carbon Temperature Electrical conductivity
Aesthetic Condition	20 and 21	24 and 25	Pollutant Exposure	Taste and odor Debris and trash

Adapted from: SWRCB, 1993; SPARC, 1997; SCCWRP, 1998; Stephenson et al., 1994; CalEPA, 1998; CABW, 1998; CDFG, 1998; Noble et al., 1999; AB 982 Scientific Advisory Group, personal communication, August, 2000.

SWAMP includes sample collection at numerous and varied locations in each RWQCB region throughout the state, with varying goals, objectives, and designs for monitoring and analysis. Due to the specific and varied nature of each of the RWQCB SWAMP Work Plans within this program, repetitive and routine monitoring of the same type (and for the same indicators, and of the same frequency of monitoring) is not the objective for data collection for the current SWAMP program. Thus, monitoring sites, monitoring objectives, monitoring parameters, monitoring schedules, and other information specific to each RWQCB region in SWAMP will not be described in detail in this Main Body of the QAMP, but rather are located in annual RWQCB Work Plans for FY02-03 in **Appendix B.**

A General Description of Field Measurements, Routine Water Chemistry, Sediment Samples, Biological and Bacteriological Analyses Commonly Conducted for SWAMP

Basic sampling which is common to many sites includes field measurements, in most cases utilizing a multiparameter probe or continuous monitoring equipment (measuring dissolved oxygen, specific conductance, pH, and temperature), collection of samples for routine water chemistry ("conventional constituents in water", such as nitrate, nitrite, ammonia, sulfate, ortho-phosphate, total phosphate, TKN, TOC/DOC, TSS/SSC, varying minerals, and others), collection of samples for a suite of indicator bacterial analyses (total and fecal coliform densities, *E. Coli*, and *Enterococcus* primarily), and where bed sediment samples are collected, sediment grain size and sediment TOC are routinely conducted.

The objectives of monitoring these parameters are to detect and describe spatial and temporal changes, determine impacts of point and nonpoint sources, and assess compliance with water quality standards. DO, water temperature, and pH are field measurements for which water quality criteria are established for each classified water body. Specific conductance is used as an indirect measure of another established water quality criteria, total dissolved solids. Secchi disk measurements are used in some cases to determine the transparency of the water column. Conductivity and salinity are monitored to estimate the total concentration of dissolved ionic matter, evaluate mixing of fresh and salt water in estuaries (and other saline waterbodies), determine density stratification, and document impact and dispersion of pollutants. The field-measured parameters are key indicators of the status of many chemical and biological processes. Monitoring of field measurements also provides complementary information necessary in evaluating chemical and biological data.

In order to relate chemical concentrations and flow, instantaneous flow measurements (or in many cases, velocity measurements only) are made at many stream sites concurrently with the collection of water samples. In some cases, stream flow is obtained at the time of sampling from a United States Geological Survey (USGS) gage if one is located nearby.

Water samples are collected, preserved, and sent to a contract laboratory, where analyses are performed. Due to the difficulty in culturing specific pathogens, fecal coliform bacteria are commonly monitored as indicators of human pathogen densities in order to assess the recreational potential of water bodies (and to evaluate compliance of the oyster waters use in estuarine segments). Water samples for fecal coliform analysis require immediate transport to the analytical laboratory, since they have a very short hold time.

Other variables are added to the RWQCB-specific SWAMP monitoring program as information needs arise, and as specified in Work Plans each year. The following paragraphs provide an outlined of additional analyses which are typically conducted for RWQCB SWAMP monitoring programs.

Organic substances (pesticides, PCB's, PAH's, semi-volatiles, and volatiles) and trace metals are commonly monitored in water, sediment, and fish/bivalve tissue at selected RWQCB monitoring sites. In most cases, these parameters are used to establish current condition (presence and/or magnitude) and then where possible from previous measurements, to detect change.

The SWAMP Program focuses toxic substances monitoring on those sites deemed to have a likelihood of being impacted and selects sample stations on criteria which include: sites near dischargers that have shown receiving water or effluent toxicity, sites that have shown recurrent ambient water and/or sediment toxicity, sites near large industrial or domestic discharges, areas that receive high nonpoint source loads, areas with exceptional recreational uses, sites near hazardous waste facilities, sites downstream of major metropolitan areas, areas adjacent to Superfund sites, and sites which exhibit biological impairment. Toxic substances in water, sediment, and fish tissue are monitored at these sites to determine their prevalence and magnitude, to detect and describe spatial and temporal changes, and to evaluate compliance with applicable water quality standards.

The results of monitoring sediment chemistry may be used to evaluate the condition of the benthic habitat, determine point and nonpoint source impacts, and to monitor rates of recovery following establishment of pollution controls or improved wastewater treatment. In addition to monitoring toxic chemical contaminants in sediments, conventional parameters in sediment are also useful to measure, if sediment samples are collected: total phosphorus and Kjeldahl nitrogen are used for evaluation of nutrient status; volatile solids for organic content; percent solids for determination of water content; oil and grease for petrochemical influences; sediment grain size for availability of contaminants and habitat availability; total organic carbon for bioavailability of organic contaminants that adsorb to particulates; and acid volatile sulfide for bioavailability of metal contaminants. Sediment grain size analysis and sediment TOC are the two most common analytical procedures conducted on sediment samples collected for SWAMP.

Biological communities (fish and benthic macroinvertebrate) are useful in assessing water quality for a variety of reasons, including their sensitivities to low-level disturbances and their functioning as continuous monitors. Monitoring of resident biota, thus, increases the possibility of detecting episodic spills and dumping of pollutants, wastewater treatment plant malfunctions, toxic nonpoint source pollution, or other impacts that periodic chemical sampling is unlikely to detect. Perturbations of the physical habitat such as sedimentation from stormwater runoff, dredging, channelization, and erosion may also be detected through biological monitoring in combination with habitat assessment.

The objectives of monitoring fish and benthic macroinvertebrate communities are to detect and describe spatial and temporal changes in the structure and function of these communities. These results can be used to assess impacts of point and nonpoint sources, assess community condition or "health", determine appropriate aquatic life uses, monitor rates of recovery following implementation of improved wastewater treatment, and provide early warning of potential impacts.