Surface Water Quality Monitoring Program

Seining for fish in the Rio Grande

Surface Water Quality Monitoring Program

Program Mission and Emphasis

The TNRCC SWQM program provides for an integrated evaluation of physical, chemical, and biological characteristics of aquatic systems in relation to human health concerns, ecological condition, and designated uses. SWQM data provide a basis for the establishment of effective TNRCC management policies that promote the protection, restoration, and wise use of Texas surface water resources.

The TNRCC SWQM program, which was initiated in 1967, includes the monitoring of streams, reservoirs, estuaries, and the Gulf of Mexico. The SWQM program encompasses the full range of activities required to obtain, manage, store, assess, share, and report water quality information to other TNRCC teams, agency management, other agencies and institutions, local governments, and the public. Primary statutory authority for the SWQM program is provided under Section 26.127 of the Texas Water Code, which states, "The executive director has the responsibility for establishing a water quality sampling and monitoring program for the state. All other state agencies engaged in water quality or water pollution control activities shall coordinate those activities with the Commission." The SWQM program is strongly influenced by Sections 104(b), 106, 205(j), 303(d), 305(b), 314, 319, and 604(b) of the CWA of 1987. The TNRCC SWQM program is partially funded through the CWA Section 106 Water Quality Management portion of the Performance Partnership Grant (PPG) from EPA Region 6.

The mission of the SWQM program is to characterize the water quality of the ambient surface waters of the state. Basic components of the program include a fixed station monitoring network, intensive surveys, and special studies. Water quality data obtained through these components are stored in the SWQM Database. The monitoring results obtained through the SWQM program may be used by the TNRCC to:

- characterize existing conditions,
- evaluate spatial and temporal trends,
- determine water quality standards compliance,
- identify emerging problems, and
- evaluate the effectiveness of water quality control programs.

The TNRCC's SWQM program is coordinated by the Surface Water Quality Monitoring Team (SWQM Team) within the Monitoring Operations Division and by the Water Program within the Field Operations Division. Fixed station monitoring is conducted by SWQM program personnel in the TNRCC's 16 regional offices. The cities in which TNRCC regional offices are located and the areas monitored by each region are shown in Figure 7. Special study monitoring is conducted by TNRCC regional office and SWQM Team central office personnel. The SWQM Team is also responsible for conducting intensive surveys.

TNRCC's CRP contributes significantly to the SWQM program (see Clean Rivers Program Section on page 85 for program highlights). The CRP is coordinated by the Watershed Management Team in the Technical Analysis Division. Fixed station and special study monitoring are important facets of the CRP and are conducted by contractors (primarily river authorities) in each of the 23 major river and coastal basins. The CRP coordinates with the TNRCC's SWQM Team to ensure consistency in water quality sampling, assessment, and data reporting protocols. The CRP is designed to provide a holistic watershed assessment. The term "watershed" in this context is broadly defined as the geographic delineation of an entire river or coastal basin and the surrounding land that drains to it.

The USGS also conducts a large amount of monitoring statewide and reports most of the data to the TNRCC. The USGS surface water collection network in Texas is primarily established to monitor stream flow continuously at many permanent sites. Field measurements, routine water chemistry, and metals in water are also collected at many of the fixed sites. Sites are chosen to represent a mix of major natural and human factors that influence water quality. Chemical variables are then related by the USGS to hydrological conditions to interpret water-resource conditions and meet water quality management needs. Estimation of point and nonpoint source loadings, stormwater management, and chemical-contaminant controls are some of these needs. Samples are collected using standard USGS methods, which are similar to those used by the TNRCC and CRP.

Coordinated Statewide Monitoring Meetings

The implementation of coordinated statewide monitoring is a priority of the TNRCC and CRP to ensure reduced duplication of effort, improve spatial coverage of monitoring sites, and improve consistency of parametric coverages. An annual meeting is held in each major river basin, hosted by the CRP Planning agency, during the spring of each year. The purpose of the meeting is to develop a coordinated basin-wide monitoring schedule (plan). All water quality monitoring groups that collect SWQM data and commit to comply with TNRCC requirements for collecting quality-

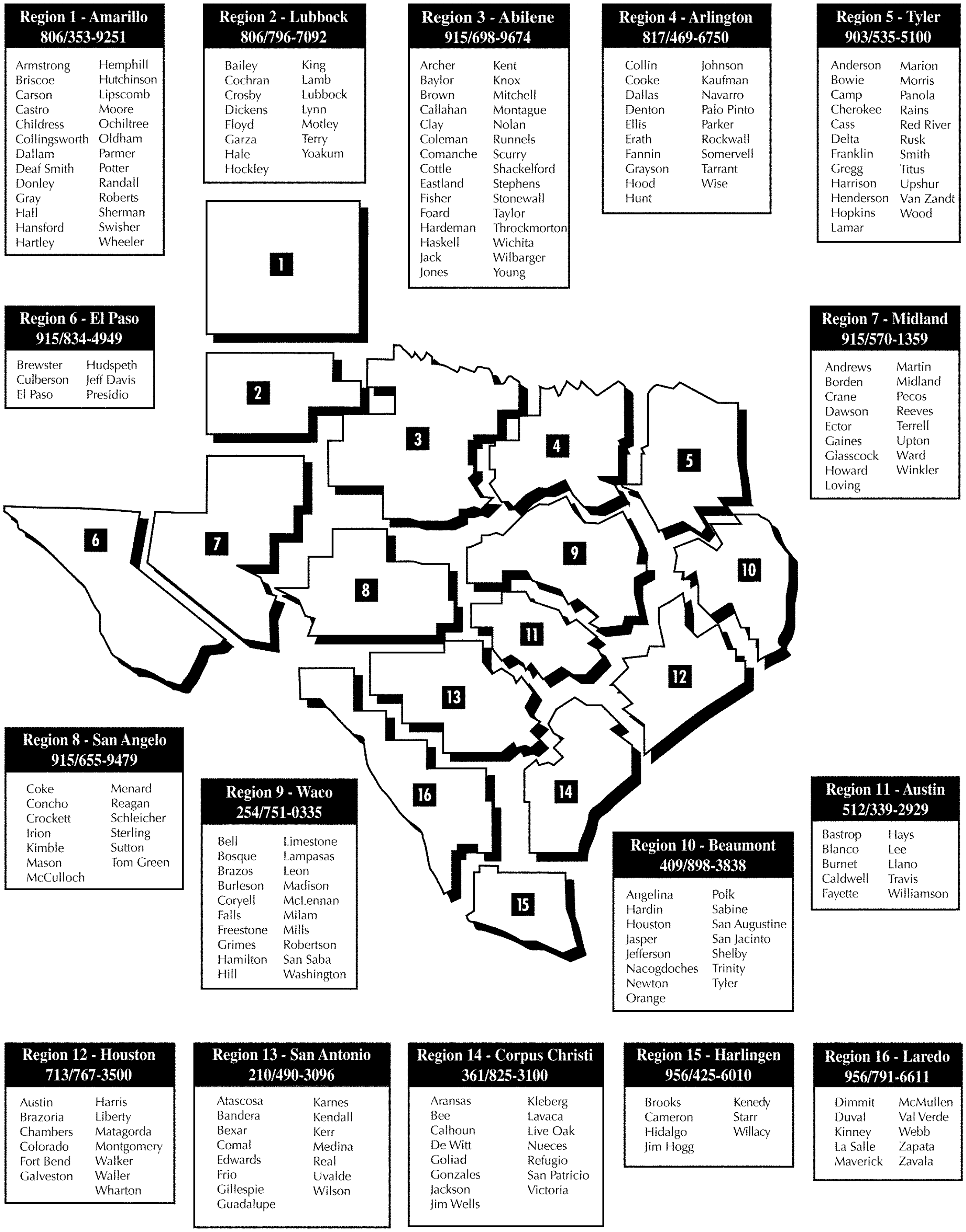


Figure 7. Map of TNRCC Regional Office Boundaries
(including counties in each regions)

assured data are invited to participate in the meetings. At each of the meetings, a basin map showing all active monitoring sites is displayed. Monitoring station locations are discussed segment by segment and station by station by those in attendance. The merits of maintaining or relocating existing sites and changing parametric coverages are discussed in relation to the status of the basin group in the five-year rotating cycle, historical baseline sampling, identification of use impairments and water quality concerns from the 305b assessment, local knowledge of water quality problems, permit activities, special studies, and TMDL monitoring projects. Special attention is focused on the position of the basin group in the five-year rotating cycle to ensure that most sites will exceed the minimum number of samples required for full assessment of designated uses and identification of water quality concerns when the assessment is conducted. Spatial gaps in station locations and gaps in different types of data are also discussed. New sites are added, existing sites may be relocated, and parametric coverages may be changed based on the discussions at the meetings.

Coordinated Statewide Monitoring Schedule

The preliminary basin-wide monitoring schedules developed at the coordinated monitoring meetings are reviewed by the CRP contractors, their stakeholder groups, and TNRCC regional offices to ensure that proposed revisions to station locations and parametric coverages and workload measures are appropriate. The CRP contractors that host the annual basin-wide meetings have responsibility for preparing the basin-wide monitoring schedule. Monitoring schedules from appropriate TNRCC regional offices and other monitoring groups within each basin are submitted to the host CRP contractors. The finalized basin-wide schedules are then submitted to the TNRCC Monitoring and Data Management and Analysis Section where they are aggregated to produce a coordinated statewide SWQM schedule. Beginning in 2001, the statewide schedule will be made available at the TNRCC Web site (http://www.tnrcc.state.tx.us/water/quality/data/).

Parametric coverages typically include field measurements, flow measurements, routine water chemistry, and fecal coliform analysis. Additional coverages may include toxic substances in water, sediment, or fish tissue, toxicity testing of water and sediment, and analysis of fish and/or macrobenthos community structure. The sampling methodologies employed by the TNRCC and CRP for the collection of each set of parameters are described in the *Surface Water Quality Monitoring Procedures Manual* (TNRCC, GI-252, 1999a). Additional information pertaining to the CRP is available in the *Clean Rivers Program Guidance and Reference Guide, FY 2000-2001* (CRP, 1999).

Table 2. Distribution of Statewide SWQM Fixed Network Sites by Water Body Type

Water Body Type	Number of Monitoring Sites
Classified Freshwater Streams and Rivers	480
Unclassified Freshwater Streams and Rivers	187
Classified Tidal Streams	109
Unclassified Tidal Streams	103
Classified Reservoirs and Lakes	262
Unclassified Reservoirs and Lakes	73
Classified Bays	174
Unclassified Bays	31
Gulf of Mexico	10
Grand Total	**1,429**

Fixed Station Monitoring Network

The TNRCC has subdivided river and coastal basins into segments for water quality management activities. Most of the major streams, reservoirs, and estuaries have been classified as segments by the TNRCC. In many cases, lengthy streams and rivers have been further subdivided into multiple segments. There are currently 224 stream segments, 99 reservoir segments, and 44 estuary segments (TNRCC, 1997a). The Gulf of Mexico is treated as one segment. Minor streams, reservoirs, and estuaries are treated as unclassified waters by the TNRCC. One of the primary goals of the SWQM program has been to establish at least one fixed monitoring station within each of the 368 classified segments, while at the same time increasing monitoring on unclassified water bodies.

The number of fixed stations monitored each year, and the frequency at which they are sampled by the TNRCC, CRP, and USGS, varies from year to year depending on the amount of funding received and the manner in which the funds are allocated. During the current year (2000) 1,429 stations contribute to the assessment and are monitored statewide by the TNRCC (431 sites), the CRP (920 sites) and the USGS (78 sites) (Figure 8). More than one agency monitors water quality at 105 of the stations. In most cases, having more than one agency sampling a site results in increased cooperation rather than duplication of effort. For example, the TNRCC monitors a site on the Rio Grande near Fort Quitman quarterly. The IBWC samples the same site, but coordinates its sampling with the TNRCC, so that sampling is done for the other eight months of the year.

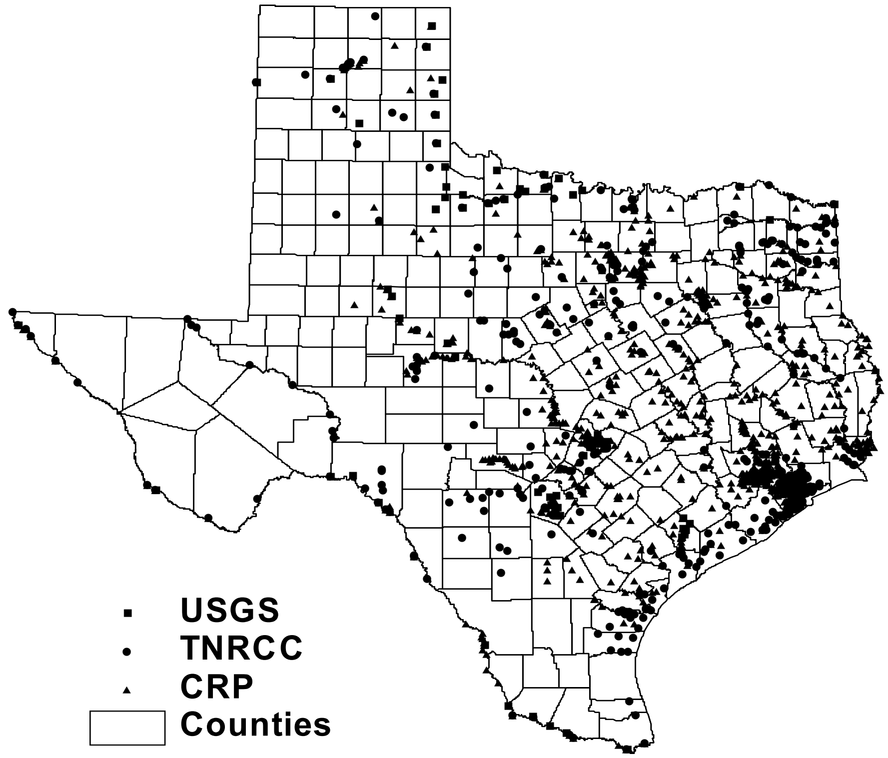


Figure 8. Map of All Fixed Sampling Sites

Locations of TNRCC, CRP, and USGS active surface water quality monitoring sites for fiscal year 2000

The total number of sites monitored represents an increase of 943 sites over the number (446) that was monitored by the TNRCC in 1996, and demonstrates the power of coordinating statewide monitoring resources. Most of the current year fixed monitoring sites (1,028; 72%) are located within classified segments, but 400 (28%) are located on important unclassified water bodies (Table 2). The number of monitoring sites on unclassified water bodies has increased substantially from the 76 that were monitored in 1996, reflecting an increased emphasis on assessment of small headwater streams. The fixed sites are monitored at varying frequencies, with 93 percent sampled quarterly or more frequently (Figure 9). Monitoring agencies have steadily increased monitoring frequency at many sites to improve confidence in water quality assessments. In 1996, no sites that contributed to the assessment were monitored more frequently than quarterly, while in 2000, 476 sites (40.1%) are monitored more frequently than four times per year.

Field Measurements, Routine Water Chemistry, and Bacteriological Analyses

Sampling that is common to all sites (1,429 in 2000) includes field measurements, routine water chemistry, and fecal coliform densities (Table 3). 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.

Water samples are collected, preserved, and sent to the TNRCC, CRP, USGS, or a contract laboratory, where many routine water chemistry analyses are performed. The routine field and water chemistry parameters measured *in situ* or in the laboratory are listed in Table 3.

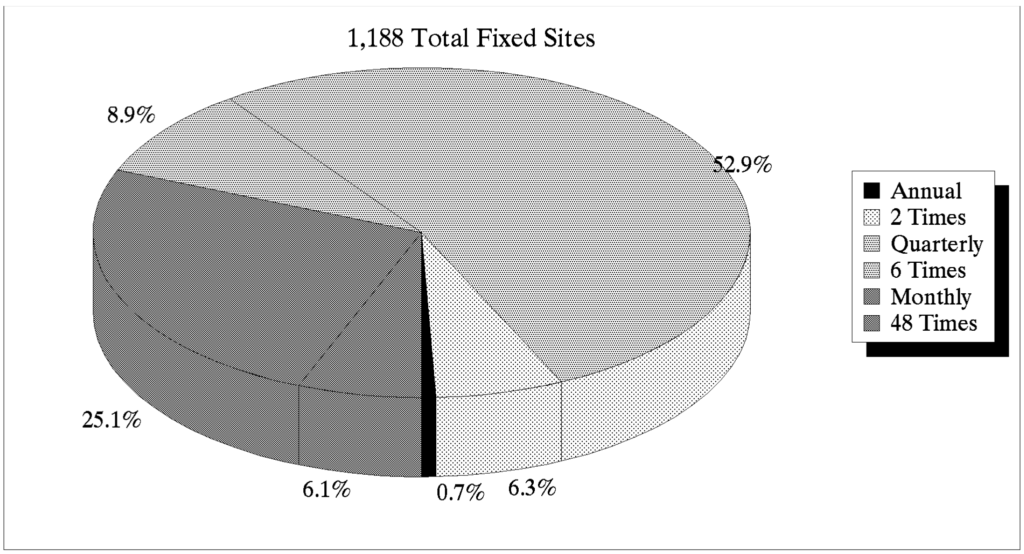


Figure 9. Sampling Frequencies at Fixed Sampling Sites in 2000

Table 3. Field Measurements and Routine Water Chemistry Analyses

Field Measurements	Routine Water Chemistry*	
Water Temperature (°C) pH (standard units) Dissolved Oxygen (mg/L) Specific Conductance (μmhos/cm) Salinity (ppt) Secchi Disk (m) Fecal Coliform (#/100 mL) Stream Flow (cfs) Flow Severity Days Since Last Significant Precipitation	Ammonia Nitrogen Chlorophyll a (μg/L) Pheophytin a (μg/L) Kjeldahl Nitrogen Nitrate + Nitrite Nitrogen Orthophosphorus Total Phosphorus	Chloride Sulfate Total Alkalinity Total Dissolved Solids Total Organic Carbon Total Suspended Solids Volatile Suspended Solids

* All routine water chemistry parameters reported in mg/L except where noted

Dissolved oxygen, water temperature, and pH are field measurements for which water quality criteria are established for each classified water body. Analysis of chloride, sulfate, and TDS is included in routine water chemistry samples; criteria for these parameters are also established for most classified water bodies.

Dissolved oxygen is a basic requirement for a healthy aquatic ecosystem. Most fish and beneficial insects "breathe" oxygen dissolved in the water. Some fish and aquatic organisms (such as gar and sludge worms) are adapted to low dissolved oxygen concentrations, but most desirable fish species (such as largemouth bass and darters) suffer if dissolved oxygen concentrations are depressed below 3 to 4 mg/L (3 to 4 milligrams of oxygen dissolved in 1 liter of water, or 3 to 4 parts of oxygen per million parts of water). Insect larvae and juvenile fish are more sensitive and require even higher concentrations of dissolved oxygen to function in a healthy way.

Many fish and other aquatic organisms can recover from short, episodic periods of low dissolved oxygen availability. However, prolonged exposure to oxygen concentrations of 2 mg/L or less can suffocate adult fish or reduce their reproductive survival by suffocating sensitive eggs and larvae. Depressed dissolved oxygen concentration is the leading cause of fish kills in the state over the past five years (see Public Health and Aquatic Life Concerns Section). Low dissolved oxygen concentrations also affect aquatic insect larvae and other prey on which fish depend for food. Low dissolved oxygen concentrations also favor anaerobic (without oxygen) bacterial activity that produces gases (methane and hydrogen sulfide) and foul odors often associated with polluted water.

Taking field measurements with a Multiprobe instrument

Oxygen concentrations in the water column fluctuate under natural conditions, but severe depletion may result from human and natural activities that introduce biodegradable organic materials into surface waters. Biodegradable organic materials, including lawn clippings, raw and treated sewage, manure, food processing wastes, rice field drainage, pulp paper wastes, leaf litter, recycled plants, and animals are some examples of oxygen-depleting organic materials that enter surface waters.

In both pristine and polluted waters, beneficial bacteria use oxygen to decay or break apart organic materials. Organic wastes originating from natural, point, and nonpoint sources provide a continuous source of food for the bacteria, which accelerates bacterial activity and growth. In polluted waters, bacterial consumption of oxygen can rapidly outpace replenishment from the atmosphere (introduced by reaeration) and daytime photosynthesis performed by algae. In streams, most of the algae (periphyton) is attached to the stream bottom or objects in the water. In slow moving streams and in reservoirs and estuaries, the algae (phytoplankton) are usually floating free in the water.

The result of overuse of oxygen by bacteria and algae is a net decline in oxygen concentrations in the water. Abundant algae can also consume large amounts of oxygen at night through respiration. Organic materials that are decayed by bacterial action may settle to the bottom of water bodies where they exert an oxygen demand in sediment, further reducing oxygen concentrations in the overlying water column.

Toxic pollutants can indirectly lower dissolved oxygen concentrations by killing algae, aquatic weeds, or fish and other aquatic organisms, thereby producing an abundance of food for oxygen-consuming bacteria. Oxygen depletion can also result from chemical reactions of some pollutants that do not involve bacteria. These pollutants place a chemical oxygen demand, caused by chemical reactions, on receiving waters and reduce the ambient concentration of dissolved oxygen.

Low temperature shock also kills fish, sometimes in large numbers. The typical situation is when a long, hot, low-flow period is interrupted by a large thunderstorm or sudden passage of a cold front. Fish stressed by the high water temperature and low dissolved oxygen concentration are suddenly exposed to a slug of cold water that results from sudden passage of an extreme cold front, or falls during a thunderstorm and flashes downstream. The shock of the rapidly lowered temperature can kill stressed fish.

Other factors such as temperature and salinity also influence the amount of oxygen dissolved in the water. Prolonged hot weather will depress dissolved oxygen concentrations and may cause fish kills, even in clean waters, because warm water can not hold as much oxygen as cooler water.

Extremes in water temperatures (both hot and cold) are the third leading cause of fish kills in the state over the past five years. In bays, prolonged hot weather may reduce freshwater inflow and accelerate evaporation, thus concentrating dissolved minerals and increasing salinity. Saline water can not hold as much dissolved oxygen as brackish or freshwater. Warm conditions further aggravate oxygen depletion impacts because they promote respiration (oxygen consumption) of bacterial, plant, and animal populations. Removal of streamside vegetation eliminates shade, thereby raising water temperatures, and accelerates runoff of organic debris. Under hot conditions, even minor additions of pollution-containing organic material from point and nonpoint sources can severely deplete oxygen.

Water temperature is also an important indicator of general water quality, since it directly affects the rates of most chemical and biological processes. Temperature affects the dissolved oxygen content of water and influences the rate of photosynthesis by aquatic plants, the metabolic rates of aquatic organisms, and the sensitivity of aquatic organisms to toxic substances, parasites, and many diseases.

Acidity affects many chemical and biological processes in water. The acidity of water is measured by determining the pH level on a scale of 0.0 to 14.0 standard units. A pH measurement of 7.0 indicates neutral conditions; greater than 7.0 indicates alkaline conditions; and less than 7.0 indicates acidic conditions. Most aquatic organisms flourish in water with a pH range of 6.0 to 9.0. The pH of water strongly influences toxicity and the bioavailability of metals. At low pH, metals become more mobile and available for uptake by aquatic life. Metals available at low pH can be toxic to sensitive aquatic species. Photosynthesis by aquatic plants (primarily periphyton and phytoplankton) removes carbon dioxide from water, which often substantially increases pH during daylight hours. Nutrient-enriched waters with active, excessive blooms of algae often exhibit maximum pH values greater than 8.5 standard units, and exhibit wide daily temporal variations in both pH and dissolved oxygen.

Conductivity is a measure of the ability of water to pass an electrical current. Conductivity in water is influenced by the presence of inorganic dissolved ions, such as chloride and sulfate which carry a negative charge, or calcium and magnesium ions which carry a positive charge. Conductivity is affected by water temperature; the warmer the water, the higher the conductivity. For this reason, specific conductance is reported as conductivity at 25 ºC. Specific conductance in streams, rivers, and reservoirs is primarily determined by the geology of the watersheds through which waters flow. Specific conductance and salinity are monitored to estimate the total concentration of dissolved solids, evaluate mixing of fresh and salt water in estuaries, determine density stratification, and document impact and dispersion of pollutants.

Transparency is a measure of water clarity, or the degree to which suspended matter in the water decreases the passage of light. All solar radiation not reflected from a water body is absorbed. The Secchi disk provides a convenient method for measuring light penetration, and thus transparency. Turbidity most importantly affects the depth to which light can penetrate, thus affecting the depth at which heating occurs. As turbidity increases (Secchi disk depth increases), heating becomes more concentrated in the surface layer. This phenomenon may have profound effects on the annual decay of stratification and depth of the thermocline. Increased temperatures, in turn, lower dissolved oxygen concentrations, because oxygen is less soluble in warm water. Turbidity may also result in a more direct decrease in dissolved oxygen by reducing the amount of available light necessary for photosynthetic activity (which produces dissolved oxygen). Under normal summer conditions of low inflow, much of the turbidity in Texas reservoirs and lakes is due to suspended algae (phytoplankton) in the water.

Many chemical and biological processes in the aquatic environment can be monitored through field measurements of parameters discussed in the preceding paragraphs (temperature, dissolved oxygen, pH, specific conductance, and transparency. Field measurements also provide complementary information necessary in evaluating chemical and biological data. For instance, to relate chemical concentrations and flow, instantaneous flow measurements are made at about half the stream sites (361 of 640 in 2000) concurrently with the collection of water samples. In some cases, stream flow is obtained at the time of sampling from a USGS gage if one is located nearby.

Numeric water quality criteria for nutrients and chlorophyll *a* in water have not been developed by the TNRCC, but their involvement in aquatic plant growth and proliferation warrants their consideration when assessing water quality. Chlorophyll *a* is the primary photosynthetic pigment and is present in all algae. The chlorophyll *a* concentration is used as an estimate of algal biomass (amount of algae). Nutrients are essential building blocks for healthy aquatic communities, but excess nutrients (especially nitrogen and phosphorus compounds) may overstimulate the growth of aquatic weeds and algae. Excessive growth of these plants can clog waterways and interfere with swimming and boating, out-compete native submerged aquatic vegetation, and, with excessive decomposition, lead to oxygen depletion. Oxygen concentrations often fluctuate widely, increasing during the day as algae conduct photosynthesis (produces oxygen), and falling at night as algae continue to respire, which consumes oxygen. In addition, elevated ammonia concentrations are toxic to aquatic life, deplete dissolved oxygen resources through bacterial nitrification, and are frequently indicators of recent sewage pollution. Beneficial bacteria also consume oxygen as they decompose the abundant food source liberated from dying algae cells.

Fertilizers used on crops and lawns, detergents, organic materials in treated sewage, and manure in agricultural runoff are some sources of nutrients and are often responsible for water quality degradation. Rural areas are susceptible to groundwater contamination from nitrates found in fertilizer and manure. Nutrients are difficult to control because they typically recycle among the water column, algae, and bottom sediments. For example, algae may greatly reduce phosphorus from the water column temporarily, but the nutrient will return to the water column when the algae die and are decomposed by bacteria. Because of this assimilative process, nutrients that are gradually added to a water body tend to accumulate over time, rather than leaving the system.

Some waterborne bacteria, viruses, and protozoa cause human illnesses that range from typhoid and dysentery to minor respiratory and skin diseases. These organisms enter water bodies from many routes, including inadequately treated sewage, stormwater drains, septic systems, and runoff from livestock holding areas. Due to the difficulty in culturing specific pathogens, the TNRCC, CRP, and TDH monitor fecal coliform bacteria as an indicator 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. These bacteria are found in great numbers in the stomachs and intestines of warm-blooded animals and humans. The presence of the indicator bacteria suggests that the water body may be contaminated with inadequately treated sewage or nonpoint source wastes and that other, more pathogenic, organisms may be present. Water samples for fecal coliform analysis may be filtered and incubated in the field with the aid of portable equipment, or returned to laboratories for setup.

Toxic Substances in Water, Sediment, and Fish Tissue

A large number of organic substances in water, sediment, and fish tissue are monitored at selected fixed stations. Included are 45 pesticides, and 32 volatile (water only) and 63 semivolatile organic substances (Tables 4 and 5). Also monitored at selected sites are 13 metals in water, 13 in sediment, and seven in fish tissue (Table 6). Additional conventional parameters are monitored in sediment each time a sample is collected to allow assessment of potential toxicity due to metals and organic substances concentrations (Table 6). The focus of toxic substances monitoring is on those sites likely to be contaminated. Sample stations are carefully selected based on criteria that 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 that exhibit biological impairment.

Toxic organic substances are synthetic compounds that contain carbon, such as PCBs, dioxins, and DDT. Pesticides are organic chemicals that are applied to control or eliminate insect, fungal, or other organisms that may seriously reduce the yields of crops or impact the health of livestock. Herbicides are organic chemicals that are applied to control unwanted weeds from crops and lawns or aquatic plants and algae in water bodies. Some synthesized compounds often persist and accumulate in the environment because they do not readily break down. When pesticides and herbicides run off the land and enter water bodies, they may become toxic to aquatic life, build up concentrations in sediments, or bioaccumulate in food chains. Some of these compounds may cause cancer and birth defects in people and other predators near the top of the food chain, such as birds and fish.

Metals occur naturally in the environment, but human activities (such as industrial processes and mining) may cause them to enter water bodies through direct discharges, spills, or storm water runoff. Metals contamination is often detected in bottom sediment or in fish tissues, even when not detected in the water column. Metals are attracted to soil particles rather than to water, and they accumulate in greater concentrations in predators near the top of the food chain.

Bottom sediments consist of mineral particles, organic material, and water. Sediment deposits form primarily from the settling of material from the overlying water. Mineral particles include rock fragments and mineral grains that result from natural erosion of terrestrial materials. Mineral components in water body sediments are composed primarily of clay, silt, sand, and gravel. Organic matter from decaying or dead aquatic plants and animals usually comprises a small volume of the sediment. Sorption and bioavailability of many organic contaminants is largely controlled by the organic nature of the sediment. The spaces between sediment particles are occupied by interstitial water.

Table 4. Routine Pesticides and Semivolatile Organic Substances in Water, Sediment, and Tissue

Pesticides and Semivolatile Organic Substances in Water (μg/L); Sediment (μg/kg dry weight) and Tissue (mg/kg wet weight)		
Semivolatiles		
Phenol	Isophorone	Fluoranthene
2-Chlorophenol	Bis(2-chloroethoxy)methane	Pyrene
2-Nitrophenol	1,2,4-Trichorobenzene	Benzidine
2,4-Dichlorophenol	Naphthalene	Butyl benzyl phthalate
3-Methyl-4-chlorophenol	Hexachlorobutadiene	Chrysene
2,4,5-Trichlorophenol	Hexachlorocyclopentadiene	Benzo(a)anthracene
2,4,6-Trichlorophenol	2-Chloronaphthalene	3,3'-Dichlorobenzidine
2,4-Dimethylphenol	Acenaphthylene	Bis(2-ethylhexyl) phthalate
2,4-Dinitrophenol	Dimethyl phthalate	Di-n-octyl phthalate
4-Nitrophenol	2,6-Dinitrotoluene	Benzo(b)fluoranthene
4,6-Dinitro-o-cresol (DNOC)	Acenaphthene	Benzo(k)fluoranthene
Pentachlorophenol (PCP)	2,4-Dinitrotoluene	Benzo(a)pyrene
N-Nitrosodimethylamine	Fluorene	Indeno(1,2,3-cd)pyrene
Bis(2-chloroethyl) ether	4-Chlorophenyl phenyl ether	Dibenz(a,h)anthracene
1,3-Dichlorobenzene	Diethyl phthalate	Benzo(ghi)perylene
1,4-Dichlorobenzene	N-Nitrosodiphenylamine	Cresols, total
1,2-Dichlorobenzene	1,2-Diphenylhydrazine	Hexachlorophene
Bis(2-Chloroisopropyl) ether	4-Bromophenyl phenyl ether	N-nitrosodiethylamine
Hexachloroethane	Phenanthrene	N-nitrosodi-n-butylamine
N-Nitrosodi-n-propylamine	Anthracene	Pyridine
Nitrobenzene	Di-n-butyl phthalate	1,2,4,5-Tetrachlorobenzene
Pesticides		
DDT, total	Atrazine	Chloropyrifos (dursban)
DDD, total	Cyanazine	Endosulfan I and II
DDE, total	Alpha BHC	Endosulfan sulfate
Aldrin	Beta BHC	Demeton
Dieldrin	Delta BHC	Guthion
Endrin	Dicofol (kelthane)	Carbaryl (sevin)
Chlordane, total	Mirex	% Lipids (tissue only)
Alachlor	Pentachlorobenzene	PCB-1242
Heptachlor	Malathion	PCB-1254
Heptachlor epoxide	Parathion	PCB-1221
Methoxychlor	Diazinon	PCB-1232
Metolachlor	2,4-D	PCB-1248
Lindane (gamma BHC)	2,4,5-T	PCB-1260
Toxaphene	2,4,5-TP (silvex)	PCB-1016
Hexachlorobenzene	Diuron (karmex)	PCBs, total
Simazine		

Table 5. Routine Volatile Organic Substances in Water

Volatile Organic Substances in Water (μg/L)		
Volatile Organics		
Chloromethane	Carbon tetrachloride	Bromoform
Bromomethane	Bromodichloromethane	Toluene
Vinyl chloride	Benzene	Ethylbenzene
Chloroethane	Chlorodibromomethane	1,1,2,2-Tetrachloroethane
Acrylonitrile	1,1,1-Trichloroethane	Tetrachloroethylene
Chloroform	1,2-Dichloropropane	Chlorobenzene
Methylene chloride	trans-1,3-Dichloropropene	Total xylenes
1,1-Dichloroethylene	cis-1,3-Dichloropropene	Bis(chloromethyl) ether
1,1-Dichloroethane	1,1,2-Trichloroethane	1,2-Dibromoethane
1,2-trans-Dichloroethene	2-Chloroethyl vinyl Ether	Methyl tert-butyl ether (MTBE)

Table 6. Routine Metals in Water, Sediment, and Tissue

Water (μg/L)	Sediment (mg/kg)	Tissue (mg/kg)
Aluminum	Aluminum	Arsenic
Arsenic	Arsenic	Cadmium
Cadmium	Barium	Chromium
Chromium	Cadmium	Copper
Copper	Chromium	Lead
Lead	Copper	Mercury
Mercury	Lead	Selenium
Mercury (total)	Manganese	
Nickel	Mercury	
Selenium	Nickel	
Selenium (total)	Selenium	
Silver	Silver	
Zinc	Zinc	
Additional Parameters Analyzed with Each Water, Sediment or Tissue Sample		
Hardness (mg/L)	Oil and Grease or Total Petroleum Hydrocarbons	% Lipids
Total Suspended Solids (mg/L)	Percent Solids (by weight)	
	Total Organic Carbon	
	Acid Volatile Sulfide	
	Sediment Particle Size	
	Clay < 0.0039 mm	
	Silt 0.0039-0.0625 mm	
	Sand > 0.0625-2mm	
	Gravel > 2 mm	

Collecting a sediment sample with an Ekman dredge

Movement of materials into and out of sediments is controlled by physical, chemical, and biological processes. The porosity (volume of spaces between particles) and permeability (ability of water to move between, into, and out of spaces) of sediment are physical factors that largely control movement of materials. Gravels and sands are the most permeable; clays are the least permeable. The coarse fractions (≥ sand) are generally noncohesive and not associated with metals or organic substances contamination. The fine fractions (silts and clays) are composed of particles with a relatively large surface-to-volume ratio and surface electric charges that cause them to be more chemically and biologically reactive than coarser materials. These physical properties increase the likelihood of sorption and desorption of contaminants. Consequently, chemical accumulations are most often associated with fine sediment. In general, sediment-sorbed contaminants are more persistent, less mobile, and occur at higher concentrations than those in the overlying water.

Toxic substances in water, sediment, and fish tissue are monitored to determine their prevalence and magnitude, to detect and describe spatial and temporal changes, and to evaluate compliance with applicable water quality standards. Water quality criteria to protect aquatic life and human health have been established by the TNRCC for some metals and organic substances. During 2000, fixed station monitoring was conducted at 382 stations for metals in water and at 99 stations for organic substances in water (Figure 10).

Although sediment criteria do not presently exist, sediments accumulate many toxic chemicals. The results of monitoring sediment chemistry may be used to evaluate the condition of the benthic habitat, determine point and nonpoint source contaminants, and to monitor rates of recovery following establishment of pollution controls or improved wastewater

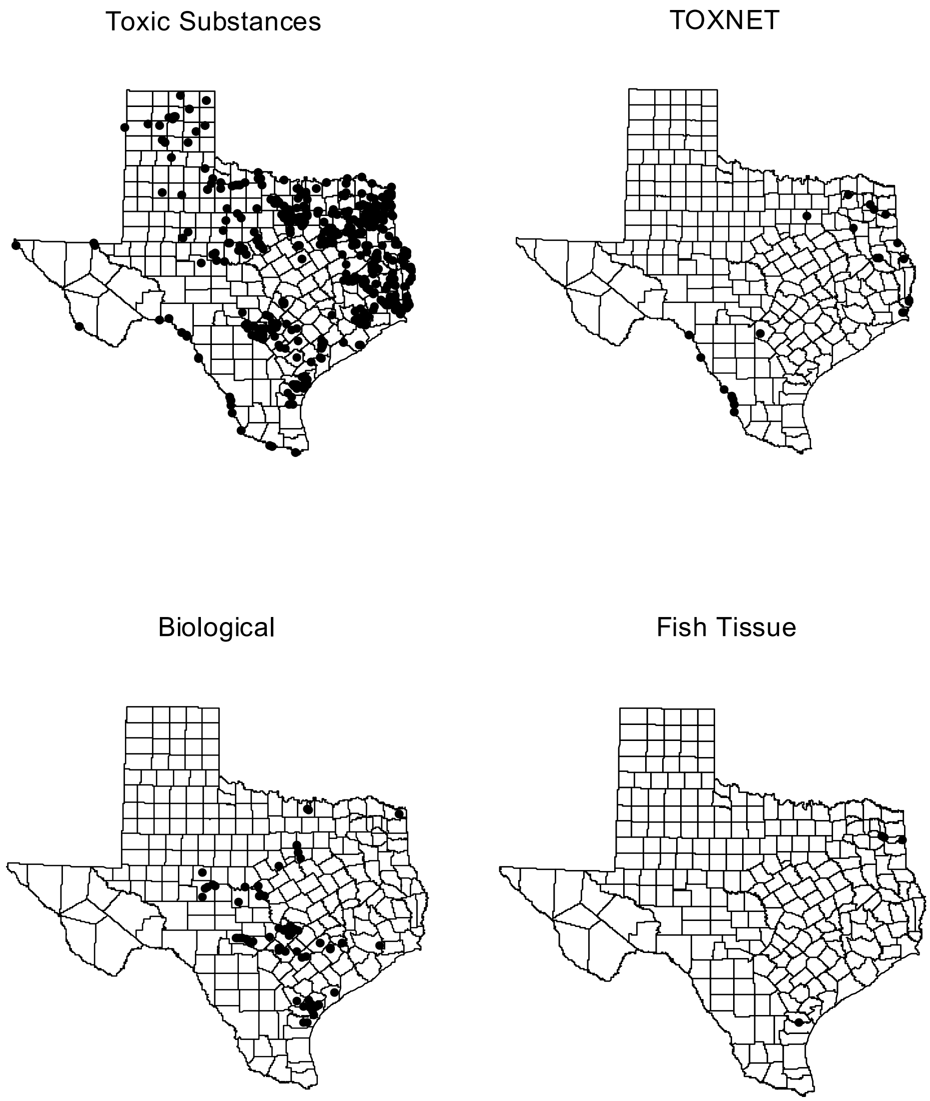


Figure 10. Maps of Sites for Different Kinds of Monitoring

treatment. Conventional parameters in sediment are also measured: percent solids, for determination of water content; oil and grease or total petroleum hydrocarbons, for petrochemical influences; sediment grain size, for availability of contaminants; total organic carbon, for bioavailability of contaminants that adsorb to organic particulates; and acid volatile sulfide, for bioavailability and potential toxicity of metal contaminants. During 2000, metals in sediment and organic substances in sediment were monitored at 261 and 33 SWQM program fixed stations, respectively (Figure 10).

Ambient Toxicity Monitoring

The ambient water and sediment toxicity testing program (TOXNET) was established in 1990 by EPA Region 6 in cooperation with the TNRCC. The TOXNET program encourages the use of ambient toxicity testing for water quality assessment, to assess potential toxicity in water bodies, and to evaluate the effectiveness of implemented toxicity control measures. Water bodies that have shown recurrent toxicity are candidates for more intensive special study assessments to confirm the occurrence of toxic conditions or aquatic life use impairment, and determine causes and sources of the toxicity.

During the current year (2000), 25 sites are being monitored for water and/or sediment toxicity (Figure 10). Ambient water and sediment samples are collected by TNRCC Regional Office SWQM program personnel and are shipped to the EPA Region 6 Laboratory in Houston. Analyses of the samples include routine water quality parameters and standardized, short-term chronic bioassays. Sediment toxicity tests are performed on elutriates. Organisms used in the tests include *Ceriodaphnia dubia* (water flea) and *Pimephales promelas* (fathead minnow) in freshwater and *Cyprinodon variegatus* (sheepshead minnow) in estuarine or saline waters. Results of the water and sediment toxicity tests are sent to TNRCC's SWQM Team, the appropriate TNRCC regional offices, and EPA Region 6. The ambient water and sediment toxicity test results are currently stored on a database maintained by EPA Region 6. The data are available through the Internet (http://www.epa.gov/earth1r6/6wq/ecopro/watershd/monitrng/toxnet/index.htm).

Biological Monitoring

The SWQM program uses biological monitoring (fish and macrobenthos) and habitat evaluations to provide integrated evaluations of water quality. Biological communities are useful in assessing water quality for a variety of reasons, including their sensitivities to low-level disturbances and their function as continuous monitors. Monitoring of resident biota 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 be detected through biological monitoring.

Collecting benthic macroinvertebrates with a Surber net

The objectives of monitoring fish and macrobenthic communities and habitat evaluations are to detect and describe spatial and temporal changes in their structure and function. 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. Detailed procedures followed by the TNRCC and CRP for biological sampling and habitat evaluations are described in *Receiving Water Assessment Procedures Manual* (TNRCC, 1999).

Macroinvertebrate communities are particularly good indicators of water quality impacts or physical habitat alterations because they are relatively sedentary, which enables the detection of localized disturbances. Their relatively long life histories and their continuous recruitment allow for integration of pollution effects.

The SWQM program uses standard procedures modeled after the rapid bioassessment (RBA) protocols developed by EPA for freshwater macroinvertebrate monitoring. Most samples are collected from riffle and other available habitats with a standard kick-net procedure. A subsample is obtained during field sorting of the samples. Organisms are typically identified to the family level in the field. Samples may be preserved and returned to the laboratory for more intensive enumeration and identification. In some cases, a quantitative technique employing a Surber net is used. In this case, several samples from a riffle area are composited and the entire sample is preserved and returned to the laboratory for identification and enumeration. At deep freshwater and estuarine sites, quantitative samples are collected with dredges. The integrity of macrobenthic communities is evaluated using metrics developed for either qualitative (5-minute kicknet and RBA snags) and quantitative (Surber and quantitative snags) sampling. During the current year (2000), macrobenthic community monitoring is conducted at 62 SWQM program fixed stations (Figure 10).

Fish communities are also useful as water quality indicators because many are high on the food chain and therefore reflect the responses of the entire trophic structure to environmental stress. Because fish are mobile, they have the potential to integrate impacts from a variety of habitats. Due to their longevity, fish also add a temporal perspective to monitoring.

Fish are typically collected by the SWQM program using a combination of seines and electrofishers (backpack or boat-mounted). In areas where electrofishing is not practical due to site constraints, elevated specific conductance, or equipment availability, gill nets and trawls may be used in combination with seines. Collections are made over a set time period, and the catch is typically identified and enumerated in the field. A portion of the catch is examined for abnormalities. These data are used to evaluate the integrity of the fish community based on the Index of Biotic Integrity (IBI). During the current year (2000), fish community monitoring is included at 16 SWQM program fixed stations (Figure 10).

Habitat includes all factors that define the stream environment and its relation to aquatic organisms. Evaluations are made to assess the condition of habitat where biological samples are collected. Changes in habitat complexity affect the structure and function of the communities. Habitat evaluations are also used to make accurate comparisons between ambient and reference conditions and to determine whether habitat might be a cause of impaired biological communities. An evaluation of habitat quality is critical to any assessment of ecological integrity.

Physical habitat (for example, instream cover, depth, width, pool depth) is characterized to describe environmental settings at sites selected for biological sampling. Physical characterization parameters include estimates of general land use and physical stream and bank characteristics. The evaluation typically begins in the stream channel and proceeds to evaluation of the stream banks, and finally the riparian zone. The habitat parameters are evaluated at transects along the stream. The transect scores are summarized and evaluated through use of a habitat quality index. The total habitat score is then used to project an evaluation of aquatic life use based on habitat alone.

Fish Tissue Monitoring

Toxic chemical contaminants may be assimilated through aquatic food chains and subsequently bioaccumulated in fish tissues. The SWQM program uses fish tissue monitoring to provide indications of areas experiencing water quality and sediment contamination, and to detect and evaluate levels of contaminants in fish that may be harmful to humans. Information concerning elevated toxic chemical contaminants in fish tissue is communicated by the TNRCC to the TDH. If the TDH concludes, based on additional sampling of edible tissues, that consumption of chemically-contaminated fish poses an unacceptable human health risk, they may issue fish consumption advisories or aquatic life closures for specific water bodies. The advisories may apply to the general population and/or a subpopulation that could be at potentially greater risk pregnant women or children, for example). Aquatic life closures apply to everyone. They may prohibit the taking of all species of aquatic life, or may specify certain species.

Fish are collected using the gear described in the biological monitoring section, above. Whole fish are typically submitted for tissue analysis. Three to five fish of the same approximate size from a target freshwater or estuarine species are collected at each site and composited to constitute a sample. In special cases where human health is an important factor, fillets from individual targeted fish species or composited fillets may be submitted for laboratory analysis of contaminants. During the current year (2000), fish tissue monitoring is being conducted at 4 SWQM program fixed stations (Figure 10).

Electrofishing in the Rio Grande

Special Studies

Special studies provide the SWQM program with an opportunity to evaluate sources, distribution, and fate of particular constituents in selected water bodies. In some instances, special studies are conducted over the entire length of one or more segments. Special studies are conducted by the TNRCC's SWQM Team in the central office, by SWQM program personnel in the 16 regional offices, and by CRP contractors. Special studies are flexible, and use combinations of water, sediment, tissue, and biological data to assess water bodies with known or suspected problems. The TNRCC uses special study monitoring for a variety of purposes to:

- assess toxicity in surface waters;
- assess impacts of point and nonpoint source discharges;
- develop water quality controls and water quality criteria;
- assess improvement in water quality after enforcement action or implementation of water quality controls;
- develop new, or revise existing, sampling and assessment procedures;
- describe impacts of habitat modifications on water quality;
- describe water quality in intermittent streams, in isolated pools of intermittent streams, and in unclassified, effluent-dominated streams;
- augment significant complaint or fish kill investigations and enforcement cases;
- define water quality and biological characteristics of streams, reservoirs, estuaries and bays, and wetlands; and
- evaluate areas identified as "hot spots" by historical SWQM data.

Special study monitoring changes substantially from year to year. During the last five years, much of the emphasis of the special studies program has been placed on biological, toxic substances, and point and nonpoint source assessments. SWQM program personnel in the TNRCC regional offices and CRP contractors select the special study monitoring projects they will conduct. All water quality data collected during special studies are stored in the SWQM Database. Thirty-six special studies have been conducted in the last five years (Table 7). Many of the special studies are published by the TNRCC in the Agency Study series.

Intensive Surveys

Intensive surveys are synoptic studies where specific hydraulic and water quality measurements (primarily dissolved oxygen) are made under low-flow conditions over several days. Intensive surveys are used by the SWQM program to evaluate wasteloads, verify stream standards, address existing or potential special water quality problems, and document water quality after controls are implemented. They are usually conducted over several days' duration on a stream, reservoir, or estuary segment.

Intensive surveys are generally conducted during steady state, low-flow conditions when the influence of point source discharges on water quality are most apparent. Segments that are selected for intensive survey monitoring generally include those with recurrent water quality standards violations, those:

- where new or amended major wastewater permits are scheduled, where substantial improvements in wastewater treatment have been implemented,
- that are affected by toxic substances,
- that are affected by nonpoint sources, and
- where a waste load evaluation or a total maximum daily load has not been developed or an existing one needs revision.

Field physicochemical, water chemistry, hydraulic, toxic substances, and biological data may be collected, depending on the scope of the project. Field measurements are collected at selected instream stations, on significant tributaries, and at major wastewater treatment plants over one 24-hour period to measure temporal fluctuations in water quality. Water samples are collected, and typically composited, to characterize average water quality conditions. Hydraulic measurements are made to determine the amount of water flowing in the water body and the amounts contributed from tributaries and wastewater discharges. Stream velocity is determined by dye studies, and representative stream widths are measured and averaged. Biological data (benthic macroinvertebrates and/or fish) are occasionally collected to complement the physicochemical data and aid in determining water quality impacts on aquatic life in the water body. Although not done routinely, samples may also be collected for ambient water and sediment toxicity evaluations and toxic substances analyses in water, sediment, and fish tissue. Water quality data collected during most intensive surveys are stored in the SWQM database. Twelve intensive surveys have been conducted during the past five fiscal years (Table 8). The number of intensive surveys has declined in recent years because water quality problems related to point sources have diminished. Results of the surveys are published by the TNRCC in the Agency Study series.

Table 7. Special Studies Conducted by TNRCC and CRP during Fiscal Years 1995-2000

Fiscal Year	Segment Number	TNRCC Region/CRP Contractor	Study Description
1995	0400/0500	5	A Survey of Mercury Concentrations within the Sabine and Cypress Creek Basins
	1412	7	Study of Wetland Flora and Associated Environmental Conditions in Monahans Draw
	2310	7	Influence of Independence Creek Inflow to the Pecos River
	2310/11	7	An Evaluation of Benthic Macroinvertebrate Communities and Water Quality in the Pecos River
	1242	9	Metals Contamination of Little Sandy Creek
	1005-07	12	Macroinvertebrate Communities in the Houston Ship Channel
	1101/02	12	Water Quality Impacts on Clear Creek from Sub-Surface Release of Volatile Compounds from the Brio Superfund Site
	2431	12	Contaminant Survey of Moses Bayou
	2309	13	Water Quality Evaluation of the Devils River
	2482	14	Trace Metal Distributions in Nueces Bay Sediments
	1105-08	SWQMT	Nekton Community Surveys of Chocolate and Bastrop Bayous
	----	SWQMT	Development of An Invertebrate Community Index for Texas Streams
	1005-07	SWQMT	Heavy Metals Evaluation of the Houston Ship Channel
	----	SWQMT	Analysis of Rapid Assessment Bioassessment Data Collected in Affected and Minimally Affected Texas Streams
	2302-14	SWQMT	Rio Grande Toxic Substances Study--Phase II
	----	SWQMT	Evaluation of Contaminated Sediments
1996	0400	5	Evaluation of Aquatic Life Use in the Cypress Creek Basin
	----	12	Comparison of Unattended D.O. Monitoring Methods
	2305	13	The Effects of Tributary Inflow on Water Quality in International Amistad Reservoir
	2313	13	Water Quality and Biological Evaluation of San Felipe Creek
	2421/39	12	Fish Kills Caused by Low D.O. in Galveston Bay
1997	0200/0800	SWQMT	Mercury Bioaccumulation Study
	1005-07	SWQMT	Metals in Water Study of the Houston Ship Channel
	1200/1400	SWQMT	Brazos/Colorado Nonpoint Source Study
	2202	SWQMT	Donna Reservoir Fish Tissue Study

Table 7. Special Studies Conducted by TNRCC and CRP (continued)

Fiscal Year	**Segment Number**	**TNRCC Region/CRP Contractor**	**Study Description**
	2304/06	SWQMT	Rio Grande Habitat Quality Study
	2421/39	12	Evaluation of Galveston Bay Sediment Quality
1998	1414	SWQMT	Pedernales River Dissolved Oxygen Study
	0404	SWQMT	Cypress Creek Basin Poultry Study
1999	Statewide	SWQMT	Statewide Metals in Water Study
	0400/1800	CRP	Poultry Operations Water Quality Impact Study
	0401	CRP	Caddo Lake Contaminants Study Associated with Longhorn Army Ammunition Plant
	1002/10	SWQMT	Metals in Water Study of Lakes Conroe and Houston
	1501/02	CRP-LCRA	Tres Palacios Bacteria Study
	1006	12	Effects of a High Conductivity Discharge on Water Quality of Sims Bayou
	2302-14	SWQMT	Rio Grande Toxic Substances Study

SWQMT - SWQM Team

Table 8. Intensive Surveys Conducted by the TNRCC during Fiscal Years 1995-2000

Fiscal Year	Segment Number	Water Body	Survey Date
1995	0604	One Eye/Box Creeks	June 1995
	1016	Greens Bayou	June 1995
	1201	Brazos River Tidal	August 1995
	2107	Atascosa River	October 1994
	2485	Oso Bay/Oso Creek	July 1995
1996		No Surveys Conducted	
1997	0500	Rabbit Creek	September 1996
	2101	Nueces River Tidal	September 1996
	2492	San Fernando River	May 1997
1998	1105/07	Chocolate/Bastrop Bayous	September 1997
	1113	Armand Bayou Hydraulic Study	March 1998
1999	0303	Rock Creek	October 1998

SWQM Database

TNRCC SWQM data are stored on an Ingres database as one component of the agency's integrated database system (TRACS). The SWQM database contains SWQM data collected by the TNRCC, CRP, and other agencies such as the USGS, the International Boundary and Water Commission, the TDH, Texas Watch, and city governments.

TNRCC regional office SWQM program personnel enter field data on an interactive screen that checks for errors and updates data into TRACS. TNRCC laboratory data and data from other agencies are reviewed by SWQM Team staff and screened by a program that flags records with invalid station numbers, dates, depths, and so on, and warns of test results that are outside of reasonable ranges. These data are reported on preprinted forms or on computer diskettes that contain specially formatted ASCII files. Details of the SWQM program data management procedures are described in detail in the *SWQM Data Management Reference Guide* (TNRCC, 1995). If questions arise, SWQM Team staff contact the data collector or the laboratory to resolve them.

As of June 2000, the SWQM database contained 3.2 million test results for 312,000 samples collected between 1967 and 2000, representing 4,187 stations sampled by 32 entities. With the addition of CRP data, USGS stream and reservoir data, and TDH fecal coliform data, the database is expected to grow rapidly. The SWQM data are available on request to other agencies, institutions, consultants, local governments, and the public in paper report formats as well as ASCII files formatted for loading into spreadsheets or databases. SWQM data may be obtained by phoning the TNRCC's data line (512/239-DATA). A station inventory (describes all current and historical monitoring sites) and parameter code inventory (codes used to describe parameters entered into the database) are available at the TNRCC Web site (http://www.tnrcc.state.tx.us/water/quality/data/wqm). A project is underway by the TNRCC to make water quality data available at the same site in the near future (2001).

SWQM Program Training

Each year, personnel from the TNRCC regional offices, CRP, and others that are involved in SWQM activities participate in a three-to-four day workshop to review administrative requirements and learn new procedures relevant to the monitoring program. Additional training workshops are conducted several times a year for TNRCC and CRP personnel to improve their skills in biological assessment and in data reporting and analysis. A SWQM program quality-assurance site visit is conducted each fiscal year in regional offices that have SWQM responsibilities. The purpose of the site visit is to ensure that TNRCC regional office SWQM program personnel are using acceptable procedures and that these are consistent with those used by other regions.

Training monitoring staff on macrobenthos sampling techniques

The quality-assurance site visits to TNRCC regional offices are conducted each year by personnel from the SWQM Team, and include any special training in field procedures and data management that the region personnel may need. Similar quality-assurance evaluations of CRP contractors are conducted by TNRCC quality assurance personnel within the Compliance Support Division. Records of site visits and memos describing performance by TNRCC region personnel and training activities are reported to TNRCC and EPA Region 6 management.

SWQM Water Quality Monitoring Procedures Manual

The *Water Quality Monitoring Procedures Manual* (TNRCC, GI-252, 1999) provides a single source of information describing procedures used by SWQM program personnel in the collection and reporting of surface water quality data. This manual has the purpose of promoting consistent methods statewide and is available to other government agencies, universities, and citizens engaged in water quality monitoring. Procedures include: instrument calibration and maintenance; in-situ field parameter and flow measurement; water, sediment, and fish tissue sample collection and preservation; bacteriological methods; biological sample collection; and data management. The manual also documents the quality assurance procedures used to demonstrate that surface water quality data collected by

TNRCC personnel are of known and adequate quality. The manual is available on the Internet (http://www.tnrcc.state.tx.us/water/quality/wqm/).

SWQM Supplementary Information Manual

The *Supplementary Information Manual* (TNRCC, 1999) annually consolidates, in one place, information about the SWQM Program and closely allied water quality management programs. The manual includes station and parameter code inventories. The current year's coordinated monitoring and special study schedules are also provided in the manual. Statewide and basin percentiles for water quality parameters by water body type are updated each year. Ambient water and sediment toxicity test results, dischargers with recurring effluent toxicity, fish kills, fish consumption advisories and aquatic life closures, and published studies are sections which are also updated at least annually. The manual is primarily distributed to TNRCC regional offices and CRP contractors. The TNRCC plans to make the manual available on its Web site during FY 2001.

Receiving Water Assessments

A receiving water assessment (RWA) is a study conducted on a stream to assess its physical, chemical, and biological characteristics. The studies are done on unclassified streams, primarily to obtain data so that appropriate aquatic life uses can be assigned. When a new or an amended permit application is received, the WQS Team determines if an RWA is necessary before the application is declared administratively complete and before the technical review is done. The WQS Team reviews the quality and quantity of the discharge, information submitted with the application that characterizes the receiving stream, and available information on other dischargers and streams in the area. The WQS Team also consults with the regional staff about stream characteristics. If there are conflicts in this information or the area appears to have a use different from that presumed in the TSWQS, an RWA will be requested.

RWAs can also be requested by the WQS Team for renewal applications if subsequent information implies that the presumed and attainable uses of an unclassified stream are different. The request for a RWA is forwarded to the Field Operations Division, which sends the request to the appropriate TNRCC regional office. The regional staff visits the facility and characterizes the receiving stream upstream or downstream of existing or proposed outfalls.

The regional staff verify stream data contained in the permit application or determine the physical characteristics of the stream. Data on stream physical characteristics include: (1) stream morphology, such as numbers of bends and substrate types; (2) information on the riparian zone, such as types of vegetation, bank slope, and percentage of erosion on banks; (3) flow characteristics, such as velocity and evidence of flow fluctuations; and (4) instream cover, such as logs and undercut banks. These physical characteristics are used to develop a habitat quality index for the stream. Habitat characteristics have been shown to be important factors affecting the structure and functionality of the aquatic communities.

Water quality parameters such as dissolved oxygen, pH, and temperature are measured in the field. A water sample may also be collected and sent to a laboratory to determine the concentrations of common constituents such as nutrients and dissolved salts. Biological characteristics are determined by sampling the fish and/or macroinvertebrate communities. Fish are collected by seining and/or electrofishing. Aquatic macroinvertebrates are collected by a variety of methods, including Surber samplers, kick nets, and/or artificial substrates. The numbers and kinds of fish and macroinvertebrates are determined. An index of biotic integrity is calculated to characterize the fish community. The numbers and types of macroinvertebrates collected are either compared to an appropriate reference site in the area or used in the calculation of indices to characterize the community. Other indices such as species diversity and species richness may also be used to characterize the biological community.

Information on the physical, chemical, and biological characteristics of the stream are reported to the WQS Team. The WQS Team reviews the RWA, checks or calculates all indices, and, using all the information in the RWA, determines the aquatic life use for the receiving stream. The information collected in a RWA can later be used in a Use Attainability Analysis (UAA) to support the raising or lowering of a presumed use for an unclassified water body. If the UAA is approved by EPA, the change in aquatic life use for the water body becomes part of the TSWQS in the next triennial review.

Table 9 lists the RWAs that were completed from October 1988 to January 2000, the water bodies that were studied, the segments into which they eventually flow, and the date an aquatic life use was assigned to the receiving water after review of the RWA information. An asterisk (*) next to the water body name indicates that the revised ALU has been incorporated into the TSWQS (Appendix D).

Use Attainability Analysis

A UAA is a scientific assessment of the physical, chemical, biological, and economic characteristics of a water body conducted by the WQS Team of

Table 9. Receiving Water Assessments, October 1988 - December 2000

Segment	First Level Segment Tributary	Use**	Second Level Tributary	Use	Third Level Tributary	Use	Date
0101	Red Deer Creek	N	Coon Hollow Creek	N			02/10/1989
0101	Rock Creek*	L	Unnamed tributary	N			03/08/1989
0201	Diversion Canal (McKinney Bayou)		Barkman Creek		Jones Creek*	I	06/28/1989
0201	Diversion Canal (McKinney Bayou)		Barkman Creek		Jones Creek*	I	01/13/1995
0202	Bois d'Arc Creek	I					12/04/1990
0202	Choctaw Creek		Mill Creek		Corneliason Creek*	L	10/27/1988
0202	Pine Creek	H	Hicks Creek	N			09/11/1992
0204	Salt Creek		Ritchie Creek*	L	Unnamed tributary	N	12/29/1989
0205	Wildhorse Creek	H					12/16/1992
0219	Holliday Creek	H	Unnamed Creek	N			02/10/1995
0301	Natural drainage channel	N					08/28/1990
0302	Big Creek*	I	Unnamed tributary	N	Unnamed tributary	N	01/31/1989
0302	Unnamed tributary	N					11/30/1989
0303	White Oak Creek		Rock Creek	I			12/08/1992
0304	Wagner Creek	I	Unnamed tributary	L	Unnamed ditch	N	12/19/1990
0304	Wagner Creek*	I	Unnamed tributary	N			08/20/1996
0305	Auds Creek		Cottonwood Branch		Unnamed reservoir	L	03/20/1989
0306	Spring Creek		Loring Creek	N	Unnamed tributary	N	11/19/1991
0400	Cross Bayou	H					03/09/1994
400	Cross Bayou (Louisiana)		Unnamed tributary	I			06/26/1992
0401	Central Bayou	H					10/29/1992
0401	Goose Prairie Bayou	H	North Bayou	I			10/29/1992
0404	Dry Creek*	I					09/05/1996

Table 9. Receiving Water Assessments (continued)

Segment	First Level Segment Tributary	Use**	Second Level Tributary	Use	Third Level Tributary	Use	Date
0404	Dry Creek*	H	Sparks Branch*	H			08/18/1997
0404	Ellison Creek Reservoir		Brutons Creek*	I	Unnamed tributary	N	02/16/1990
0404	Hart Creek	L	Unnamed tributary	N			06/07/1989
0404	Tankersley Creek	L					02/16/1990
0404	Tankersley Creek*	H					01/29/1998
0407	Beech Creek	I					06/19/1991
0409	Clear Creek		Bog Creek	N			06/06/1989
0409	Sugar Creek	H					11/02/1992
0409	Walnut Creek	H					01/24/1992
0501	Little Cypress Bayou		East Fork Cypress Bayou		ditch 5D, 5E	N	11/06/1992
0503	Caney Creek*	H					12/30/1996
0503	Dempsey Creek		Unnamed tributary*	I	Unnamed ditch	N	02/26/1990
0504	Flat Fork Creek		Unnamed trib (perennial)	H	Unnamed trib.(int. w/ pools)	L	05/17/1993
0504	Tenaha Creek		Praire Creek		Cedar Creek	I	04/02/1991
0505	Eightmile Creek*	I	Parker Creek	L			04/29/1993
0505	Grace Creek*	I	Unnamed tributary	L			07/02/1991
0505	Hatley Creek	I	Wards Creek	I			10/02/1995
0505	Hawkins Creek*	L					02/18/1989
0505	Mason Creek*	L	Unnamed tributary	N	Open Channel	N	07/20/1990
0505	Potters Creek		East Potters Creek	L	Unnamed ditch	N	09/19/1991
0505	Rabbit Creek*	I	Bighead Creek	I			06/09/1993
0505	Rabbit Creek		Little Rabbit Creek	L	Unnamed tributary	N	10/22/1991

Table 9. Receiving Water Assessments (continued)

Segment	First Level Segment Tributary	Use**	Second Level Tributary	Use	Third Level Tributary	Use	Date
0505	Unnamed tributary*	I					04/07/1989
0506	Harris Creek	H	Wiggins Creek*	H	Unnamed tributary	N	07/23/1999
0506	Mill Creek	I					10/29/1992
0506	Rogers Creek	L					08/24/1990
0506	Sandy Creek*	L					12/05/1988
0506	Unnamed slough	L	Unnamed trib. (Red Creek)	N			11/16/1990
0506	Unnamed slough	I	Red Creek	N			07/31/1996
0506	Unnamed tributary (Nine Mile Creek)*	L	Unnamed tributary	N			01/16/1998
0507	Caddo Creek		West Caddo Creek*	L			08/10/1989
0507	South Fork Sabine River		Sabine Creek	I			04/27/1989
0511	Coon Bayou (Tidal)*	H	Unnamed tributary	L	Drainage ditch	N	05/02/1989
0511	Unnamed trib(West Bunch Gully)*	H					01/24/1991
0601	Meyer Bayou	I	Schoolhouse Ditch	I			04/23/1990
0601	Meyer Bayou		Tiger Creek*	L			04/20/1989
0601	Meyer Bayou		Tiger Creek	I	Caney Creek	I	06/10/1991
0602	Massey Lake Slough		Unnamed trib.(Booger Br.)*	L			10/26/1988
0604	Bean Creek		One-eye Creek	I			06/12/1995
0604	Caney Creek		Dabbs Creek*	H	Unnamed tributary	H	06/25/1992
0604	Larrison Creek*	L	Alto Branch*	L			12/06/1988
0604	Piney Creek		Bear Creek	H	Dry Creek	H	06/27/1991
0604	Wells Creek	H					10/16/1992
0605	Saline Creek	I					08/16/1990

Table 9. Receiving Water Assessments (continued)

Segment	First Level Segment Tributary	Use**	Second Level Tributary	Use	Third Level Tributary	Use	Date
0606	Prairie Creek		Black Fork Creek*	L			06/15/1990
0607	Boggy Creek*	H	man made/natural ditch	N			01/30/1998
0607	Willow Creek		Batiste Creek	I	School House Ditch	N	04/02/1991
0608	Cypress Creek*	H	Unnamed tributary	N			10/27/1995
0608	Mill Creek	L	Unnamed trib. (Icehouse Br.)	N			12/20/1990
0608	Turkey Creek*	H					11/22/1994
0608	Turkey Creek		Big Cypress Creek		Magnus Br.(and Barclay Lk.)	H	11/07/1990
0608	Turkey Creek	H	Doucette Branch	N			12/15/1989
0610	Anderson Creek		Unnamed tributary	I	Unnamed ditch	N	07/18/1990
0610	Ayish Bayou*	I					08/20/1996
0610	Papermill Creek		Mill Creek*	H	Unnamed tributary*	L	04/04/1989
0610	Pomponaugh Creek		Little Sandy Creek*	I			10/13/1989
0611	Bayou LaNana*	I					07/27/1990
0611	Mud Creek		Keys Creek	L	Ragsdale Creek	L	09/21/1990
0611	Mud Creek		Kickapoo Creek	N	Unnamed tributary	N	08/23/1989
0611	Mud Creek		West Mud Creek	L			11/19/1991
0611	Mud Creek		Blackhawk Creek*	I			08/01/1996
0611	Mud Creek		West Mud Creek*	L			08/01/1996
0611	Mud Creek*	H	Keys Creek*	H	Ragsdale Creek*	I	08/01/1996
0611	Shawnee Creek	I	Bromley Creek	H			11/18/1997
0611	Striker Creek and Lake Striker		Johnson Creek		Unnamed tributary*	L	07/10/1989
0611	Striker Ck,L.Striker,Bowles Ck		Mill Creek	H	Hampton Creek	L	08/11/1993

Table 9. Receiving Water Assessments (continued)

Segment	First Level Segment Tributary	Use**	Second Level Tributary	Use	Third Level Tributary	Use	Date
0611	Striker Ck,L.Striker,Bowles Ck		Mill Creek		Hampton Creek	L	11/02/1990
0701	Rodair Gully*	I					05/08/1989
0701	Taylor Bayou		South Fork Taylor Bayou		Mayhaw Bayou	I	12/20/1990
0702	Main Canal D, Canal A, B, C*	I					05/08/1991
0704	Bayou Din	H	Kidd Gully	H			11/20/1992
0802	Long King Creek	H	Choates Creek	H			06/10/1991
0803	Turkey Creek ditch	H	West Turkey Creek	H	Unnamed tributary	N	02/14/1994
0804	Big Brown Creek		Unnamed tributary	N			11/08/1988
0804	Catfish Creek		Coon Creek	H	Unnamed ponds	I	11/02/1994
0804	Cedar Lake		Cedar Lake Slough	H	Clear Lake	N	02/14/1994
0804	Hurricane Bayou	H	Unnamed tributary	L			09/30/1994
0804	Keechi Creek	H	ditch	N			07/29/1994
0804	Rush Creek	H	Unnamed tributary	N			08/03/1992
0804	Town Creek	H	Basset Creek	H			10/20/1999
0804	Wolf Creek	L	Unnamed tributary	-	drainage ditch	-	05/10/1995
0805	Parsons Slough	H	Hickory Creek	N			09/07/1994
0805	Tenmile Creek	H					02/25/1992
0810	Big Sandy Creek		Jones Creek	L	Unnamed tributary	N	08/24/1990
0814	Mill Creek		Elm Branch	N			10/05/1990
0815	Waxahachie Creek	I					10/01/1991
0818	Caney Creek		Reservoir	H	One Mile Creek*	I	07/23/1997
0819	Buffalo Creek (3rd ord)(North)*	L	Unnamed tributary	N			02/09/1989

Table 9. Receiving Water Assessments (continued)

Segment	First Level Segment Tributary	Use**	Second Level Tributary	Use	Third Level Tributary	Use	Date
0819	Duck Creek	I					04/23/1991
0819	South Mesquite Creek	I					10/18/1989
0821	Pilot Grove Creek*	L					06/22/1990
0821	Slayter Creek	I	Unnamed tributary	N			08/03/1990
0823	Little Elm Creek*	I	Unnamed tributary	N			08/09/1989
0823	Pecan Creek	L					10/10/1990
0823	Stewart Creek	N					08/27/1993
0826	Denton Creek		Elizabeth Creek	H	Unnamed tributaries	N	10/26/1990
0826	Denton Creek*	H	Trail Creek*	H			07/19/1989
0826	Denton Creek		Hog Branch	N	Unnamed tributary	N	12/01/1999
0827	White Rock Creek*	I	Floyd Branch				09/11/1997
0828	Village Creek		Deer Creek		Unnamed trib. (2nd order)	L	04/13/1990
0831	South Fork Trinity River		Town Creek	I			05/25/1990
0836	Pin Oak Creek*	I					04/13/1998
0837	Battle Creek	I	Unnamed tributary	N			08/14/1990
0838	Mountain Creek		Grassy Creek	N	Unnamed tributary	N	02/10/1989
0840	Indian Creek		Lake Kiowa		Indian Creek	N	08/16/1990
0840	Jordan Creek		Unnamed tributary		Stock Ponds	L	12/30/1988
0840	Spring Creek	H					03/22/1993
1002	Tarkington Bayou*	H	Unnamed tributary	N			09/19/1999
1004	Crystal Creek	H	West Fork Crystal Creek	I			03/09/1994
1004	Crystal Creek		West Fork Crystal Creek	L	Red Hollow Branch	N	06/29/1990

Table 9. Receiving Water Assessments (continued)

Segment	First Level Segment Tributary	Use**	Second Level Tributary	Use	Third Level Tributary	Use	Date
1004	White Oak Creek		W.Fork White Oak Creek*	H			02/12/1999
1006	Halls Bayou (lower)*	I	Halls Bayou (upper)*	L			12/27/1990
1008	Willow Creek		Cannon Gully		Metzler Creek	L	07/10/1989
1008	Willow Creek	H	Unnamed tributary	N			07/02/1992
1008	Willow Creek		HFCD Ditch M121-00-00	N			04/13/1998
1008	Panther Branch		Lake Woodlands	H	Panther Branch*	L	05/18/1998
1008	Panther Branch*	I					05/18/1998
1009	Dry Creek*	I	Drainage ditch	N			03/10/1997
1009	Little Cypress Creek	I					11/09/1990
1009	Turkey Creek	L	Harris Co. FCD	N	Lateral H Turkey Creek	N	10/01/1996
1012	Atkins Creek		Town Creek*	I			10/01/1996
1014	Buffalo Bayou		Mason Creek*	I			10/27/1992
1014	Buffalo Bayou		Willow Fork Buffalo Bayou*	I			01/03/1990
1014	South Mayde Creek*	L	Bear Creek*	I	Langham Creek*	L	02/15/1995
1016	Garners Bayou*	L	Williams Gully	N			02/25/1991
1016	North Fork Greens Bayou		HCFCD P145-03-00	L	Storm sewer	N	10/01/1996
1017	Vogel Creek*	L					01/24/1994
1102	Cowart Creek*	L	Roadside ditch	N			02/16/1990
1104	Bushway Draw	I					09/04/1991
1107	Corner Bayou		Unnamed tributary	I			08/21/1989
1202	Bessies Creek*		Brookshire Creek	L			04/15/1996
1202	Dry Creek		House Bayou	I	Gapps Slough	I	12/18/1997

Table 9. Receiving Water Assessments (continued)

Segment	First Level Segment Tributary	Use**	Second Level Tributary	Use	Third Level Tributary	Use	Date
1202	Rabbs Bayou*	L					07/17/1992
1203	Steele Creek*	H					06/14/1994
1203	Whitney Creek	N	Unnamed tributary	N			06/22/1990
1205	McCarty Branch*	L					06/12/1989
1209	Carters Creek	I	Burton Creek	L			07/29/1991
1209	Carters Creek		Wolfpen Creek*	L			04/03/1989
1209	Cedar Creek	I					10/07/1993
1209	Peach Creek		Unnamed tributary	L			12/19/1990
1211	Davidson Creek*	I					01/02/1990
1213	Darrs Creek	L					07/15/1991
1213	Donahoe Creek		Indian Creek		Town Branch	N	07/26/1989
1213	Unnamed tributary	N					01/08/1990
1221	Pecan Creek	I					08/25/1993
1221	Pecan Creek*	L					06/18/1998
1222	Station Creek	I					10/25/1999
1224	Lake Olden*	H	Leon River*	H	South Fork Leon River*	H	10/01/1991
1227	Buffalo Creek*	L					04/28/1989
1228	Nolan River		West Nolan Creek	N			02/07/1991
1229	Squaw Creek		Squaw Creek Reservoir	H	Squaw Creek	L	03/14/1990
1230	Palo Pinto Creek	H	Unnamed tributary	N			10/12/1995
1232	Deadman Creek	I	Freewater Creek	N	Unnamed ditch	N	08/10/1992
1232	Hubbard Creek	H	Gonzales Creek	H			03/01/1995

Table 9. Receiving Water Assessments (continued)

Segment	First Level Segment Tributary	Use**	Second Level Tributary	Use	Third Level Tributary	Use	Date
1235	Mule Creek	H	Rice Springs Branch	H			05/03/1993
1238	Duck Creek	L	Spade Draw	N			03/19/1992
1241	NFDMF Brazos River*	L					04/13/1990
1242	Deer Creek	I					03/23/1993
1242	Pond Creek*	L	Salt Creek	N			04/08/1994
1242	Thompson Creek	H	Still Creek	H	Cottonwood Branch	I	05/22/1995
1244	Brushy Creek	I					07/15/1991
1246	Unnamed tributary of South Bosque*	I					11/21/1989
1248	Mankins Branch	H	Unnamed tributary	I			09/14/1990
1254	Hackberry Creek	L					02/21/1991
1304	Linnville Bayou*	L					11/13/1989
1402	Cedar Creek*	H	Cedar Creek Reservoir*	H			11/09/1989
1402	Rabbs Creek		Sandy Creek		Unnamed tributary	N	06/29/1989
1412	Beals Creek*	L	Unnamed tributary	N	Red Draw Reservoir	L	12/13/1988
1412	Big Sulphur Creek		Deep Creek	I			12/04/1990
1412	Big Sulphur Creek		Deep Creek*	I			12/06/1996
1414	Barons Creek*	H					04/24/1989
1414	Town Creek	L					01/10/1989
1415	Comanche Creek*	L					12/22/1988
1415	Dry Draw		Unnamed tributary	N			06/16/1989
1416	Brady Creek*	I					03/24/1995
1416	Unnamed slough	L					06/22/1990

Table 9. Receiving Water Assessments (continued)

Segment	First Level Segment Tributary	Use**	Second Level Tributary	Use	Third Level Tributary	Use	Date
1420	North Prong Pecan Bayou		Kaiser Creek*	L			06/28/1989
1420	Turkey Creek*	H					11/08/1990
1502	Tadpole Creek	N	Roadside ditch	N			10/15/1990
1602	Clarks Creek		Big Brushy Creek	H			11/19/1999
1604	East Mutang Creek*	H	Drainage ditch	N			02/04/1998
1604	Sandy Creek		Middle Sandy Creek		Unnamed tributary	N	04/26/1989
1804	Walnut Branch	H					07/14/1995
1810	Town Creek	H					05/29/1990
1901	Escondido Creek	L	Abandoned Escondido Creek	N			09/30/1993
1902	Martinez Creek	L					11/07/1994
1903	Polecat Creek*	H					08/09/1991
2004	Poesta Creek	L					12/06/1993
2107	Goose Creek	N	Unnamed tributary	N			07/23/1996
2108	Chacon Creek*	I	Fort Ewell Creek*	I			06/30/1992
2117	Cibolo Creek		Unnamed tributary	N			06/08/1990
2202	Drainage ditch*	L					12/11/1996
2202	Unnamed Tributary*	H					11/19/1997
2304	Chacon Creek(Lower)	L	Chacon Creek(Upper)	N	Unnamed tributary	N	01/24/1989
2304	Cienegas Creek*	H					07/10/1989
2304	Espada Creek		Pinto Creek	N			07/23/1990
2304	Las Moras Creek	H					10/22/1993
2426	Goose Creek(tidal)		Goose Creek*	L	West Fork Goose Creek	N	04/11/1989

Table 9. Receiving Water Assessments (continued)

Segment	First Level Segment Tributary	Use**	Second Level Tributary	Use	Third Level Tributary	Use	Date
2437	Hurricane Levee Canal	I					09/24/1990
2441	Live Oak Bayou		Lake Austin and Peyton Creek		Cottonwood Creek	L	01/24/1992
2454	Huisache/Cox Creek Impoundment	H	Unnamed tributary	N			03/12/1992
2456	Carancahua Creek		West Carancahua Creek		Unnamed tributary	N	05/01/1989
2481	Kinney Bayou -tidal	I	Kinney Bayou - above tidal	N	West Fork Kinney Bayou	N	01/26/1989
2491	North Floodway		County Flood Control Syst		Unnamed Drainage Ditch	N	02/16/1989
2492	Cayo Del Grullo		San Fernando Creek		Santa Gertrudis Creek	L	07/20/1992
2492	Laguna De Los Olmos	I	Los Olmos Creek	I			08/11/1989

* Water bodies that have had the aquatic life use incorporated into the TSWQS, Chapter 307, Appendix D

** Letters represent the aquatic life use assigned to the water body:

N - No significant
L - Limited
I - Intermediate
H - High

TNRCC to determine existing and attainable uses of a water body. UAAs are conducted on either a single water body, a segment of a water body, or a group of segments with similar characteristics. They are conducted:

- when the designated uses for a water body do not include those uses specified in Section 101(a) of the federal Clean Water Act, that is, fishable/swimmable goals,
- when subcategories of uses specified in Section 101(a)(2) require less stringent criteria, or
- to affirm that a designated use is appropriate.

The UAA identifies and defines the existing and potential (attainable) uses of a water body and determines if designated uses established in the TSWQS are too stringent or impaired. If there is impairment, the cause and source of that impairment is identified, and it is determined whether the water body can support the designated use in the absence of the pollutant(s) or with improved water treatment. If the use cannot be supported, then the TNRCC can use the UAA to lower the designated use or make the numerical water quality criteria less stringent. Conversely, if designated uses and numerical water quality criteria are found not to be protective of the existing and potential uses, the TNRCC can use the UAA to upgrade the uses and criteria for the selected water body.

Use attainability analyses vary in scope depending on the nature of the water body, the available data, and the specific problem(s) defined. They may include a water body survey and assessment, a waste load allocation, and/or an institutional evaluation. The TNRCC initially conducts a thorough review of historical physical, chemical, hydrological, and biological data from each water body selected for a UAA. Some UAAs are based on existing data, while others may require the collection of additional supporting data.

After a UAA is completed, it is submitted to the EPA for approval, if changes in designated uses or water quality criteria are recommended. If the EPA approves the UAA, it is incorporated into the next triennial review of the TSWQS. Thirty-two UAA reports have been prepared by the TNRCC and approved by the EPA (Table 10).. Three additional UAA reports have been completed by the TNRCC, but final EPA approval has not been received. These reports are:

- Pease River (Segment 0230);
- Angelina River/Sam Rayburn Reservoir (Segment 0615); and
- Nueces River Tidal (Segment 2101).

Table 10. Use Attainability Reports

Segment No.	UA No.	Segment Location	Date of UA
105	32	Rita Blanca Lake	March 1995
225	5	McKinney Bayou	June 1984
303/06/07	19	Sulphur River	Feb. 1987
304	3	Days Creek	Apr. 1984
404	14	Big Cypress Creek	Jan. 1985
406	12	Black Bayou	Aug. 1984
407	6	James' Bayou	June 1984
508	7	Adams Bayou	June 1984
511	25	Cow Bayou	Dec. 1988
601	20	Neches River	Feb. 1987
606	16	Neches River	Jan. 1986
701	15	Taylor Bayou	June 1985
704	22	Hillebrandt Bayou	June 1988
805/41	28	Trinity River	May 1989
1006/07	2	Houston Ship Channel	March 1984
1013/14	23	Buffalo Bayou	Sept. 1988
1104	21	Dickinson Bayou	May 1988
1206	27	Brazos River	Feb. 1989
1218	17	Nolan Creek	Aug. 1986
1226/46/55	29	Bosque River	Aug. 1991
1227	26	Nolan River	Dec. 1988
1244	11	Brushy Creek	July 1984
1245	30	Oyster Creek	Oct. 1991
1417/31/32	1	Pecan Bayou	June 1982
1424	31	South Concho River	Feb. 1994
1427	18	Onion Creek	Oct. 1986
1901/11	8	San Antonio River	June 1984
1902/13	9	Cibolo Creek	June 1984
2201/02	4	Arroyo Colorado	May 1984
2203/04	24	Petronila Creek	Sept. 1988
2308/14	10	Rio Grande River	June 1984
2426	13	Tabbs Bay	Aug. 1984

Border Monitoring

Rio Grande Toxic Substances Study

In February 1992, the United States and Mexico issued the first stage of the Integrated Border Environmental Plan (IBEP, now called Border 21) for the U.S.–Mexico Border area. This plan set up the framework for the two countries to work jointly on solutions to environmental problems along the border. On November 13, 1992, the U.S. and Mexican sections of the IBWC approved Minute No. 289, titled "Observation of the Quality of the Waters Along the United States–Mexico Border." A result of this agreement was the Rio Grande Toxic Substances Study, a binational, multi-agency, multiphase effort to characterize toxic contamination of the Rio Grande and its tributaries.

Through funding from the EPA, the TNRCC was given the responsibility to coordinate and carry out the multiphase investigation jointly with various state, federal, and Mexican agencies. The TNRCC's primary partner in the joint effort is the Comision Nacional del Agua (CNA). The U.S. and Mexican sections of the IBWC act as diplomatic liaisons, providing logistics support and coordinating the participation of the Mexican agencies. The IBWC is also responsible for reviewing, approving, and publishing a final binational report based on draft reports from the TNRCC and CNA.

Field work for Phase 1 of the Rio Grande Toxic Substances Study was done from November 1992 through March 1993. During this intensive monitoring program, 45 sites were sampled under low-flow conditions, including 19 on the main stem and 26 on tributaries (13 in Texas and 13 in Mexico). Monitoring consisted of: (1) toxic chemical and toxicity testing in water and sediment samples at 45 sites; (2) toxic chemicals in fish tissue samples from 24 sites; (3) biosurveys of benthic macroinvertebrate communities at 18 sites; and (4) biosurveys of fish communities at 24 sites. The findings of Phase 1 were published in the September 1994 report titled *Binational Study Regarding the Presence of Toxic Substances in the Rio Grande/Rio Bravo and its Tributaries Along the Boundary Portion Between the United States and Mexico* (EPA, 1994).

Field work for Phase 2 of the Rio Grande Toxic Substances Study was conducted from May 1995 through December 1995. Due to the need to collect samples under low-flow conditions, monitoring from El Paso to Big Bend National Park was delayed three months by high flows in the Rio Grande. Large releases from Elephant Butte Reservoir in New Mexico made the river inaccessible until December. During this second phase of intensive monitoring, samples were collected at 46 stations, including 27 main stem sites and 19 tributary sites. Sites from Phase 1 that showed a low potential for impact were excluded from Phase 2. Sixteen sites were added to Phase 2 in areas not covered in Phase 1. Four of these new sites were located on Falcon and Amistad International Reservoirs. Monitoring consisted of: (1) toxic chemical and toxicity testing in water at 37 sites and sediment at 33 sites; (2) toxic chemicals in fish tissue samples from 24 sites; (3) biosurveys of benthic macroinvertebrate communities at 16 sites; and (4) biosurveys of fish communities at 24 sites. The findings of Phase 2 were published in the two volume September 1997 report titled *Binational Study Regarding the Presence of Toxic Substances in the Rio Grande/Rio Bravo and its Tributaries Along the Boundary Portion Between the United States and Mexico* (EPA 1997).

Field work for the third and final phase of the study was conducted in November 1998 in the area upstream from the El Paso/Ciudad Juárez metropolitan area to the lower end of Big Bend National Park. Phases 1 and 2 identified a high potential risk for toxic substance effects for the reach from El Paso/Ciudad Juárez to Presidio/Ojinaga, and a moderate potential for toxic substance effects at Big Bend National Park–Santa Elena Canyon. This section of the Rio Grande/Rio Bravo was also cited in Mexico's Phase 2 technical report as an area requiring further study due to increasing salinity. El Paso/Ciudad Juárez to Big Bend National Park was chosen for Phase 3 because it was one of the main areas of concern. This reach of the Rio Grande/Río Bravo offers a unique opportunity to assess a variety of factors over these three areas including: habitat alteration, land use, water/sediment quality, flow variations, and biological communities. Since toxic impacts alone can not be cited as the cause for aquatic life deterioration, both point and nonpoint sources of pollution as well as habitat modification must be investigated to be able to accurately describe the water quality and aquatic life conditions in the river. These components can be brought together to identify key stressors on each of these areas. El Paso/Ciudad Juárez and Presidio/Ojinaga both represent sources of stress on the Big Bend National Park area and the protected areas in Chihuahua and Coahuila Mexico, all of which are important and valued natural resources.

The primary goals of this project were to:

- better define problems identified in Phase 1 and Phase 2, with more intensive monitoring at fewer sites;
- use multivariate analytical tools to identify which stressors (habitat, land use, physical/chemical water quality data) contribute to observed differences among sites; and
- determine the stressors that have the greatest effects on aquatic communities and human health.

Collecting fish from the Rio Grande

Rio Grande Biocriteria Development

Although the Rio Grande Toxic Substances Study has provided invaluable information of the overall presence of toxic substances in water and sediment, and their impact on the aquatic communities (fish and macro-invertebrates), it has been recognized that specific aquatic criteria (bio-criteria) would prove useful. This project will serve to develop such indicators or "biocriteria" for two ecoregions along the international reach of the Rio Grande: Southern Desert and South Texas Plains. Upon completion of this project, the TNRCC (at its discretion) may adopt these criteria as part of the agency's water quality criteria. Otherwise, these criteria will serve as another indicator, along with currently adopted numerical water quality criteria and toxicity testing, for detecting impairments to aquatic communities.

Clean Rivers Program

The Clean Rivers Program (CRP) is a unique, water quality monitoring, assessment, and public outreach program that is funded by state fees. The CRP is a collaboration of 15 regional water agencies and the TNRCC, and is authorized by Senate Bill 1190. The CRP provides the opportunity to approach water quality issues within a watershed or river basin at the local and regional level through coordinated efforts among diverse agencies and various programs.

A set of 9 key goals were developed with input from all regional cooperators to outline the focus of the program. Associated with each goal are specific objectives that are implemented throughout Texas' 23 river and coastal basins. These goals and objectives are described in the Long-Term Action Plan, updated for fiscal years 2000-2005 (TNRCC, CTF-02/000.

Implementation of the 9 key goals of the CRP is manifest in the biennial CRP Guidance document developed by TNRCC project management staff with input from the regional water agencies. The Guidance identifies 7 key tasks, each with a number of deliverables designed to accomplish the goals and objectives set out in the Long-Term Action Plan.

Factors Influencing Implementation of the Clean Rivers Program

Each regional water agency implements the CRP Guidance based on the unique circumstances that are present in its basin. There is a minimum expectation set forth in the CRP Guidance, but based on a number of factors, there is a certain amount of individuality in the focus and implementation of the program in each basin.

Funding is based on the number and size of wastewater treatment plants and surface water right permittees that reside within each river basin. Some basins receive a much larger allocation than others, since at least 70 percent of the dollars collected from a river basin are returned to that basin for conducting CRP tasks.

Stakeholder input determines the unique focus of the CRP within a river basin. Each basin holds annual steering committee meetings to discuss current studies and findings, and to receive input on the focus for future tasks. The stakeholder process is extremely important to this program, because it ensures that regional and local priorities are considered.

The geographic size of a river basin can have an impact on how the program is implemented. River basin size varies widely in Texas. The cost to monitor and assess all the streams in a river basin that is almost as wide as Texas is much greater than the cost to monitor one that is the size of four typical Texas counties.

Density of population and industry can also have an impact on the costs associated with implementing the CRP. The greater the density of factors that tend to have an impact on water quality, the greater the density of water quality issues that require attention.

The CRP Monitoring Strategy Supports Four Objectives

Long-term trend analysis is accomplished through "routine" monitoring of the same sites for the same constituents over a five-to-ten-year period of time, or longer.
Identification of water quality issues is accomplished through both routine and "systematic" water quality monitoring. Systematic monitoring consists of sampling at sites selected in areas where routine monitoring is not located (smaller tributaries) for a period of one to two years. Systematic monitoring is used when resources are too limited to enable routine monitoring on every stream in the basin. The available resources are applied to a few watersheds at a time and then moved to another set of watersheds each year (or every two years) so that most streams in the basin are monitored to determine their water quality.

Definition of water quality issues and sources is accomplished through special studies of sites or areas identified to have potential water quality problems based on either routine or systematic monitoring data, as well as stakeholder input.

Information for permit decisions is acquired through "targeted" monitoring of those streams directly related to wastewater permits. Targeted monitoring provides information that can be used in the permit development process to base decisions on site-specific conditions instead of default criteria.

Overview of CRP Functions

Monitoring

Routine water quality monitoring is performed at a number of stations on either a monthly or quarterly basis for constituents such as dissolved oxygen, temperature, conductivity, pH, flow, total dissolved solids, total suspended solids, chloride, sulfate, nutrients (nitrogen and phosphorus), and chlorophyll *a*. In addition, a number of regional water agencies conduct semi-annual and annual monitoring of metals in water and biological communities (benthic macroinvertebrates, fish, and habitat).

Systematic water quality monitoring is performed at a number of stations on either a monthly or quarterly basis. Systematic monitoring may include all or a subset of the constituents sampled in routine monitoring, based on knowledge of the factors in the watershed. This monitoring is generally conducted for only one to two years to determine whether any water quality issues exist. If the data show a potential problem, a systematic sampling site or area may become the basis for a special study.

Special studies are performed in areas where the data have shown a potential problem or where stakeholders indicate there is a special need for data collection. The study will have a sampling design that is specific to the identified issues.

Targeted water quality monitoring follows the TNRCC methodology for collecting the data to support a determination of the appropriate uses and site-specific values for streams that carry wastewater effluent.

Quality Assurance

In order to ensure consistent, comparable, high-quality data across the state, all field methods, laboratory analysis methods, and data management functions follow a pre-defined quality assurance project plan (QAPP), which is reviewed and approved every two years by the TNRCC.

Identify Factors Influencing Water Quality

Each regional water agency collects information on potential sources of pollution throughout its planning area or river basin. This information is used to correlate water quality to the environmental factors that influence it, such as soils, climate, hydrology, wastewater treatment plants, urban runoff, and agricultural runoff.

Water Quality Data Assessment and Reporting

The CRP strives to report water quality data in a user-friendly format to inform the public and to provide support for the state's review of water quality. An annual basin status report, the *Basin Highlights Report*, is published for each basin, and provides an overview of water quality issues and the status of ongoing projects/tasks. A detailed and in-depth data analysis is provided for each basin in the *Basin Summary Report* once every five years. Timing of the report is based on the state's Basin Management Cycle. This report provides trend analysis, spatial analysis (correlating environmental factors to water quality), an explanation for why certain water quality issues exist, and recommendations for addressing persistent water quality problems.

Public Involvement

The program strives to involve the public and other stakeholders on a regional and local basis in the assessment of water quality within each river basin. Each regional water agency maintains a list of steering committee members from the basin who receive water quality assessment reports, meet with the regional water agencies at least once per year, and are requested to provide direction for monitoring and assessment activities for the basin. This has resulted in a significant degree of participation and "buy-in" by the stakeholders. They are able to discern a benefit from the program, not only from the discussion of water quality issues, but also due to the presentation of supporting documentation in a user-friendly format. This dissemination of information enables their participation in decision-making and gives them a more complete understanding of the water quality issues in their basin and how those issues relate to each individual.

Texas Watch Environmental Monitoring Program

Texas Watch Goals and Philosophy

Because the combined resources of Texas' governmental organizations are not adequate to assess the quality of Texas' environment, the protection of our natural resources requires the cooperative participation of all Texans. Texas Watch promotes that participation by coordinating volunteer environmental monitoring and nonpoint source (NPS) water pollution education activities among water resource stakeholders throughout the state. Texas Watch pursues three main goals:

- to produce the environmental information needed by agencies, waste generators, and the public to make environmentally sound decisions;
- to improve communication about the environment and environmental issues; and
- to resolve conflicts over environmental impacts through positive cooperation.

These goals are based on the premise that water quality and quantity issues are inextricably linked with air, biological, land, and human resource issues.

The Texas Watch program is a partnership among the EPA, the TNRCC, and Southwest Texas State University (SWT). Texas Watch offers guidance to citizens with water quality concerns and trains committed individuals to collect useful water quality data. It also supports other active volunteer monitoring programs in Texas. Texas Watch facilitates effective liaisons between citizens, industries, river authorities, water districts, private foundations, students and teachers, and governmental entities at the local, state, and federal levels.

Partner Activities

The Texas Watch partners program solicits the assistance of public and private entities in training, equipping, managing, and general support for the growing number of volunteer monitors. Partner support is a key to the success of Texas Watch. The partners program facilitates communication and cooperation between partners and citizens.

Current Program Status

As Texas Watch enters its tenth year, the total number of participants includes 299 groups, 128 of which are schools; 2,230 certified monitors; 168 trainers; and 53 quality assurance officers. Volunteers monitor a wide variety of habitats ranging from rivers, creeks, ponds, and lakes to bays, bayous, and estuaries. Texas Watch supports a wide range of monitoring activities, including a rigorous certified water quality monitoring program and nonpoint source education programs.

Texas Watch is dedicated to establishing open lines of communication with the public and among institutions concerned about water quality. The Texas Watch central office is located in the Department of Geography's Freshwater Research and Policy Center at SWT. Texas Watch produces a quarterly newsletter, which currently reaches 4,000 subscribers. Its Web site provides NPS information, Texas Watch water quality data, and contact information about partnering organizations who support Texas Watch.

Texas Watch Volunteers measuring dissolved oxygen

Quality Assurance of Texas Watch Data

For volunteer data to be useful, they must be collected and recorded following established quality assurance methods. The EPA Region 6 provides the funding for Texas Watch a nonpoint source grant program under CWA Section 319. Federal policy requires that data collected through EPA grants be collected following precise standards. These standards must be specified in an approved QAPP. By adhering to these guidelines, Texas Watch is able to assure all users that volunteer data meet specified quality standards.

Looking Ahead

Texas Watch has completed a one-year transition to the Department of Geography at SWT. During this transition, the program has successfully transferred administrative and programmatic systems and resources to SWT, including the Texas Watch Web site, database, data viewer, and newsletter. In 2000-2001, Texas Watch will implement a wide range of monitoring programs which will make water quality data available for use in assessments, environmental screening, and environmental education. Monitoring strategies and outreach activities will be coordinated with the statewide basin management schedule. New initiatives include expansion of classroom environmental education tools, an annual Earth Day sampling event, on-line chats with environmental experts, and development of the Texas Watch Special Fund which will allow the program to expand its funding base.

Nonpoint Source Assessment

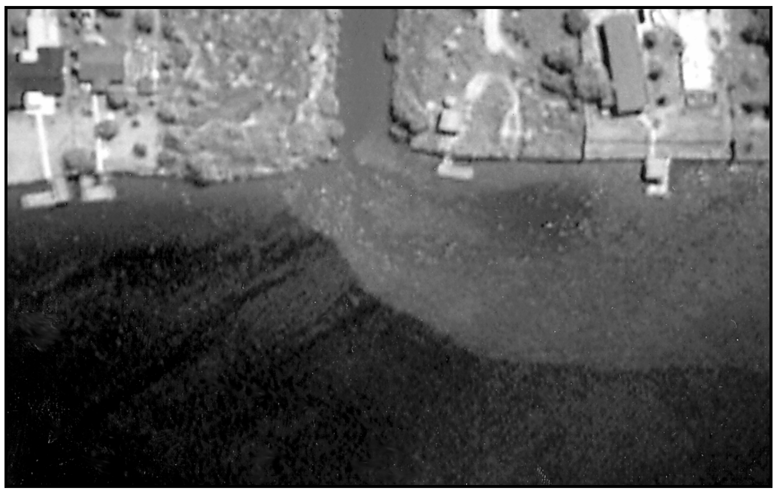
Identifying actual and potential impacts from NPS is a vital aspect of NPS pollution management. A problem must be identified and well-defined before it can be addressed effectively. Monitoring and assessment has to occur at several levels: to routinely and systematically identify threats or impairments, to conduct detailed assessment of problems and identify their sources, and to monitor the effectiveness of BMPs implemented to protect or restore water quality. These tasks are accomplished by the SWQM and CRP programs, and by agencies that carry out projects funded under federal NPS grants administered by the TNRCC.

Coastal Zone Assessment

The Texas General Land Office (GLO) leads the Coastal Coordination Council to implement the state's *Texas Coastal Nonpoint Source Control Program*. The Council has provided funding for TMDL projects at Armand Bayou and Oso Bay. The Coastal Bend Bays and Estuaries

Program and the Galveston Bay Program are also active with the GLO and other regional agencies in assessing NPS pollution in heavily-developed urban areas on the Texas coast.

The Texas Water Development Board (TWDB) calculates inputs to bays and estuaries from nonpoint sources in coastal watersheds as part of their ongoing work to determine the influence of freshwater inflows on Texas bays and estuaries. During 1999, compilations were completed for the Mission-Aransas Estuary. In conjunction with this effort, the TWDB funded studies to enhance methods of estimating rainfall runoff for use in modeling nonpoint source loadings. A project to estimate nonpoint source nutrient loadings to Sabine Lake was begun in 1999.



Sediment entering coastal waters, as seen from the air

Currently, the GLO, the TNRCC, the TSSWCB, and other agencies are preparing amendments to the 1998 *Texas Coastal Nonpoint Source Control Program* in response to comments from the National Oceanic and Atmospheric Administration (NOAA) and the EPA. An additional effort is underway to prepare a five-year implementation plan and 15-year program strategies to describe overall implementation of the Coastal Program.

Special Projects

There are a number of special studies and TMDL projects underway around Texas to provide the scientific basis for action plans in NPS-affected watersheds. Several projects are assessing NPS impacts at a regional level. Some establish specialized procedures for NPS monitoring and assessment that address an existing problem and provide a model for the NPS assessment for future projects. The TSSWCB and the TNRCC have cooperative agreements for special studies with the USGS and research stations of Texas A&M University.

The Texas Agricultural Experiment Station (TAES) examined opportunities for effluent trading to meet TMDL limits. Project staff analyzed economic and policy issues related to effluent trading to meet water quality goals. The TAES is also active in assessment projects that support TMDL development in several watersheds.

The TAES has several projects in progress to prevent NPS pollution from animal feeding operations (AFOs). These include development and testing of BMPs to: reduce phosphorus excretion from feedlot cattle through ration management; reduce ammonia volatilization loss through humate application to feedlots; devise land application practices for feedlot manure, and develop NPS dispersion models for odor and dust.

The Blackland Research Center (part of the TAES system) is using two models, the Soil and Water Assessment Tool (SWAT) and the Agricultural Productivity Extender (APEX) to assess the aggregated effects of loadings in several subwatersheds of concern. The information from these models is used to improve understanding of flow, sediment, and nutrient relationships and is a valuable aid in locating new sites for effective monitoring stations. The SWAT model is also being used to simulate NPS pollution and BMP effectiveness in affected watersheds.

Pesticide and volatile organic compounds (VOCs) are major nonpoint source contaminants of concern. A USGS project examining this concern has two primary objectives: 1) to determine the occurrence and distribution of pesticides and VOCs in surface- and ground-water supplies in Texas representative of the various land uses, hydrology, and geology found across the state, and 2) to develop a comprehensive contaminant occurrence database and to present this information by watershed, land use, and aquifer type. Data on the occurrence of these contaminants at low detection levels in public-water-supply source waters are being collected to determine what factors or activities may contribute to the contamination, which source waters are most vulnerable, and where and for which pollutants monitoring should be intensified or could be reduced. The resulting database will be used to determine, to the extent possible, statistical relations between explanatory variables, such as land-use characteristics of the watershed and the occurrence of a contaminant.

The TNRCC is conducting a project to address a statewide problem with bacteria. Roughly 45 percent of impaired water bodies in Texas have concentrations of fecal coliform bacteria that exceed contact recreation standards. The sources of this bacteria include failing or inadequate onsite sewage facilities, agricultural operations, and in some instances, naturally-occurring dense populations of waterfowl.

The bacteria project is evaluating various indicators to determine whether there may be a better indicator of contact recreation safety than fecal coliform bacteria, which is not highly correlated with actual disease outbreaks. The project is also investigating DNA-based technology for determining pollution sources. The Coastal Coordination Council has funded projects along the Texas coast to use DNA techniques to identify pollution sources. The relationship between in-stream bacteria and urban sources at various levels of density is being compared with the bacteria levels in a stream located in a natural, undeveloped area.