Chapter 10

Water And Sediment Quality

Priority Problems

Water masses in the bay are important in the transport and mixing of contaminants. Sediments act as the ultimate sink for deposition of those water column contaminants bound to suspended particles. Although the bay is in overall good condition, there are local problem areas which threaten both public health and the ecology of the estuary system. Toxic hot spots, eutrophication, and low dissolved oxygen (DO) levels occur in problem areas suffering from high pollutant/nutrient input and poor circulation/flushing. In these areas, degraded water and sediment quality may result in toxicity, habitat degradation, and low dissolved oxygen levels. A limited number of samples have indicated possible water quality criteria exceedences of organic chemicals DDT and PCBs in HSC and San Jacinto River segments (Ward and Armstrong, 1992). Other studies have suggested possible elevated levels of arsenic, cadmium, chromium and nickel in bay sediments. Efforts to maintain and improve water and sediment quality must address ambient toxicity in the Bay and causes of low DO in certain problem areas.

Management Goals and Objectives

Water and Sediment Quality Task Force members established the following high-priority management goals:

- Attain and maintain concentrations of toxics of concern in estuarine waters and sediments below levels posing unacceptable risks to ecosystem resources and human health

- Attain and maintain levels of dissolved oxygen, at or above water quality criteria

Data Information Needs

The primary goal of the monitoring program is the assessment of the effectiveness of actions in achieving the stated objectives. Long term data information needs to assess these management objectives include:

- Identification of specific criteria to assess water and sediment quality,
- Identification of toxic chemicals of concern (COCs), and information on the magnitude and distribution of COCs in Bay water and sediments,
- Data on the magnitude and distribution of conventional water and sediment quality parameters in Bay waters and sediments,
- Data on the magnitude and distribution of water column and sediment toxicity of Bay waters and sediments, and
- Collection of dissolved oxygen data consistent with requirements for state standards criteria.

Not all chemicals in the environment warrant equal attention. Chemicals of concern (COCs) are a limited set of chemicals that may adversely affect Bay biota and human populations. Identification of concentrations of COCs in Bay waters and sediments are a key information need. Knowledge of the spatial distribution of COC concentrations allows evaluation of water and sediment quality in particular segments of the bay as well as comparisons among different bay segments.

Dissolved oxygen will be directly compared to State of Texas water quality criteria as an indicator of whether environmental levels pose a problem to bay biota. Areas within the bay system found to exhibit variations in DO which may indicate potential problems with meeting state criteria will be monitored with continuous monitoring instrumentation. This will supplement data collected as part of the Tier One DO sampling effort. This data will be used to evaluate diurnal patterns of DO and compliance with state water quality criteria.

Conventional water quality parameters are also needed to (1) interpret responses by Bay biota or (2) infer the relative strength of certain physical processes. For example, salinity may be used to infer the role of freshwater inflow and exchange of Bay and Gulf waters. Nutrient concentrations in bay waters may have an effect on primary productivity within the Bay. Elevated levels can result in algal blooms and eutrophication problems. Conversely, low levels of nutrients can be limiting factors in the bay's overall productivity. Water quality issues related to pathogens were discussed by Water and Sediment Quality Task Force members. Their discussions were incorporated in Chapter 6: Public Health Protection.

Water and Sediment Quality Task Force members also recognized the need for monitoring contaminant sources. Contaminant sources (e.g., point source, non-point source, dredged material) drive the input of potentially toxic substances into the Bay. Task Force members emphasized the need for information characterizing contaminant sources and their relative contribution. However, the regional monitoring effort focuses on characterizing ambient conditions in the bay. Point source NPDES Stormwater Permit compliance monitoring data can be used with regional monitoring data to assess the potential effects these sources may have on bay biota as well as human populations.

Objective 1:	Eliminate ambient toxicity in Galveston Bay water and sediments by 2014
Action WSQ-1.	Reduce contaminant concentrations to meet standards and criteria
Action WSQ-2.	Determine sources of ambient toxicity in water and sediment
Action WSQ-3.	Establish sediment quality criteria
Action WSQ-4.	Perform TMDL loading studies for toxics
Action WSQ-5.	Support Clean Texas 2000 Pollution Prevention Program

Objective 2:	By 2004, ensure that all water quality segments within the estuary are in compliance with established dissolved oxygen standards
Action WSQ-6.	Reduce nutrient and BOD loadings to problem areas
Action WSQ-7.	Perform TMDL loading studies for oxygen demand and nutrients

Programmatic Monitoring

The ultimate measure of success in this element will be measured in environmental terms. However, there are programmatic measures important to the success of the Water Quality element.

Action WSQ-2 calls for the identification of sources of toxicity in water and sediment. Knowledge of the point source loadings to the bay and estimates of non-point sources is essential to evaluate this action. The Program office will obtain and evaluate this information from the TNRCC permit self-reporting information and other sources of information such as TRI data, county permit reporting and sampling data sets. In addition non-point source estimates will be available from NPDES stormwater programs and other monitoring sources.

Action WSQ-3 acknowledges the need for development of appropriate sediment criteria for aquatic life and human health protection. The TNRCC is charged with establishing and adopting such criteria. Progress toward development of these criteria will be tracked and reported by The Galveston Bay Program.

Action WSQ-4 requires the performance of TMDLs (total maximum daily load) for toxics integrating both point and non-point sources into the process. TMDLs are to be performed in water quality segments not meeting standards and areas with a high potential for impact. The Program will compile information on the number of toxic TMDLs performed.

Action WSQ-5 supports the Clean Texas 2000 Pollution Prevention Program. The Program will track participation by bay-area industries and municipalities, and will document significantly successful participants. This can be monitored by surveys directed at measuring participation in the program. Toxic Release Inventory data will be monitored for anticipated reductions in toxic emissions and discharges as a result of this program. Action WSQ-6 calls for the reduction of nutrient and BOD loadings to most sensitive and most impacted areas. The Program will track the process of identifying these areas. In addition The Program will track the reductions in loadings achieved through this initiative.

Action WSQ-7 calls for the performance of TMDL studies for oxygen demand and nutrients accounting for both point and non-point loadings. The Program will track the number of such TMDL studies that are accomplished.

Environmental Monitoring

Monitoring activities must provide information to evaluate whether progress toward management objectives is being made. The water and sediment quality component of the regional monitoring program must provide data to assist in:

- Characterizing the concentration and trends of selected toxics in Bay waters and sediments,
- Characterizing the distribution and trends of toxicity in waters and sediments.
- Characterizing the magnitude, extent, and trends of selected conventional water and sediment quality parameters
- Data to evaluate whether ambient COC levels in water and/or sediment may cause alterations in aquatic populations and habitats,

Furthermore, local compliance monitoring must be conducted concurrently to determine the relative contribution of toxics sources. It is fully expected that regional monitoring program data will be used by those conducting compliance monitoring programs and short-term studies to assess the effectiveness of pollutant source control actions.

Water Column Sampling Program

Geographical Boundaries

The boundaries of the Galveston Bay Regional Monitoring Program are defined as all open-bay areas and tidal portions of tributaries. Open bay and tidal portions are defined as marine waters for criteria application. Marine waters are defined as waters having measurable elevation changes due to normal tides or in the absence of tidal information, waters with salinity's of two parts per thousand or greater in a significant portion of the water column. The Texas Natural Resource Conservation Commission (TNRCC) segmentation scheme designates tidally influenced segments and will be used to define the geographic extent of this program. These are given in §307, Appendix B of the water quality standards document (TNRCC, 1991) .

Water Quality Monitoring Objectives

To make Bay-wide estimations of toxicity in terms of areal extent (±10%). Toxicity shall be defined as Inland Silverside, *Menidia beryllina,* mortality in a 7-day chronic test significantly greater than the control and/or mortality to mysid shrimp, *Mysidopsis bahia,* in a 96-hour acute test is significantly greater than mortality in the control group. Significance is to be determined using a one-tailed Dunnets test with a 95% confidence interval.

To make bay-wide estimates ; in terms of areal extent (±10%), and temporal trend, in terms of areal extent and magnitude, of exceedences in State standards criteria. Criteria evaluated will be human health and aquatic life criteria, as defined in the Texas State Surface Water Quality Standards.

To make bay-wide estimates in terms of areal extent (±10%) and temporal trends, in terms of areal extent and magnitude, those waters in violation of state criteria for dissolved oxygen as defined in the Texas State Surface Water Quality Standards.

To make Bay-wide estimates of the eutrophic condition of waters in Galveston Bay in terms of aerial extent (±10%). Such estimates will be developed from collection of water quality information (nutrients, TSS and turbidity) and estimates of primary productivity from chlorophyll-*a* measures.

Parameter Selection and Data Quality Objectives

Selection of appropriate parameters for inclusion in the ambient water portion of the Regional Monitoring Program was accomplished through review of the established data information needs and monitoring objectives. Beyond those specific parameters needed to assess monitoring objectives, numerous standard monitoring parameters of specific agency and historical importance have been included. Recommendations by those responsible for the review of historical trends (Ward & Armstrong) were also considered. Recommendations from the TWDB which has responsibility for modeling the bay system were solicited (David Brock, TWDB, Personal communication). The Monitoring Work Group conducted this review and established the list of parameters given in Table 10-1. Monitoring for these parameters will allow assessment of the effect of plan actions and establish a better understanding of the Galveston Bay system.

Monitoring for plan actions requires that comparisons be made to toxic criteria. State water quality standards specify criteria for protection of aquatic life and public health concerns. Specific aquatic life numerical criteria have been established and adopted in the state water quality standards document "for those specific toxic substances for which adequate toxicity information is available, and which have the potential for exerting adverse impacts on water in the state" (TNRCC, 1991). Human health criteria have been established "to prevent contamination of fish and other aquatic life to ensure that they are safe for human health consumption". Specific human health concentration criteria for water are applicable to waters in the state which have sustainable fisheries, and /or designation or use as a public drinking water supply. The state standards further states that, "all bays, estuaries, and tidal rivers" are defined as having a sustainable fishery. The Regional Monitoring Program will, where appropriate, evaluate monitoring results against state criteria for both aquatic life and public health protection.

State water quality standards establish both freshwater and marine aquatic life criteria. All open-bay and tidal portions of tributaries, our designated area of interest, are defined by the State as marine waters. Therefore marine criteria will be used for evaluation of analytical results. All parameters having either marine aquatic life and public health protection criteria, or both, have been included in Table 10-2 as the list of COCs for water quality monitoring.

Numerical values for marine, acute and chronic, aquatic life protection have been adopted for inclusion in the state water quality standards. Acute criteria are "applicable to all waters of the state, with the exception of small areas of initial dilution at discharge points". Chronic criteria are applicable to "all waters of the state with designated or existing aquatic life uses, except inside mixing zones and below critical low-flow conditions" (TNRCC, 1991). For purpose of this program comparisons to both acute and chronic criteria will be made.

The lower of the aquatic life or human health criteria will be used to establish appropriate performance criteria for analytical procedures. Where these levels of analytical discrimination are not attainable, minimum analytical levels will be determined. The State defines minimum analytical level as the lowest concentration at which a particular substance can be "quantitatively measured, with a defined precision level, using approved analytical methods" (TNRCC, 1991). Minimum analytical levels are established based on analyses of the analyte in the matrix of concern.

Selected stations will be designated as standards attainment stations for TNRCC segments. Stations designated for standards attainment will be selected by the TNRCC as required by §307.9.a.1 of the State water quality standards. These stations will be sampled four times a year for Tier One and Tier Two parameters.

TABLE 10-1. PARAMETERS AND PERFORMANCE CRITERIA FOR WATER AND SEDIMENT QUALITY.

Ambient Water Column:

Tier One Monitoring Parameter	**Data Quality Objectives**
Insitu Measures	
• Temperature	±0.5 °Celsius
• Salinity	±0.1 ppt
• Conductivity	umhos/cm, three significant figures
• pH	±0.1 S.U.
• Dissolved Oxygen	±0.1 mg/l
• Turbidity, as Secchi depth	±0.1 meters
• Sample depth	±0.1 meters
• Photosynthetically active radiation	
Analytical Samples:	
• TSS, VSS	±1.0 mg/l
• Oxygen demand, 5-day CBOD (tributary monitoring only)	±1.0 mg/l
• Nutrients: Nitrogen - NH_3-N, nitrate, nitrite,	±0.01 mg/l
Phosphorous - Total and ortho	±0.01 mg/l
Carbon - TOC	±1.0 mg/l
• Chlorophyll-a	
• Fecal coliforms	# colonies/100 ml
Tier Two Monitoring Parameters	
• Water Hardness (for salinity < 2 ppt)	±0.1 mg/l as $CaCO_3$
• Dissolved Metal COCs	ug/l [1]
• Organic toxic COCs	ug/l [1]
• Pesticide COCs	ug/l [1]
• Ambient toxicity	% survival

Sediment Quality Monitoring Parameters:

• Grain size	
• Sediment bound metals	ug/l [1]
• Sediment bound organics	ug/l [1]
• Benthic community assessments	Community index
• Sediment toxicity tests	% survival
• TOC	±1.0 mg/l
• AVS (to be added at later date)	

1 - Data Quality Objectives will be based on the lower of ambient criteria or State defined minimum analytical levels.

TABLE 10-2. CONTAMINANTS OF CONCERN FOR THE GALVESTON BAY REGIONAL WATER QUALITY MONITORING PROGRAM.

Organics

Aldrin (A,H)
Alpha-hexachlorocyclohexane
Benzene (H)
Benzidine (H)
Beta-hexachlorocyclohexane (H)
Bis (chloromethyl) ether (H)
Carbaryl (A)
Carbon tetrachloride (H)
Chlordane (A,H)
Chrlorobenzene (H)
Chloroform (H)
Chlorpyrifos (A)
Cresols (H)
DDD (H)
DDE (H)
DDT (A,H)
Danitol (H)
Demeton (A)
Dibromochloromethane (H)
1,2- dibromoethane (H)
Dieldrin (A,H)
1,2- dichloroethane (H)
1,1- dichloroethylene (H)
Dicofol (H)
Dioxins / Furans (TCDD Equiv.) (H)
Endosulfan(A,H)
Endrin (A,H)
Guthion (A)
Heptachlor (A,H)`
Heptachlor epoxide (H)
Hexacholrobenzene (H)
Hexachlorobutadiene (H)
Hexachlorocyclohexane(Lindane) (A,.H)
Hexachloroethane (H)
Hexachlorophene (H)
Malathion (A,H)
Methyl ethyl ketone (H)
Methoxychlor (A)
Mirex (A,H)
Nitrobenzene (H)
n- Nitrosodiethylamine (H)
n- Nitroso-di-n-butylamine (H)
Total PCBs (A,H)
Parathion (A)
Phenanthrene (A)
Pentachlorobenzene (H)
Pentachlorophenol (A,H)
Pyridine (H)
1,2,4,5- Tetrachlorobenzene (H)
Tetrachloroethylene (H)
Toxaphene (A,H)
2,4,5- Trichlorophenol (A)
Vinyl chloride (H)
Total petroleum hydrocarbons

Inorganics

Aluminum (D,A)
Arsenic (D,A)
Cadmium (D,A)
Chromium III (D,A)
Chromium VI (D,A)
Copper (D,A)
Cyanide (A)
Lead (D,A,H)
Mercury (D,A,H)
Nickel (D,A)
Selenium (D,A)
Silver, as free ion (D,A)
Tributyltin (A)
Zinc (D,A)

(D) Dissolved portion.
(A) Texas Aquatic Life Criteria Parameter. Criteria are based on ambient water quality criteria documents published by USEPA.
(H) Texas Human Health Criteria Parameter. Concentration in marine waters to prevent contamination of fish and other aquatic life to ensure that they are safe for human consumption.

Spatial Design and Statistical Resolving Power

Integration of information from multiple sources on the various resources of Galveston Bay, especially water and sediment quality, was determined to be a critical function for successful system-wide sampling. Two distinct sampling environments have been used in design of the Regional Monitoring Program. They are classified as open-bay and tidally influenced stream segments. Classification designations have been adopted from Section 307, Appendix A. of the State Surface Water Quality Standards document. The adoption of a common sampling design agreed to by all participants in the regional monitoring effort will greatly contribute to this integration effort. Two separate spatial strategies were adopted for bay and tidal segments.

<u>Open-Bay Monitoring</u>

Several potential spatial strategies were evaluated by the Monitoring Work Group. These included randomized sampling, stratified random designs and a probabilistic sampling model such as the one used in the USEPA Environmental Monitoring and Assessment Program (EMAP). The spatial design model adopted for the open-bay water portions of the Regional Monitoring Program is a probability-based, hierarchical grid design developed and first implemented by the EPA's EMAP. The design uses probability sampling theory to provide rigorous, unbiased estimates of environmental conditions. EMAP stated goals and objectives (U.S. EPA, 1992b) were determined to be consistent with our own:

- Estimate the current status and trends in the condition of ecological resources within a defined spatial scale, with known statistical confidence; and
- Seek associations among anthropocentric stress and ecological conditions; and
- Provide periodic statistical summaries and interpretive reports on ecological status and trends to resource managers and the public.

Recently conducted R-EMAP projects, including one in Galveston Bay in 1993, have demonstrated the utility of the grid structure in addressing any spatially distributed and well defined ecological resource. In addition, this approach has been successfully applied to several estuary monitoring programs including the Delaware Bay, Tampa Bay and Sarasota Bay National Estuary Programs. In the opinion of the Work Group this design had numerous advantages over other considered designs. Those advantages include:

- Significant research and field validation efforts have been conducted to make the sampling design statistically valid and defensible,
- A probability based sampling design is free of subjectivity and site selection bias,
- A grid insures that the samples are evenly distributed over the spatial extent of the resource. This allows the development of distribution functions based on areal extent,

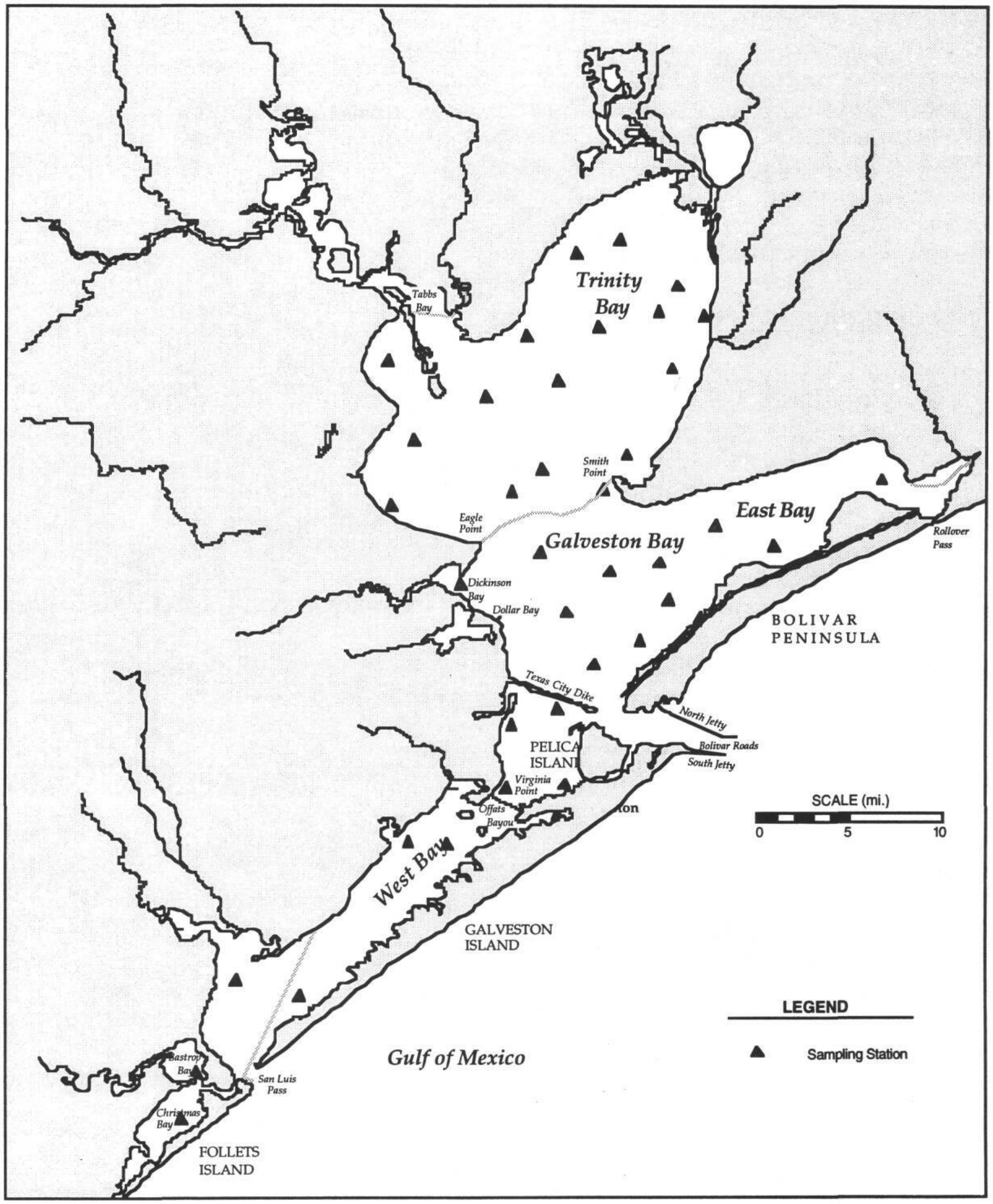
- It has been demonstrated that historical sites, of the sort sampled for years by resource agencies, can be incorporated into the regional plan and still maintain statistical validity,
- Estimates of indicator values in terms of areal extent can be made and the uncertainty associated with the estimate can be determined (e.g. 90% ±10% of Galveston Bay meets sediment criteria levels),
- The types of estimates that can be made (i.e. areal distribution) are more easily understood by non-technical managers and the public,
- The data can be grouped or sub-divided numerous ways and estimates of uncertainty can be made with known levels of confidence.

With the stated level of uncertainty and desiring to make annual estimates, sample site selection was made by randomly placing a 4-fold enhancement of the EMAP grid structure over the Galveston Bay area. The result is hexagons of approximately 70 km^2 with a 7.5 km distance between the grid centers. From each hexagon which included any part of the defined area, a single station was randomly selected. If the sample point fell on land or outside of the defined sampling area it was thrown out. The sample selection process was repeated four times to provide four sets of sampling stations (Appendix C). The result is an average of 34 stations per year. The program has the option of sampling the same set of stations each year or a new set each of four years before revisiting a site. Sampling the same stations each year will increase trend detection capabilities but will also increase the uncertainty in the ability to make statements based on areal extent. Conversely, if a new set of stations is visited each year, with a subset revisited to enhance trend detection, long term trend detection capabilities are reduced, but the 10% uncertainty of areal extent is upheld. A final decision on this detail of the program has not been made pending results of the first year sampling. The program will be implemented with the first year set of stations which are represented by Figure 10-1.

The Regional Monitoring Work Group acknowledges Dr. Kevin Summers of the EMAP-Estuaries program in Gulf Breeze, Florida, who provided the technical assistance for development of the Galveston Bay Regional Monitoring Program probabilistic sampling design.

<u>Tidal Streams</u>

Monitoring tidal stream segments, including the Houston Ship Channel, and upstream segments is a second element in the Regional Monitoring Program. Data gathered from this monitoring element will provide information on inflow loadings of COCs to the bay system and will be used as appropriate in assessment of plan objectives. Tributary sampling design will utilize current sampling efforts conducted by monitoring entities. The program has designated five stream basin areas for development of tributary monitoring stations. The two major river basin watersheds for the Galveston Bay system are the San Jacinto and lower Trinity River systems. These two watersheds provide an estimated 82% of the freshwater inflow to Galveston Bay. Other designated basins are the upper Houston Ship



SOURCE: EPA, 1994

Figure 10-1. Galveston Bay Regional Monitoring Program Ambient Water and Sediment Quality Sampling Stations

Channel drainage basin, Clear Lake-Clear Creek basin, Dickinson Bay basin and Chocolate Bay basin. Adoption of comparable sampling and analytical methods will allow creation of a regional database incorporating data from all local and state agencies sampling in these basins. Figures showing the distribution of sampling programs in these tributary systems are found in Chapter 3. This effort is being closely coordinated with the Texas Clean Rivers Program to ensure comparability with open-bay sampling. Clean Rivers is a state program administered locally by the Houston-Galveston Area Council. The Texas Clean Rivers Act was passed by the legislature in 1991. Clean Rivers seeks to provide coordinated river basin assessment information utilizing a watershed management approach. Close coordination with the Clean Rivers Program will assure a truly regional monitoring program which will include the entire lower Galveston Bay watershed.

Temporal Sampling Strategies

To define monitoring frequencies water quality parameters are divided into two tiers. Tier One parameters will be monitored at a minimum frequency of quarterly. Quarterly samples will be collected during fall (October-November), winter (January-February), spring (April-May), and summer (August-September). For Tier Two parameters sampling will be done on a minimum of annually with many being sampled twice a year. Select Tier Two parameters such as pesticides will be sampled during high freshwater inflow periods, and in late summer. Tier Two parameters which are sampled only once a year will be sampled during the late summer period. Historically, levels for COCs are higher in late summer samplings.

Volunteer monitoring can be an excellent resource for filling gaps in temporal monitoring coverage at impacted or potentially impacted sites. By utilizing volunteer monitoring there is potential to extend both the temporal and the spatial coverage of the monitoring program. This monitoring program acknowledges that volunteer monitors provide quality data and can contribute much to what we know about Galveston Bay.

Performance Criteria

Performance criteria are defined as levels of environmental change that can be detected by the monitoring design. Two means of detecting change to be utilized in the Galveston Bay Regional Monitoring Program are: 1) estimates, in terms of areal extent, of the bay that meet defined environmental conditions and 2) long term trend detection in terms of concentration. The level of change that can be detected is influenced by several variables. These include the monitoring frequency, the number of samples, the variability of the contaminant, the duration of monitoring and, all too often, cost.

In making estimates of areal extent, a response variable can be classified as exhibiting a binary response when compared to a benchmark level (i.e. water quality criteria levels). For example, if the acute criteria for copper is 16.3 ug/l and a sample result of 8.4 ug/l is found then that sample would be classified as having a positive binary response. Conversely if a sample level of 20.0 ug/l is recorded then a negative response would be entered for that sample. Using such an approach, with a probabilistic sampling design, the proportion of an area meeting this response level can be estimated using the binomial distribution. An advantage of this method over traditional trend detection of concentration changes is that prior estimates of variance are not required.

Estimates of the precision in the response variable can be used to predict the probability of detecting a change. In the binomial distribution the precision of the estimate of the response variable is a function of the sample size. The probabilistic sampling program is then designed by determining the sample size needed to meet the *a priori* conditions of uncertainty desired by the sampling design. The level of uncertainty desired by the GBRMP was to be able to make predictions within 10% on an areal basis annually. With this information a probabilistic sampling design was developed which would meet this stated goal.

Projections of the trend detection capability of the sampling design can be estimated using power analyses. Performance criteria for trend detection were established from projections of power analyses conducted on historical data. Power analyses were conducted to evaluate the ability of the proposed systematic sampling program to detect trends, both within segment and bay-wide. Estimates of the level of detectable difference that can be achieved by the proposed sampling design, require the number of samples and an estimate of the variance of the data. Trends can be projected on a bay-wide or more meaningfully a bay segment basis. By using a systematic sampling design any number of segmentation schemes can be overlaid onto the grid without violating conditions of random selection.

A primary segmentation scheme used in the bay is the TNRCC water quality segmentation system. To evaluate the design capability to detect within segment trends using this scheme, the TNRCC segmentation scheme was superimposed on the probabilistic design. From this a nominal value for the number of stations per segment was set at 5. Since the probabilistic design is done on a bay-wide basis stations are not geographically weighted. Therefore, segments with larger areas will receive a larger proportion of the samples. Estimates of the variance within the data sets were calculated by extracting the most recent 5 year period from the historical data sets compiled by Ward & Armstrong during the characterization phase of the program. The power analyses were conducted using the power analysis function available in the Macintosh based JMP® statistical package developed by the SAS Institute Inc.

Power estimates, of ability to detect minimum differences within segments, were generated for three parameters; TOC, ammonia-N, and total zinc. A more complete discussion of this process is included in Appendix D of this document. As expected, these analyses demonstrated that sample sizes required to meet recommended power criteria of 80 percent are highly variable. Minimum detectable differences from the historical mean ranged from 16% for TOC, 18% for total zinc, and 70% for ammonia-N. It should be stated that the values for variance used in these evaluations will provide conservative estimates of detection levels. In calculating the estimates of variance no consideration was given to the effect of between segment or seasonal effects on variance. General estimates of variance, such as standard deviation, show that when evaluated on a segment by segment basis, variance may be lower or higher than the estimates used in this exercise.

The finding is that the proposed sampling scheme will provide adequate and protective estimates of trend detection which are theoretically acceptable. Evaluations of data collected will be conducted biennially to determine if modifications to the program need to be made. As data from the expanded monitoring effort becomes available additional evaluations of the data will be conducted and determinations will be made as to whether modifications to the sampling program need to be made to enhance trend detection.

Some parameters do not lend themselves to trend detection. As can be seen in Table 10-3 many inorganic toxic parameters are reported at concentrations well below the criteria limits. For example, from Table 10-3, silver had only 2.9% of observations above the reported detection level (DL). For organics, a historical review of data shows that more than 80% of the documented samples are reported with concentration levels below detection levels and most criteria levels are below detection capabilities. From this data no meaningful trend detection can be determined. In these cases trends based on areal extent will be utilized to show areas with contaminants at elevated levels against an established level.

Water Column Sampling Methods

Texas Surface Water Quality Standards (Section 307.9) specify sampling procedures for determining standards attainment. With comparisons to standards criteria being a primary issue in water column sampling the Regional Monitoring Program has been designed to be consistent with these requirements. GBRMP Protocols incorporate clean sample collection methods. Clean sample protocols will be implemented immediately to insure accurate results.

For bacteriological and temperature comparisons, water column sampling involves collecting the sample at one foot below the surface in all cases. However, for some standards parameters (e.g. DO, pH) the appropriate collection depth varies, dependent on the type of water body and criteria. Specific sampling requirements for bays, tidal, and non-tidal flowing streams are given in the Texas Water Quality Standards §307.9.b.2- 3.

All in situ field measures will be collected at every sampling event. For open-bay and tidal stations, a surface to bottom profile of DO, pH, salinity, and temperature shall be obtained. For non-tidal stations a surface to bottom profile of DO, pH,

TABLE 10-3 HISTORICAL CONCENTRATION VALUES FOR DISSOLVED METALS IN GALVESTON BAY. ALL VALUES ARE GIVEN IN ug/L. (from, WARD & ARMSTRONG, 1992)

Parameter	Criteria [1]	# Obs.	% Obs. >DL[2]	Avg. w/ BDL= 0[3]	Avg. w/ BDL=DL[4]
Arsenic	149/78	33	15.2	.71	5.34
Cadmium	45.6/10.0	65	40	.54	1.47
Copper	16.3/4.4	80	47.5	1.78	5.73
Lead	140/5.6	80	38.8	3.5	4.73
Mercury	2.1/1.1	62	71	.59	0.65
Nickel	119/13.2	70	47.1	6.02	9.8
Selenium	564/136	35	0	0	5
Silver	7.2/0.9	35	2.9	.46	18.7
Zinc	98/89	78	91	18.8	19.3

1 Marine Acute/Chronic Criteria.
2 Percent of observations reported as greater than detection limit (DL).
3 Average concentration using 0 as value when below DL (BDL) is reported.
4 Average concentration using DL as value when <DL reported.

conductivity, and temperature will be obtained. Vertical (depth) profiles will be collected according to Section 3.5 of the TNRCC Water Quality Monitoring Procedures Manual. Secchi depth and light penetration will be recorded.

Samples collected for Tier One analytical parameters, will be collected as grab samples at a depth of one foot. Tier Two samples will consist of samples for toxic inorganics and organics. Sampling methods for these parameters will incorporate the use of practical clean method precautions in sampling and analytical procedures. Further development of clean methods will be pursued. Tier Two samples for standards attainment for aquatic life criteria shall be collected at a depth of one foot. The use of a bucket for this sampling is not recommended because of the possible inclusion of the surface layer. This layer may contain sufficiently elevated concentrations of trace metals, or organic compounds that could influence the overall concentration for the sample. For these samples the collection method for the one-foot depth should minimize the contribution of this surface layer. Direct bottle filling from under the surface should be employed for Tier Two samples. Tier Two organics collected at designated standards attainment stations will be collected as a vertical composite from the surface to the natural bottom. Specific sampling procedures can be found in the *Protocols for Sample Collection and Analysis: Galveston Bay Regional Monitoring Program* (Tetra Tech, 1994b).

The GBRMP will identify areas at high risk for DO impacts through its Tier One monitoring effort. Once high risk areas are identified continuous 24-hour monitoring consistent with state DO criteria will be conducted to determine compliance with state DO criteria. These sampling requirements are outlined in §307.9(d)6 of the Texas surface water quality standards. These monitoring activities will support results from plan actions designed to improve DO levels through reductions in nutrient and BOD loadings.

Water Column Analytical Methods

There is a great deal of experience in monitoring most in situ and Tier One parameters. For this reason the methods recommended are those which are currently employed by the many agencies and organizations involved. DO, pH, salinity/conductivity, and temperature are most commonly measured by probe. Volunteer monitoring groups do not have access to probes but do follow a formal Quality Assurance Project Plan (QAPjP) (TNRCC, 1993) utilizing approved protocols from *Standard Methods*. No specific requirements are required beyond the ability to meet the minimum data quality objectives listed in Table 10-1. Monitoring entities should follow their own monitoring protocols or manufacturers recommendations for probe maintenance and use.

Methods as listed in Table 10-4 will be selected based on their ability to provide the lowest practical detection levels. Current analytical capabilities, for metals, by participating laboratories are limited to Atomic Absorption (AA) Furnace methods. The US EPA Region 6 Laboratory is adding inductively coupled plasma - mass spectrometry (ICP-MS) instrumentation (D. Stockton, U.S. EPA - Region 6 Laboratory, Personal communication) and the program will work with them to make these capabilities available for our sampling effort.

Water Column Quality Assurance and Quality Control

All samples will be collected according to *Protocols for Sample Collection and Analysis: Galveston Bay Regional Monitoring Program*. This document specifies collection procedures, container requirements and preservation requirements for proper sample quality assurance. In addition to this document the Galveston Bay Program will coordinate an annual training workshop to provide additional standardization of sample collection procedures.

The ability to determine metals at ambient water quality criteria levels requires the use of stringent quality control procedures to avoid contamination and ensure validity of analytical results (U.S. EPA, 1994). Improved sampling methods must be developed to assure that trace metals determinations are not influenced by contamination during the sampling process.

Quality control specifications for water analyses have been incorporated into state law (Texas Surface Water Quality Standards § 319.1- 319.12). Although originally designed to satisfy National Pollution Discharge Elimination System (NPDES) monitoring programs these requirements, shown in Table 10-5, are equally appropriate for ambient water quality evaluations. This program specifies type and frequency of quality control measures to be run on sample sets. Control measures include blanks, duplicates, spikes and standards. All laboratories conducting analyses for the Galveston Bay Monitoring Program will utilize these QA/QC measures. Additional quality assurance for participating laboratories will come from participation in extramural quality control programs.

A number of commercially available programs are currently utilized by agency labs. One such program available to all laboratories participating in the Regional Monitoring Program is the USEPA Water Pollution Evaluation Study. This program consists of a series of samples shipped to the study participants every six months. Each set includes samples for demands (TOC and CBOD), nutrients (NH3-N, nitrate, ortho and total phosphorous), trace metals, and organics (PCB's, pesticides, volatiles, and aromatics). These results are evaluated against true values and are made available to both the laboratory and the State. Participation in this or other equivalent programs is required at a minimum frequency of twice per year with quarterly evaluations recommended. The GBRMP recognizes QA/QC procedures outlined in the TNRCC Texas Watch QAPjP (TNRCC, 1993) for volunteer monitoring data.

TABLE 10-4. COMPARABLE AND ACCEPTABLE ANALYTICAL METHODS FOR THOSE PARAMETERS TO BE CONDUCTED BY LABORATORY ANALYSES.

Parameter	EPA Method	Standard Methods	Other
TSS	160.2	2540 D	
VSS	160.4	2540 E	
CBOD5	405.1	5210	
NH3-N	350.1*, 350.3	4500-NH3 D,F,H	
Nitrate- nitrite	353.1,353.2*, 353.3	4500-NO3 C,D,E,F	
Phosphorous (all types)	365.1, 365.2. 365.3, 365.4	4500-P D,E,F	
Total Organic Carbon	415.1	5310 B,C	
Chlorophyll-a		1002.G.2	TNRCC
Fecal coliforms		9222 D	
Water hardness	130.1, 130.2	2340 C	
Dissolved metals	AA Furnace, ICP-MS	3113 B	
Mercury	245.1, 245.2, 245.5 (Sediment)	3500 Hg-B	
Volatile organics	624,1624	6220 B	
Acid-base Neutral Organics	625, 1625	6410 B 6440	
Pesticides	608, 625	6410 B 6630 B,C	

* Recommended Method in U. S. EPA Monitoring Guidance for the National Estuary Program.

TABLE 10-5. REQUIRED QUALITY CONTROL ANALYSIS FOR GALVESTON BAY REGIONAL MONITORING PROGRAM.

Parameter	Blank	Standard	Duplicate	Spike
Bacterial	A		B	
Alkalinity		A	B	
Ammonia Nitrogen	A	A	B	B
BOD	A	A	B	
BOD-Carbonaceous	A	A	B	
COD	A	A	B	B
Chloride	A	A	B	B
Chloride-Total or Free		D		
Cyanide-total or Ammenable to Chlorination	A	A	B	B
Fluoride	A	A	B	B
pH		C		
Kjeldahl Nitrogen	A	A	B	B
Metals (all)	A	A	B	B
Nitrate Nitrogen	A	A	B	B
Nitrite Nitrogen	A	A	B	B
Oil and Grease	A	D		
Orthophosphate	A	A	B	B
Oxygen (dissolved)		A	B	
Phenols	A	A	B	
Phosphorus-Total	A	A	B	B
Specific Conductance	A	A		
Sulfate	A	A	B	B
Sulfide	A	A	B	
Sulfite	A	A	B	
TOC	A	A	B	B
TSS	A		B	
TDS	A	A	B	
Organics by GC or GC/MS	A	A	E	E

A - Wherever specified, at least one blank and one standard shall be performed each day that samples are analyzed.

B - Wherever specified, duplicate and spike analyses shall be performed on a 10% basis each day that samples are analyzed. If one to 10 samples are analyzed on a particular day, then duplicate and one spike analysis shall be performed.

C - For pH analysis, the meter shall be calibrated each day that samples are analyzed using a minimum of two standards which bracket the pH value(s) of the sample(s).

D - For the oil and grease analysis and chlorine-total or free analysis, standards shall be analyzed on a 10% basis. If one to 10 samples are analyzed in lieu of standards for the oil and grease analysis and chlorine-total or free analysis.

E - For GC and GC/MS analyses, duplicate and spike analyses shall be performed on a 5% basis. If one to 20 samples are analyzed in a month, then one duplicate and one spike analysis per month shall be performed.

Source: Texas Surface Water Quality Standards - Sections 319.1 - 319.12

Marine Sediment Quality

Estuarine sediments represent an important habitat for many commercially, recreationally, and ecologically important organisms. Sediments also represent the ultimate sink for many chemical toxics in the estuarine environment. Sediment quality monitoring will provide information to characterize the condition of the aquatic environment, evaluate potential stresses to aquatic and sediment-dwelling organisms, and track habitat recovery following environmental interventions.

Sediment Quality Monitoring Objectives

General sediment monitoring objectives and goals have been previously stated in the introduction to this chapter. Specific sediment quality monitoring objectives are as follows:

To make Bay-wide estimations of sediment toxicity by areal extent (±10%). Where toxicity is defined as Inland Silverside, *Menidia beryllina*, in a 7-day sediment elutriate exposure test are shown to be significantly greater (p=0.05) than those seen in the control and/or where mortality to *Mysidopsis bahia* in a 96-hour sediment elutriate test significantly exceeds (p=0.05) mortality seen in the control group.

To make Bay-wide estimates of areal extent (±10%) and temporal trends, in terms of areal extent and magnitude, for potential biological effects resulting from sediment concentrations greater than the median effect values as published by Long and Morgan (1990). (These evaluations will be made utilizing adopted sediment criteria when they become available.)

To make Bay-wide estimates of areal extent (±10%) and temporal trends in terms of areal extent of sediment benthic evaluations which show degraded benthic communities.

Parameter Selection and Data Quality Objectives

Candidate measures for sediment monitoring were selected to address the management objectives outlined previously in this chapter. Information is needed to assess the trends in concentrations in sediments and the possible effect of these concentrations on living resources. A triad approach to sediment evaluation was selected. This approach utilizes contaminant concentration, toxicity and benthic community evaluations to establish the overall condition of sediment quality.

Estimations of areal extent for toxic COC's requires establishment of a reference level of contaminants that have the potential to cause biotic effects. Since sediment criteria are not available for this evaluation, the Monitoring Work Group has recommended the use of levels published by Long and Morgan (1990), as criteria to assess potential degradation from chemical contaminants (Appendix C). There are two concentration levels at which biotic effects are hypothesized. One level is the hypothesized concentration level at which a biotic effect was seen in 10% of the samples. The second level is the mean concentration at which a biotic effect was seen. These are the same criteria used in the USEPA EMAP program to assess potential for sediment degradation in the Louisianan Province which includes the Texas Coast. Consistent with the EMAP monitoring program, all values above the median values associated with biotic effects (Long and Morgan, 50% effects) will be assessed as representative of sediment degradation. Evaluations using the 10% concentration levels will be conducted to identify areas of potential concern.

Performance Criteria

Trend analyses were conducted on historical data from Galveston Bay (Tetra Tech, 1994) . To provide a range of expected program performance, the power analysis was performed using three contaminants: one with the highest variability (CV=501%), one with the least variability (CV=32.6%), and one with a typical level of variability (CV=138%). For each contaminant, residuals from a simple linear regression were used to estimate the parameters of a two parameter log normal distribution of concentrations, and a random number generator was used to generate a series of random concentrations from this distribution. A trend of known magnitude was then added to the random sequence of concentrations to simulate data collected by a monitoring program of a specified length and number of sampling stations. The simulated data were then tested for the presence of a trend using a significance level of 5% and the results were recorded. This procedure was repeated 1000 times and the percentage of simulations that correctly identified the trend was recorded as the power of the test.

Simulation tests were conducted to evaluate the effect of the number of stations, sampling frequency, replicate sampling and monitoring program duration on trend detection. This analysis demonstrated two important principles. First, the more samples per segment, the greater the power to detect trends. It also showed that there is a point of diminishing returns in program performance as the number of stations increased. Any gains in the ability to detect smaller trends due to increasing stations should be weighed against costs. Second, the more variable a contaminant, the more samples required to get an appreciable increase in power. Improving program performance for extremely variable contaminants may not be financially feasible. Rather than to design a program to detect trends of the most variable of contaminants, it is more effective to design a program around contaminants with typical variability. This strategy will ensure an adequate level of trend detection for the majority of contaminants found in the estuary. From these principles it was decided that all further evaluations would be conducted on the variable with typical variability.

The proposed probabilistic sampling plan for sediment will result in approximately 3 samples per segment. As a result the probabilistic sampling design was determined to be adequate and appropriate for meaningful trend detection. Sediment samples will be collected concurrently with water samples whenever possible. Sediment samples will be collected at half of the bay stations annually, approximately 17 stations, so that all stations are sampled every two years. This will raise the uncertainty level on predictions of areal extent for sediment samples. It is not known at this time what the true level of uncertainty will be but it is expected to be within acceptable limits (<20%). This will be determined after the first round of sampling. If the level of uncertainty is not acceptable the sampling program will be modified accordingly.

Temporal Sampling Strategy

Based on the above analyses an annual sampling schedule was determined to be adequate and appropriate for the goals of the Regional Monitoring Program. All sediment sampling will be conducted along with late summer water quality sampling. All sediment analyses: physical, chemistry, toxicity and benthic evaluations will be conducted for each sample.

Toxic Chemicals of Concern

In the absence of sediment criteria, the chemicals of concern for this sampling program will be as consistent as possible with the EPA EMAP program (Table 10-6). This will allow the program to evaluate its results against the EMAP program for variability and provide additional data for overall program evaluation.

Sediment Sampling and Analytical Methods

Sediment samples will be collected from the aerobic layer of the sediment as defined by color, using an Eckman dredge. If the aerobic layer is less than 3 centimeters, the upper 2-3 centimeters will be collected and homogenized. A minimum of three replicate samples will be collected at each station and composited to form the final sample. The same composite sample will be used for sediment toxicity tests and sediment chemistry. A separate sample will be collected for benthic community analyses.

Toxicity of bay sediments will be evaluated using sediment elutriate tests adopted from USEPA toxicity methods. These tests, run by the USEPA Region 6 laboratory for the TNRCC, have been shown to provide valuable information on bay-area sediment quality (T. Hollister, U.S. EPA - Region 6 Laboratory, personal communication). Both a vertebrate and invertebrate species will be evaluated for their response to exposure to Bay sediments. Marine tests are the 9-day embryo-larval and teratogenicity chronic test for Inland Silverside, *Menidia beryllina*, and the 96-hour acute test for mysids, *Mysidopsis bahia*.. These methods will be evaluated over a two year period to determine if valuable information is being obtained. Tests will be modified or eliminated as indicated from the data review.

The identification and enumeration of benthic macro-invertebrates will be used to characterize benthic communities, assess sediment quality, and assist in predicting potential impacts to bottom-feeding living resources. Benthic macro-invertebrates are important components of the ecosystem and are sensitive indicators of environmental stress. All taxa will be identified and enumerated. Sediment quality will be assessed based on species composition values. Recommended measurements of community structure include: number of individuals, number of species, species dominance, abundance of contaminant-sensitive species, and abundance of opportunistic and contaminant-tolerant species.

Other measures which provide valuable information include depth of aerobic sediment, gain size, TOC, and measures of acid volatile sulfides (AVS). Grain size data is valuable in explaining and identifying potential causes of temporal or spatial variability in benthic communities. The depth of aerobic sediments provides a direct measure of the biologically active zone. AVS has been shown to be of use as a tool for predicting bioavailability of metals in anoxic sediments (DiToro, et al, 1990). AVS analytical capabilities will be developed and utilized, as available, to assess sediment quality.

TABLE 10-6. SEDIMENT CONTAMINANTS OF CONCERN FOR USEPA EMAP LOUISIANIAN PROVINCE SAMPLING.

PAH'S

Acenaphthene
Acenaphthylene
Anthracene
Benzo(a)anthracene
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo(e)pyrene
Benzo(g,h,i,)perylene
Benzo(k)fluoranthene
Biphenyl
Chrysene
C1, C2, C3, C4 Chrysene
Dibenzo(a,h)anthracene
Dibenzothio
C1,C2, C3 -dibenzothio
Fluoranthene
C1-fluoranthpyrene
Fluorene
C1, C2, C3 fluorene
Naphthalene
C1, C2, C3, C4- naphthalene
Perylene
Phenanthrene
C1, C2, C3, C4-phenanthrene
Pyrene
1,2,3-c,d-pyrene
1-methylnaphthalene
2-methylnaphthalene
2,3,5- Trimethylnaphthalene
2,6- Dinethylnaphthalene
1- methylphenanthrene
High Molecular Wt. PAH's
Low Molecular Wt. PAH's
Total PAH's

PCB's

Pesticides

2,4'DDD
4,4'DDD
2,4'DDE
4,4'DDE
2,4'DDT
4,4'DDT
Aldrin
alpha-BHC
beta-BHC
delta-BHC
alpha- chlordane
gamma- chlordane
Dieldrin
Endrin
Heptachlor
Heptachlor epoxide
Methoxychlor
Lindane
Toxaphene
Malathion
Parathion
Diazinon
Endosulfan
Mirex
Total BHCs

Inorganics

Aluminum
Antimony
Arsenic
Cadmium
Chromium
Copper
Iron
Lead
Manganese
Mercury
Nickel
Selenium
Silver
Tin
Tri-butyl tin
Zinc