APPENDIX 3

DEP MONITORING ACTIVITIES

DEP carries out a wide range of water monitoring activities.

In this section we'll describe the DEP monitoring activities most relevant to citizen monitoring programs:

1) Water Quality Network (WQN)
2) Unassessed Waters
3) Aquatic Life Special Water Quality Protection Surveys
4) Cause/Effect Surveys
5) Use Attainability Studies
6) Lakes

1) Water Quality Network (WQN)

The WQN is a long term network of approximately 150 fixed monitoring stations on rivers, streams and lakes throughout the state. It is the backbone of the state's efforts to monitor conditions on a broad scale. These stations are located in:

- *Major Streams:* Streams with a drainage area of roughly 200 square miles or more. These waters are monitored bi-monthly for water chemistry and annually for macroinvertebrates, to show trends over time throughout the state.
- *Selected Reference Waters:* Defined as waters “minimally affected by humans" and that represent the quality normally found in an ecoregion. These sites are benchmarks against which to judge conditions and changes at sites that are more affected by human activities. They are monitored monthly for water chemistry and three times per year for macroinvertebrates.
- *Selected Lakes:* Ten to fifteen lakes are selected for five year monitoring cycles based on size, public access, intensity of use and the availability of existing data. The WQN favors large lakes with heavy public use and historical data because changes in these lakes can seriously affect water uses by lots of people. These lakes are monitored three times per year (including the spring and fall overturns and summer stratification).

Each of these stations is sampled for stream discharge or lake height and for various physical and chemical indicators, described below.

Physical/Chemical Indicators

DEP groups the indicators it measures at each type of station into "standard analysis codes (SAC)." These include:

Standard Field Analysis - all stations

- pH
- Temperature
- Dissolved oxygen

Standard Laboratory Analysis (SAC 010) - all routine stations

• pH • alkalinity • specific conductivity • sulfate • hardness • total phosphorus • nitrate nitrogen • total calcium	• nitrite nitrogen • ammonia nitrogen • total dissolved solids • suspended solids residue non-filterable • total organic carbon	• selected total recoverable metals: *aluminum* *copper* *iron* *magnesium* *manganese* *nickel* *lead* *zinc*

Optional Toxics (SAC 011) - selected stations

• Indicators in the Standard Laboratory Analysis plus	• fluoride • oil & grease • phenols • total and free cyanides

Optional Reference (SAC 013) - selected reference stations

• Indicators in the Standard Laboratory Analysis list less total organic carbon, plus	• fecal coliforms, • BOD 5-day inhibited • the dissolved form of the metals • total fluoride • chlorides • phenols • osmotic pressure • methyl blue active substances • barium

Optional Low Alkalinity (SAC 016) - selected low alkalinity stations

• Indicators in the Standard Laboratory Analysis list less total organic carbon, plus:	• BOD 5- day inhibited • the dissolved form of the metals	• magnesium • calcium • total acidity

Reference Low Alkalinity (SAC 015) - at selected reference and low alkalinity stations

Includes analyses from Standard Laboratory Analysis and Low Alkalinity lists.

Optional Lakes (SAC 017) - at selected lakes

• pH • alkalinity • sulfate • hardness • total phosphorus • ammonia nitrogen • total nitrogen	• suspended solids residue non-filterable • total organic carbon • chlorophyll a • total recoverable calcium	• selected total recoverable and dissolved metals: *aluminum* *copper* *iron* *magnesium* *manganese* *lead* *zinc*

All analyses are performed according to Standard Methods or EPA methods.

Biological Indicators

- ♦ A biological evaluation using ***benthic*** *macroinvertebrates* is carried out once per year at routine stream stations, and three times per year at reference stations.
- ♦ At selected stations on Lake Erie, qualitative samples for ***plankton*** *and* ***chlorophyll a*** are collected.
- ♦ ***Fish tissue*** *is* sampled at 35 stations per year, with the locations determined each year. Samples are analyzed for the following to determine suitability for human consumption:

• PCB's • pesticides • total mercury	• total cadmium • total chromium	• total copper • total lead

2) Unassessed Waters

The majority of Pennsylvania's 83,000 miles of free-flowing surface waters are not covered by the Water Quality Network and have not been assessed. That means that the quality and integrity of these waters is largely unknown. Historically, DEP assumed in the absence of point source discharges, that these unassessed waters were of good quality. However, data collected in recent years challenges this assumption. Therefore, the unassessed waters strategy was formulated to assess these waters: to locate and identify good quality waters, to locate and identify point and nonpoint sources of pollution and to determine the extent of impacts from these sources.

The purpose of the Unassessed Waters Strategy is to assess all of these waters, with priority given to waters where there is the potential for primarily nonpoint source pollution impacts.

This strategy has several major steps, where any one of a number of surveys may be carried out. Each of these steps is described below:

A. Identify Priority Assessment Watersheds

DEP has ranked each of 104 watersheds as high, medium or low priority depending on the potential for nonpoint source pollution. These are called *assessment watersheds.*

B. Identify Priority Assessment Units

Assessment units have been identified and ranked within each of the high priority assessment watersheds. They are typically 50 square miles in size. Each assessment unit will be identified as *wadeable* or *non-wadeable* when it is assessed.

C. Identify and Screen Representative Sub-Basins for Impairment

Within each priority assessment unit, representative sub-basins will be field checked and screened using the **Pre-screening Field Reconnaissance** and **Biological Screening** surveys described below:

Pre-screening Field Reconnaissance: Streams having similar physical habitat and land use characteristics will be clumped so that only one representative sub-basin needs to be assessed. Representative rocks from the mouth of all mainstem tributaries will be checked to see the general type of benthic macroinvertebrate community present and the location of representative sampling sites for various portions of the sub-basin. Note: *DEP personnel need to coordinate this effort and carry out the monitoring,* though volunteers can be involved in the land use characterization.

Biological Screening: DEP uses a rapid field bioassessment[1] for benthic macroinvertebrates to determine the presence or absence of impairment. Note: *DEP personnel need to carry out the monitoring.*

Sampling Locations:

- Mouth of representative tributaries
- Main stem:
  - headwaters
  - mouth
  - brackets around selected tributaries
- Point source discharges:
  - immediately upstream
  - in the potential impact zone
  - in the downstream recovery zone

Information Collected:

- Visual habitat assessment
- Benthic macroinvertebrate collection using a net from "best available" riffle habitat and identified to the family level in the field.

Data Analysis:

Results are compared with criteria in a checklist to determine impairment.

D. Carry Out Further Assessments in Impaired Waters

DEP carries out further assessments to pinpoint the source of impairment. The type of assessment depends on whether the sources of impairment are point or nonpoint (or both) in nature.

[1] US EPA Rapid Bioassessment Protocols, 1999.

Nonpoint Sources - Detailed Nonpoint Source Assessments: If no point sources are present, the DEP assumes that impairment is due to nonpoint sources. A more detailed assessment will be carried out as follows:

Sampling Locations:

- Control station immediately upstream of the source
- in the potential impact zone
- in the downstream recovery zone

Information Collected:

This will include the following:

• water chemistry	• more thorough biological and habitat information
• population	• land use and trends
• water supplies	• other resources and economic concerns in the area

As of this writing, no list of specific parameters or methods has been developed.

Data Analysis:

Results at the impact and recovery stations will be compared with those at the control station to determine impacts. The result will be a final report that lists the miles of water affected by nonpoint source pollution. Then, a remediation plan can be developed.

Point Sources - Intensive Follow-up Survey: If point sources are present, an intensive follow-up survey will be carried out.

Sampling Locations:

- Control station immediately upstream of the source
- In the potential impact zone
- In the downstream recovery zone
- Additional stations as needed to assess nonpoint sources

Information Collected:

This will include the following:

General Information

• Population	• land use and trends
• water supplies	• other resources and economic concerns in the area
• biological and habitat information	

Field Water Chemistry

• field pH	• field conductivity
• field temperature	• field dissolved oxygen

Lab Water Chemistry (as appropriate to the nature of the source)

Sewage (SAC907)	***Toxics* SAC908)**	***AMD* [2]*(SAC909)***
• pH	• pH	• pH
• total dissolved solids	• alkalinity	• alkalinity
• total suspended solids	• hardness	• total sulfates
• Ammonia	• total cadmium	• total manganese
• Nitrate	• total copper	• total zinc
• Nitrate	• total lead	• total aluminum
• Total Phosphorus	• total nickel	• total acidity
• BOD_5	• total zinc	
	• total aluminum	

Analytical methods used are Standard Methods or EPA Methods for water chemistry. For biological and habitat information, DEP methods are used.[3]

Data Analysis:

Results at the impact and recovery stations will be compared with those at the control station to determine impacts. For biological data, habitat comparability and a standard set of biological metrics will be used. The result is an assessment of whether the impairment is due to point sources, nonpoint sources or a combination of the two. In any case, a remediation plan will be developed.

E. Develop Remediation Plans

All impaired waters that do not meet water quality standards, even after technological solutions for point and nonpoint pollution sources are applied, require the development of Total Maximum Daily Loads (TMDLs) in Remediation Plans. A load is an amount of pollutant that enters the water in a specified period of time (e.g. pounds per day). A TMDL is the sum of all the loads allowed for all point and nonpoint pollution sources in a watershed for each pollutant plus a margin of safety. Allowed point source loads are called "wasteload allocations" or "WLAs." Allowed nonpoint source loads are called "load allocations" or “LAs."

Nonpoint Sources - For Nonpoint Source Only Impaired Waters: Nonpoint Source (LA) Remediation Plans (TMDLs) will be needed. These will use the results of the detailed nonpoint

[2] Abandoned Mine Drainage.
[3] Pa. DEP Standardized Biological Field Collection and Laboratory Methods, 1997 (Draft).

source assessments (see above) to identify the nonpoint pollution sources in a watershed, so that individual control measures and / or load allocations can be specified.

Point Source Only Impaired Waters: Point source TMDLs will be needed. That involves determining the amounts of each pollutant that will be allowed over a period of time from each point source.

Point and Nonpoint Source Impaired Waters: Point and nonpoint source TMDLs will be needed. That involves determining the amounts of each pollutant that will be allowed over a period of time from each point source (WLA) and nonpoint source (LA).

3) Aquatic Life Special Water Quality Protection Surveys

The purpose of these surveys is to assess the need for special water quality protection and, if needed, to revise the water quality standards to provide that protection in order to maintain existing high quality. These surveys are initiated by DEP staff, a petition to the Environmental Quality Board or upon requests from the Pa. Fish and Boat Commission.

Protocol for these surveys is currently under revision by DEP and no details are available as of this writing. DEP staff must conduct these surveys.

4) Cause/Effect Surveys

The purpose of Cause / Effect Surveys is to see if specific sources of point or nonpoint source pollution are causing known or reported problems. The goal is to identify the source(s) in order to define the impact of these activities on the receiving waters. The surveys are done primarily to monitor the effectiveness of permitted treatment facilities, but are also used to investigate nonpoint source or unpermitted discharges.

Sampling Locations:

Control, impact and recovery sites are chosen depending on the nature of the source, the presence of other discharges, location of tributaries, hydrologic patterns and other factors.

Information Collected:

Following is a menu of possible indicators to be measured. The final list for specific surveys is customized to the situation.

Physical Evaluations

• habitat assessment	• flow

Field Water Chemistry

• temperature	• dissolved oxygen
• pH	• specific conductance

Lab Water Chemistry

• chlorine residual	• sulfate	• chloride
• BOD_5 and BOD_{20} inhibited	• hardness as $CaCO_3$	• total iron
• total organic carbon	• alkalinity as $CaCO_3$	• total manganese
• nitrate • nitrite • ammonia	• total phosphorus • total dissolved phosphorus	• total dissolved solids • total suspended solids • residual volatile solids

Biological Evaluations

• fecal coliform bacteria	• benthic macroinvertebrates

Water chemistry is analyzed using Standard Methods.[4] Biological evaluations are carried out according to DEP standard protocols.[5] Flow is measured according to USGS approved methods.

Data Analysis:

Physical, chemical and/or biological data collected during surveys are generally evaluated using non-parametric, classification type analyses designed to display differences or similarities between sampling stations.

5) Use Attainability Studies

These studies are carried out to review and revise (if needed) water quality standards to ensure that designated fish and aquatic life uses are protected.

Sampling Locations:

Sampling locations are chosen to ensure that data representative of conditions in a given stream reach or lake/impoundment will be obtained. Factors considered in locating these stations include: watershed land uses, volume and chemical characteristics of known point source wastewater discharges, physiographic and demographic conditions that contribute to non-point source problems and water body hydrology. In flowing water bodies, every effort is made to sample representative, homogeneous low-flow water columns at comparable locations. However, because weather, stream flow conditions, and accessibility vary, stream discharge measurements are made, and observations of instream and riparian physical characteristics are recorded for reference in estimating water quality under various hydrologic conditions. In impounded water bodies, sample collections are made during the peak growing season/summer stratification.

Information Collected:

The types of information gathered depends on whether the water is flowing or impounded behind a dam.

***Flowing Waters*:**

Physical Evaluations

• habitat assessment	• flow

Field Water Chemistry

• temperature	• dissolved oxygen
• pH	• specific conductance
• transparency	

[4] APHA Standard Methods for the Examination of Water and Wastewater, most recent edition and/or EPA Methods for Chemical Analysis of Water and Wastes, EPA/600/A-79-020, Revised March 1983.

[5] Pa. DEP, 1997. Quality Assurance Work Plan: Cause/Effect Surveys. Document ID #391-3200-003

Lab Water Chemistry

• BOD_5 and BOD_{20} uninhibited • BOD_5 and BOD_{20} inhibited	• nitrate nitrogen • nitrite nitrogen • ammonia nitrogen	• sulfate
• total organic carbon	• alkalinity as $CaCO_3$	• chloride
• total phosphorus • total dissolved phosphorus	• hardness as $CaCO_3$	• total dissolved solids • total suspended solids • residual volatile solids

Biological Evaluations

• fecal coliform bacteria	• benthic macroinvertebrates
• fish	

Impounded Waters:

Physical Evaluations

• habitat assessment	

Field Water Chemistry

• temperature	• dissolved oxygen
• transparency	• specific conductance
• pH	

Lab Water Chemistry

• total phosphorus • total dissolved phosphorus • orthophosphate • nitrate nitrogen	• nitrite nitrogen • ammonia nitrogen • chlorophyll a • alkalinity as $CaCO_3$	• hardness as $CaCO_3$ • total organic carbon • total dissolved solids

Biological Evaluations

• benthic macroinvertebrates	• fish

Water chemistry is analyzed using Standard Methods.[6] Biological evaluations are carried out according to DEP standard protocols[7]. Flow is measured according to USGS approved methods.

Data Analysis:

Data is used, as part of a water quality standards review process, to assess current attainment or potential attainability of designated fish and aquatic life uses. In flowing waterbodies, this assessment involves the comparison of the portion of the waterbody under study with a "reference" segment on the same or a similar waterbody. The "reference" segment provides baseline data on physical, chemical and biological characteristics of the waterbody which define its potential uses while the same data from the study segment yield information on the current attainment of designated water uses. In impounded waterbodies this assessment involves analysis of specific selected area(s) in order to define existing or potential uses.

[6] APHA Standard Methods for the Examination of Water and Wastewater, most recent edition and/or EPA Methods for Chemical Analysis of Water and Wastes, EPA/600/A-79-020, Revised March 1983.

[7] Pa. DEP, 1997. Use Attainability Studies for Flowing and Impounded Waters. Document ID #391-3200-005

6) Lakes

Section 314 of the Federal Clean Water Act requires states to:

- Identify and classify all publicly owned freshwater lakes according to trophic condition;
- Establish methods and procedures to control sources of pollution to these lakes; and
- Establish methods and procedures to restore the quality of lakes to provide maximum uses and benefits to the public.

To accomplish this, Pennsylvania's lakes are monitored at several levels. Trends in lake quality are monitored at selected lakes as part of the Water Quality Network (see part 1 of this appendix). Aside from the on-going WQN lake monitoring, there are three levels of DEP lake assessment:

Evaluation of Trophic Status: A broad assessment of the status of Pennsylvania's "significant lakes".[8]

Phase 1 Diagnostic - Feasibility Study (EPA Clean Lakes Program): An intensive study that results in a management plan to control pollution sources and restore lake quality.

Phase 2 - Management Plan Implementation Assessment (EPA Clean Lakes Program): On-going monitoring to see if the protection and restoration efforts in the management plan are working.

A. Evaluation of Trophic Status

The purpose of this evaluation is to assess the status and productivity of Pennsylvania's significant freshwater lakes. The results are used to evaluate the impacts of lake nutrients and to determine the need for a Phase 1 Diagnostic - Feasibility Study.

Samples are collected from these lakes at least three times per year: 1) spring overturn (April / May); 2) peak growing season (July / August); and 3) fall overturn (October / November).

Sampling Locations:

A minimum of two stations is required:

- Deepest part of the lake
- Upstream in the lake

Additional stations may be needed on large lakes or those with unique morphological characteristics, such as many bays.

Information Collected:

Field Water Chemistry

• temperature	• dissolved oxygen
• Secchi transparency	• specific conductance
• pH	

Lab Water Chemistry

• total phosphorus	• total nitrogen	• chlorophyll a

Samples for field water chemistry (except transparency) are collected at one meter intervals. Samples for nutrients are collected one meter below the surface and one meter above the bottom.

[8] Defined as a lake with publicly owned access and retention time of 14 days or greater.

Samples for chlorophyll a are collected at one half the Secchi depth. Water chemistry is analyzed using Standard Methods.[9]

Data Analysis:

Carlson's Trophic State Index is calculated using Secchi depths, near surface phosphorus and near surface chlorophyll a. Other measurements are used to evaluate aquatic life use support. Impaired waters will undergo a Phase 1 Diagnostic - Feasibility Study.

B. Phase 1 Diagnostic - Feasibility Study (EPA Clean Lakes Program)

The purpose of this study is to identify and classify all publicly owned freshwater lakes in the state according to trophic condition, establish methods and procedures to control sources of pollution to these lakes, and establish methods and procedures to restore the quality of these lakes.

Phase I includes a diagnostic study and a feasibility study.

- The **diagnostic study** consists of an overall characterization of the lake's current condition, including historical baseline data and one year of current data. This is described in this section below.
- The **feasibility study** consists of an analysis of the diagnostic information to determine lake protection and restoration methods and a Phase 2 monitoring program to evaluate the effectiveness of those methods. The requirements for Phase 2 monitoring are described in section C below.

Sampling Locations:

A minimum of two stations are required, one in the deepest part of the lake and a second at the outflow. Additional stations may be needed on large lakes or those with unique morphological characteristics, such as many bays or where major tributaries adversely affect lake quality.

Information Collected:

General Information

• geology of basin	• public access
• size and economic structure of population living near lake	• historical lake uses
• lake users most affected by degradation	• water use compared with nearby lakes
• point pollution sources and control actions	• description, percent and loadings from each nonpoint pollution source
• biological resources and ecological relationships	• present trophic condition

Physical Lake and Watershed Characteristics

• surface area	• maximum depth
• average depth	• residence time
• watershed area	

[9] APHA Standard Methods for the Examination of Water and Wastewater, most recent edition? and/or EPA Methods for Chemical Analysis of Water and Wastes, EPA/600/A-79-020, Revised March 1983.

Field Water Chemistry

• temperature	• dissolved oxygen
• Secchi transparency	• pH

Temperature and dissolved oxygen samples are collected throughout the vertical water column.

Lab Water Chemistry

• total phosphorus • soluble reactive phosphorus	• organic nitrogen • nitrate • nitrite • ammonia
• representative alkalinities	• suspended solids
• chlorophyll a	

Chlorophyll a is measured in the upper mixing zone.

Biological Monitoring

• algal assay or • total N to total P ratio	• algal biomass
• vascular plants (predominant species and portion of shoreline affected)	• bacteria (if public contact use)
• fish flesh for organic and heavy metals	

Vascular plant growth is estimated between zero and 10 meter depth or twice the Secchi depth.

Data Analysis:

The information is analyzed to define the quality of the lake, including the location and loading characteristics of significant pollution sources. Analysis includes an assessment of phosphorus and nitrogen (if it is the limiting lake nutrient), inflows and outflows and a hydraulic budget (including groundwater). Carlson's Trophic State Index is calculated using Secchi depths, near surface phosphorus and chlorophyll a. Phase 1 monitoring is used to define the methods and procedures for controlling pollution sources, determining the best methods and developing a technical plan for protecting and restoring the lake.

C. Phase 2 Monitoring (EPA Clean Lakes Program)

The purpose of Phase 2 monitoring is to assess the effectiveness of the procedures and methods to control pollution and restore lake quality. "Limited" monitoring must be maintained before, during and after the control and restoration procedures are implemented.

The specific requirements for Phase 2 monitoring are described below.

Sampling Locations:

A minimum of two stations are required, one in the deepest part of the lake and one at the outflow. Additional stations may be needed on large lakes or those with unique morphological characteristics, such as many bays or where major tributaries adversely affect lake quality.

Samples consist of two subsamples. One is one meter from the surface. The other is one meter from the bottom. Samples should be taken monthly September through April, and bi-weekly May through August. Samples must be collected between 8 a.m. and 4 p.m.

Information Collected:

Field Water Chemistry

• temperature	• dissolved oxygen
• Secchi transparency	• pH

Temperature and dissolved oxygen samples are collected throughout the vertical water column. All samples are collected and analyzed using EPA-approved methods.

Lab Water Chemistry

• total phosphorus • soluble reactive phosphorus	• organic nitrogen • nitrate • nitrite • ammonia
• representative alkalinities	• suspended solids
• chlorophyll a	

Chlorophyll a is measured in the upper mixing zone. All samples are collected and analyzed using EPA-approved methods.

Biological Monitoring

• algal assay or • total N to total P ratio	• algal biomass
• vascular plants (predominant species and portion of shoreline affected)	• bacteria (if public contact use)

Vascular plant growth is estimated between zero and 10 meter depth or twice the Secchi depth.

Data Analysis:

The information is analyzed to define the quality of the lake, including the location and loading characteristics of significant pollution sources. Analysis includes an assessment of phosphorus and nitrogen (if it is the limiting lake nutrient), inflows and outflows and a hydraulic budget (including groundwater). Carlson's Trophic State Index is calculated using Secchi depths, near surface phosphorus and near surface chlorophyll a. Phase 2 monitoring is used to assess the effectiveness of the procedures and methods to control pollution and restore lake quality.

7) Groundwater Network (GWN) Monitoring

The amount of groundwater in the United States at any given moment is 20 to 30 times the amount of water in all of the lakes, streams and rivers. Groundwater contributes a major portion of flow to surface streams and rivers. In times of drought, groundwater flow provides nearly all of the sustaining baseflow to streams and rivers. High quality groundwater is essential to all users, including industrial, agricultural and domestic users. Groundwater is extremely important in Pennsylvania. At least 28 percent of Pennsylvanians depend on self-supplied groundwater as their main supply of water for domestic needs. When community and non-community water systems are included in a tally of groundwater users, the percentage of Pennsylvanians that use groundwater is nearly 50 percent.

The Bureau of Watershed Management uses the Ambient and Fixed Station Network Monitoring program to monitor the general quality of groundwater. The program is described in the DEP

document "Pennsylvania's Groundwater Quality Monitoring Network: Ambient and Fixed Station Network (FSN) Monitoring Programs" (document 383-3200-009 / 6/97).

The purposes of the groundwater network (GWN) monitoring are to support several goals on a basin-wide, regional and statewide basis. These goals include:

- Assist in describing general groundwater quality conditions.
- Assist in identifying groundwater quality problem areas.
- Provide a limited and general measure of background groundwater quality.
- Monitor for changes in the groundwater quality.
- Generate statistical reports and assessments of sample results and trends.

Basic statistics can be calculated to generally characterize groundwater quality by station and basin. These values can be compared to drinking water standards such as Maximum Contaminant Levels (MCLS) or Secondary Maximum Contaminant Levels (SMCLs). Data results can be used by industry for locating certain qualities of groundwater that are needed for specific manufacturing or industrial processes.

The monitoring programs are designed to provide a measure of background at unaffected or minimally affected sampling locations. FSN sampling can contribute to an understanding of longterm water quality trends that result from land use practices, and can be used to assess the impact of land management practices on groundwater quality.

The evaluation of ambient and FSN monitoring data will promote an understanding of the overall groundwater quality in Pennsylvania. An evaluation of the data also should provide an overview of the effectiveness of the groundwater management programs from point and nonpoint source impacts. It may indicate changing groundwater conditions that result from activities beyond the scope of the groundwater program, but which impact groundwater quality.

Pennsylvania has been divided into 478 groundwater basins. These basins were delineated based on the Stream Map of Pennsylvania (1965) compiled by H.W. Higbee. Higbee divided his map into 104 basins having an average area of 435 square miles. Though each basin is not a true hydrologic unit, each Higbee area was defined to take into account similar hydrologic and physical features. For establishing groundwater monitoring networks, it was determined that the Higbee basins were too large. The 104 basins were divided into 478 smaller, more manageable units. The average size of these groundwater basins is approximately 100 square miles. Typically 20 to 30 monitoring points are used to characterize the groundwater of a basin. The chemical indicators sampled at a monitoring point (well or spring) are listed below.

Chemical Indicators

Standard Laboratory Analysis (SAC 056) - all stations

• pH (Lab)	• Total Alkalinity	• Total Filterable Residue (Dried at 105(C)
• Total Ammonia Nitrogen	• Total Nitrite Nitrogen	• Total Nitrate Nitrogen
• Total Phosphorus	• Total Organic Carbon	• Total Hardness
• Calcium	• Magnesium	• Sodium
• Potassium	• Chloride	• Sulfate
• Silica	• Arsenic	• Barium
• Cadmium	• Chromium	• Copper
• Iron	• Lead	• Manganese
• Zinc	• Mercury	• Turbidity (Lab, NTU)