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Three Total Maximum Daily Loads for Chloride, Sulfate, and Total Dissolved Solids in Petronila Creek Above Tidal

For Segment Number 2204

Prepared by the:
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TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

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Three Total Maximum Daily Loads for Chloride, Sulfate, and TDS in Petronila Creek Above Tidal

EXECUTIVE SUMMARY

This document describes a project developed by the Texas Commission on Environmental Quality (TCEQ) to address water quality impairments related to excessive chloride, sulfate, and total dissolved solids (TDS) in Petronila Creek Above Tidal (Segment 2204). Petronila Creek is a freshwater stream approximately 44 miles long, with a 526-square-mile watershed, in Nueces and Kleberg Counties. General water quality uses were identified as impaired in the *2000 Texas Water Quality Inventory and 303(d) List*.

Petronila Creek Above Tidal is designated for contact recreation and intermediate aquatic life uses under the Texas Administrative Code (TAC) [Title 30, Chapter 307 (30 TAC 307): *Texas Surface Water Quality Standards*, §307.7 Site-specific Uses].

The goal for this TMDL is to determine the allowable loading that will still make it possible to meet water quality standards. Current numeric standards for annual averages to support aquatic life uses are defined in the *Texas Surface Water Quality Standards* as 1,500 milligrams per liter of chloride, 500 milligrams per liter of sulfate, and 4,000 milligrams per liter of TDS.

The TCEQ conducted an investigation to identify possible point and nonpoint sources of chloride, sulfate, and TDS, and to quantify the appropriate reductions necessary to comply with established water quality standards. Field investigations identified that excessive chloride, sulfate, and TDS concentrations occur in the downstream section of Petronila Creek, southeast of U.S. Hwy 77, in an area where man-made nonpoint sources such as produced water, brine pits, and brine injection wells are most numerous (EA, 2006).

Based on the analysis of the load allocation scenario, a TMDL allocation to meet the respective water quality standards requires:

- 100 percent reduction of loading from abandoned brine pits, and;
- 88 percent reduction of loading from the produced water.

Overall, the loading from nonpoint sources of chloride and TDS must be reduced by 88 percent and the loading of sulfate must be reduced by 78 percent to meet the goal.

INTRODUCTION

Section 303(d) of the federal Clean Water Act requires a state to identify waters that do not meet, or are not expected to meet, applicable water quality standards. For each listed water body that does not meet a standard, a state must develop a total maximum daily load (TMDL) for each pollutant that contributes to the impairment of water. The TCEQ is responsible for ensuring that TMDLs are developed for impaired surface waters in Texas.

In simple terms, a TMDL is like a budget that determines the amount of a particular pollutant that a water body can receive and still meet its applicable water quality standards. In other words, TMDLs are the best possible estimates of the assimilative capacity of the water body for a pollutant under consideration. A TMDL is commonly expressed as a load with units of mass per period of time, but may be expressed in other ways. TMDLs must also estimate how much the pollutant load must be reduced from current levels in order to achieve water quality standards.

The TMDL Program is a major component of Texas' effort to improve and manage surface water quality. The Program addresses impaired or threatened streams, reservoirs, lakes, bays, and estuaries (water bodies) in the state of Texas. The primary objective of the TMDL Program is to restore and maintain the beneficial uses — such as drinking water supply, recreation, support of aquatic life, or fishing — of impaired water bodies. This TMDL addresses impairments to general uses from chloride, sulfate, and TDS in Petronila Creek above Tidal. General use supports aquatic life with a moderately diverse habitat.

Section 303(d) of the Clean Water Act and the implementing regulations of the U.S. Environmental Protection Agency (EPA) (40 Code of Federal Regulations, Part 130) describe the statutory and regulatory requirements for acceptable TMDLs. Following these guidelines, this document describes the key elements of the TMDL, as are summarized in the following sections:

- Problem Definition
- Endpoint Identification
- Source Analysis
- Seasonal Variation
- Linkage between Sources and Receiving Waters
- Margin of Safety
- Pollutant Load Allocation
- Public Participation
- Implementation and Reasonable Assurance

This TMDL document was prepared based upon the report titled "Petronila Creek Above Tidal (Segment 2204) Total Maximum Daily Load for Chloride, Sulfate, and Total Dissolved Solids" prepared by:

- EA Engineering, Science, and Technology, Inc. in Lewisville, Texas;
- The Louis Berger Group, Inc. in Washington, D.C.; and
- The TMDL Section in the Water Programs of the Chief Engineer's Office at the TCEQ.

This TMDL document was adopted by the Texas Commission on Environmental Quality on January 10, 2007. The EPA approved the TMDLs on March 14, 2007, at which time they became part of the state's Water Quality Management Plan.

PROBLEM DEFINITION

This document describes a project developed to address water quality impairments related to chloride, sulfate, and total dissolved solids (TDS) in Petronila Creek (Segment 2204). Petronila Creek is a freshwater stream approximately 44 miles long, with a 526-square-mile watershed. Petronila Creek begins at the confluence of Agua Dulce Creek and Banquete Creek, west of Robstown in Nueces County. It flows generally southeast for about 43.5 miles across Nueces County and into Kleberg County, where it ultimately empties into Alazan Bay, part of the Baffin Bay estuarine complex (Paine et al, 2005) (Figure 1). General water quality uses were identified as impaired in the *2000 Texas Water Quality Inventory and 303(d) List*.

Figure 1. Petronila Creek Watershed

The designated uses for Petronila Creek Above Tidal are contact recreation use and intermediate aquatic life use (30 TAC 307, §307.7). Aquatic life uses recognize the natural variability of aquatic community requirements and local environmental conditions.

The goal of this TMDL for Petronila Creek is to achieve the water quality standards. The water quality standards provide numeric and narrative criteria to meet designated uses. Current numeric standards to support general uses are as follows: chloride concentration of 1,500 milligrams per liter (mg/L), sulfate of 500 mg/L, and TDS of 4,000 mg/L (Table 1). Violations of the chloride, sulfate, and TDS standards resulted in the listing of segment 2204 on the 2000 Texas 303(d) list.

In response to the listing, the TCEQ conducted a project to identify possible point and nonpoint sources of chloride, sulfate, and TDS, and to quantify the reductions necessary to comply with established water quality standards. Possible sources and/or causes include:

a) the presence of primary saline pore water in the Beaumont Formation, a local shallow aquifer present in this coastal area;
b) salt particles blown inland and deposited by prevailing onshore winds;
c) extensive inland flooding of saline gulf and estuarine water during recurrent tropical storms;
d) surface and near-surface discharge of saline water during hydrocarbon exploration and production, including discharge and infiltration from surface brine pits;
e) direct discharge into creeks and ditches; and
f) leaking injection or brine-disposal wells (Paine et al, 2005).

Table 1: Numeric Criteria for Petronila Creek Above Tidal

Segment	Criteria						
	Cl (mg/L)	SO4 (mg/L)	TDS (mg/L)	Dissolved Oxygen (mg/L)	pH Range (standard units)	Indicator Bacteria #/100ml (E. coli)	Temperature (°F)
2204: Petronila Creek Above Tidal	1,500*	500*	4,000*	4.0	6.5-9.0	126+/ 394++	95

* expressed as annual average values
\+ expressed as a geometric mean
++ expressed as an instantaneous grab sample

Petronila Creek above Tidal was added to the Texas 303(d) list for 2000 because average chloride, sulfate, and TDS exceed the segment-specific criteria of 1500 mg/L, 500 mg/L, and 4000 mg/L respectively. Recent chemical analysis and field investigations of surface water in Petronila Creek, its tributaries, and in local drainage ditches indicate that TDS and chloride concentrations are low upstream from the U.S.77 bridge at Driscoll, but increase to levels that fail to meet surface water quality standards downstream from US 77 where man-made nonpoint sources such as produced water, brine pits, and brine injection wells are more numerous, as shown in Figures 2 and 3.

A variety of man-made and natural sources can be responsible for elevated levels of chloride, sulfate, and TDS. For example, a common man-made source of dissolved solids is “brine,” a byproduct of oil production that can run off soil and into water bodies. In response to these conditions, the TCEQ initiated a TMDL project to determine the measures necessary to restore water quality in Petronila Creek Above Tidal. Chemical and biological conditions in Petronila Creek were dominated for more than 50 years by oil field brine discharges of about 50 times the stream salinity (Shipley 1991). In 1969, the Texas Legislature passed a law prohibiting open pit disposal of oil field brine. Direct brine discharges to Petronila Creek ceased in January, 1987.

Designated Uses and Water Quality Standards

The State of Texas requires water in Petronila Creek Above Tidal to be suitable for contact recreation and intermediate aquatic life use. The Nueces River Authority (NRA), the TCEQ, and the United States Geological Survey (USGS) conduct water quality monitoring in the Nueces Rio-Grande Coastal Basin. Their testing has found that elevated levels of chloride, sulfate, and TDS are affecting the water quality in a section of Petronila Creek, designated as "Segment 2204, Petronila Creek above Tidal" in the Texas Surface Water Quality Standards.

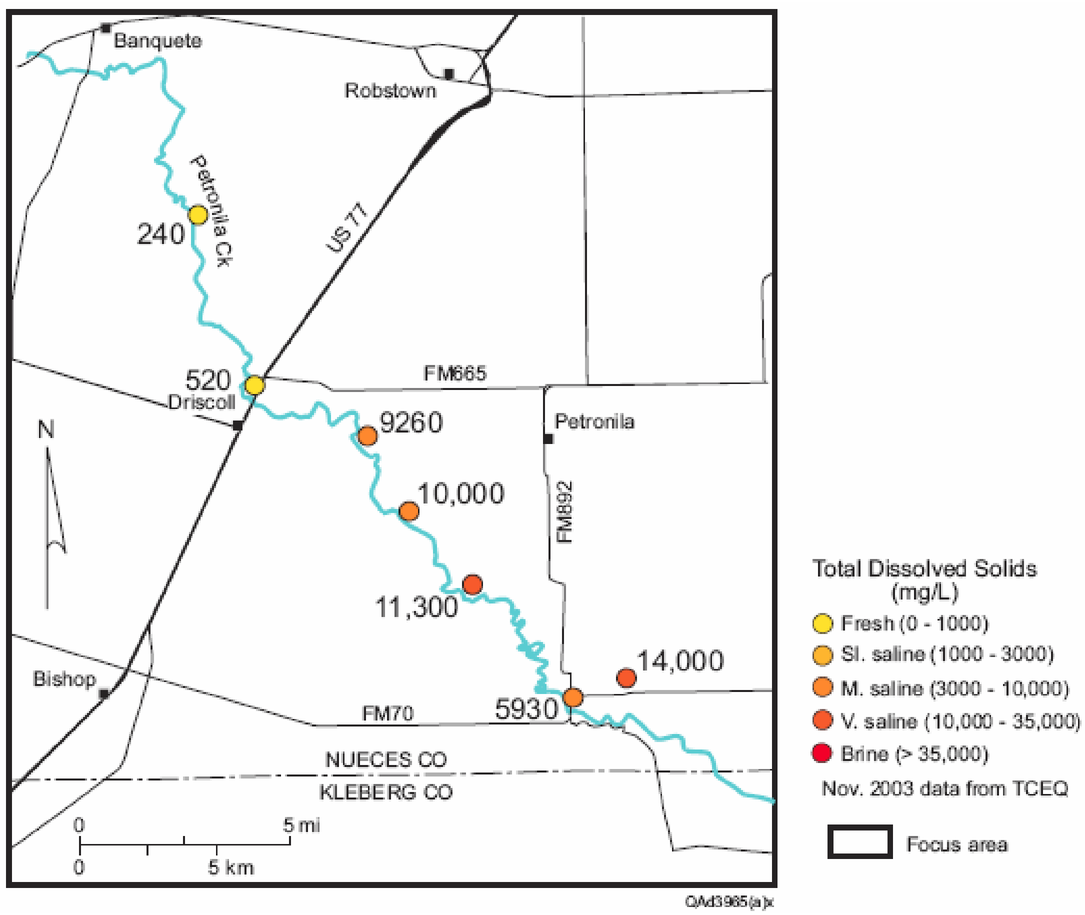


Figure 2. Map of Petronila Creek depicting TDS concentration along the creek in November 2003 (Paine et al, 2005)

High chloride concentrations can cause bad-tasting water, harm plumbing, and increase the risk of hypertension in humans. High sulfate concentrations can cause odor and taste problems in drinking water. Large amounts of dissolved solids can be toxic to species that live in freshwater (Shipley, 1991).

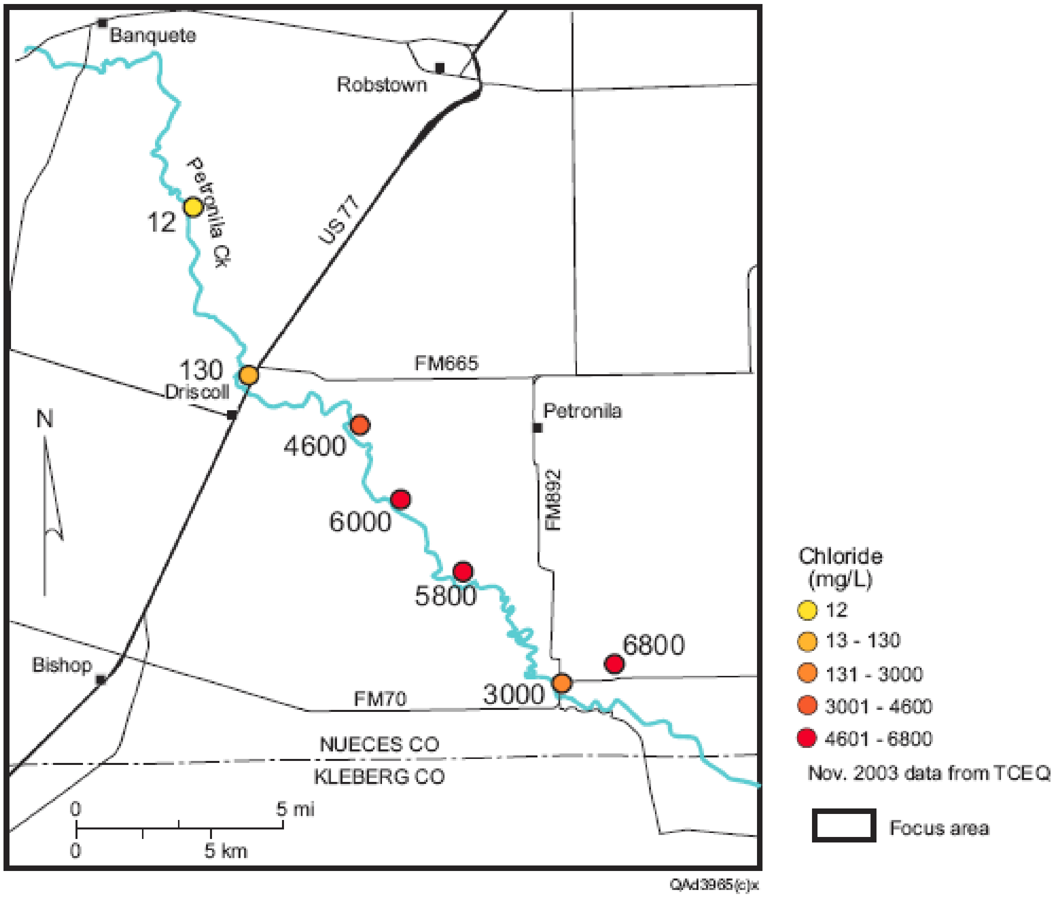


Figure 3. Map of Petronila Creek depicting Chloride concentration in surface water samples along the creek in November 2003 (Paine et al, 2005)

DESCRIPTION OF THE WATERSHED

Petronila Creek is a 44-mile long freshwater stream. The stream is formed by the confluence of Agua Dulce and Banquete creeks, which occurs one mile southeast of Banquete in western Nueces County (at 27° 48' N, 97° 47' W), and is located within the Nueces-Rio Grande Coastal Basin southwest of Corpus Christi, Texas. Nearby cities include Petronila, Driscoll, Bishop, Agua Dulce, Banquete, Corpus Christi, Orange Grove, San Pedro, and Robstown.

The Nueces-Rio Grande Coastal Basin has a drainage area of about 10,442 square miles. Petronila Creek drains approximately 543 square miles of this basin, and is a part of the Baffin Bay watershed. Petronila Creek runs southeast to its outlet on Alazan Bay, 16 miles northeast of Riviera Beach in eastern Kleberg County (at 27° 28' N, 97° 32' W). The surrounding terrain varies from flat with local shallow depressions to some rolling areas. Surface features include clay and sandy loams that support grasses, some scrub brush, and cacti. The streambed crosses tidal flats in its last six miles, and is designated as a tidal stream.

Climatic, Economic, and Geographic Conditions

Conditions related to the climate, economy, and geography of the watershed directly affect water quality in a stream.

Climate

In Nueces County, thunderstorms are recorded on an average of 30 days per year, peaking in May and September. The 30-year record (1961-90) indicates that normal precipitation in the coastal basin ranges from about 30 to 40 inches per year. Mean precipitation per year is 31.41 inches; the number of days per year with precipitation of 0.1 inches is 39 days. Temperatures are generally moderate, with temperatures at or below freezing only about seven days of each year, and with 101 days above 90 ºF.

Economy

Nueces County is comprised of 1,166 square miles and has a population of 313,645. The county has grown in population, with the majority of the increase occurring in the Corpus Christi metro area, which is primarily outside of the Petronila Creek watershed. Approximately 89% of the county population lives in urban areas. The county contains 330 square miles of navigable waterways. Oil, gas, and petrochemical production contribute significantly to the economy; tourism, area retailing, seaport activity, farming, ranching and military facilities are also contributors to the local economy.

Nueces County is the center of agribusiness activity for the Coastal Bend region of Texas. In 1997, there were 282 full time farms located in the county, with an average farm size of 770 acres. Total land area for farms and ranches in the county decreased by 1% between 1992 and 1997, but farms and ranches still comprise 82% of the total land area (534,976 acres) in the county. The majority of livestock production is cattle and calf farms, with a few hog and sheep farms also. The primary crops in Nueces County are cotton and grain or seed sorghum.

Stream Segment Geology and Hydrogeology

The geology of the southern Texas Gulf Coast region encompassing Petronila Creek is composed of clay, silt, sand, and gravel deposits. The primary geologic unit in the study area is the Beaumont Formation. The formation includes iron oxide and iron-manganese oxide concretions, along with concretions and massive accumulations of calcium carbonate (caliche) in weathered zones. This underlying geologic formation controls topography, area drainage, and soil types that represent stream channel, coastal marsh, mud flats, and backswamp environments.

Groundwater in the area is associated with the Gulf Coast aquifer, also known as the coastal lowlands aquifer system. The aquifer system lies beneath relatively level, low-lying coastal plains. The amount of sand within the aquifer decreases from east to west, with a maximum sand thickness of about 1,300 feet in the east and about 700 feet in the west.

Soils

Soil characterization in the Petronila Creek watershed was based on the Soil Survey of Nueces County, Texas (USDA Soil Conservation Service Series 1960). The predominant soil in Petronila Creek is a Victoria association, which covers 66% of Nueces County. Victoria soils have a surface layer of dark-gray, calcareous heavy clay. This clay is about three feet thick and is underlain by a layer of light and dark-gray clay that is 18-inches thick.

Land Use

Land use characterization was based on the most recent National Land Cover Data (NLCD), developed by USGS in 1992. Dominant land uses for this area are agricultural (83%) and rangeland (15%), which together account for 98% of the land area draining to the impaired segment of Petronila Creek. Cropland is ubiquitous throughout the watershed. Rangeland occurs predominantly in the northwest section of the watershed of Petronila Creek Above Tidal. Urban and residential areas are scattered throughout the boundaries of the watershed. The land use distribution in the watershed of Petronila Creek Above Tidal is shown in Figure 4.

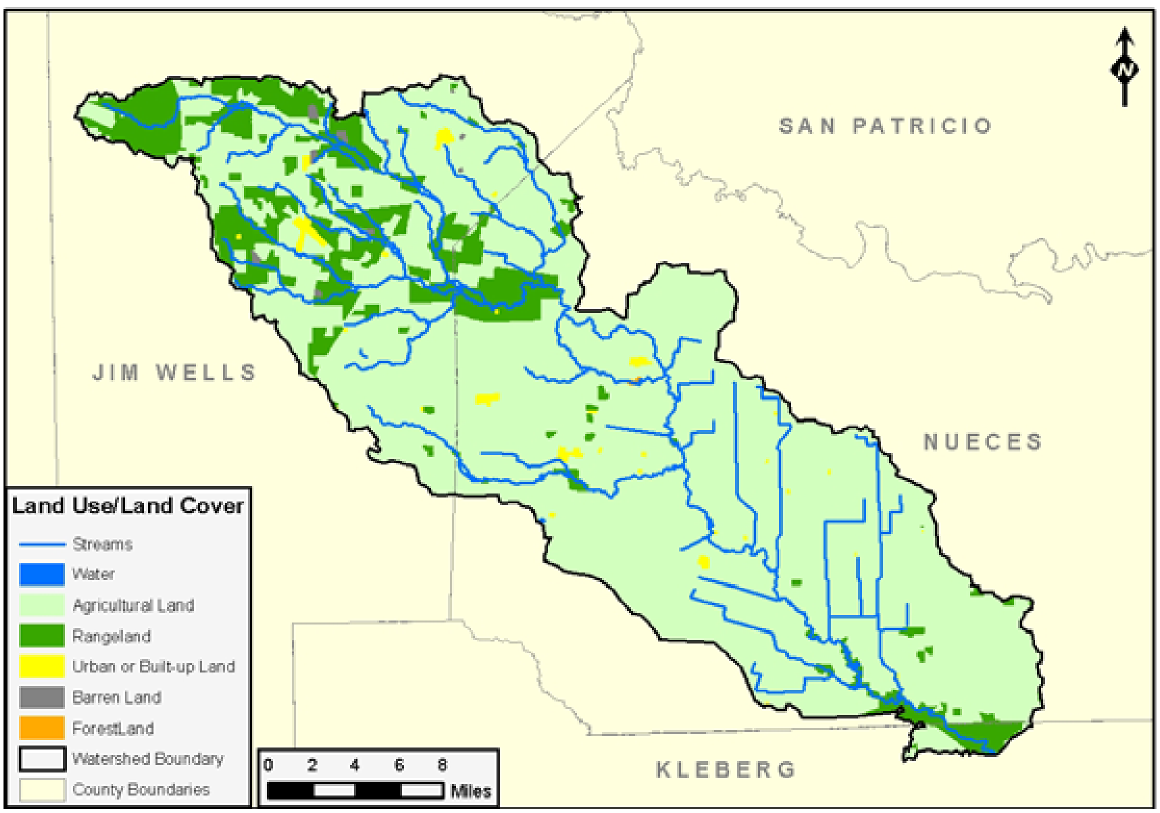


Figure 4: Petronila Creek Land Use Distribution

Oil and Gas Production

Oil and gas production and exploration are the dominant industrial activity in the Petronila Creek watershed. As of September 2001, there were a total of 1,248 gas wells in

Nueces County. Of these, 696 were active, regularly producing wells, 55 were temporarily abandoned, 479 were inactive, and 18 were used to inject fluid (water, air, CO2) into productive formations. There are currently 627 oil wells in Nueces County, with 209 of these regularly producing, 387 inactive, and 31 serving as injection wells. Figure 5 depicts non-compliant (abandoned and orphaned) oil and gas wells and injection wells present in the watershed. This information is based on data provided by the Railroad Commission of Texas. The TCEQ Nonpoint Source Program has and continues to work with the RRC to eliminate potential sources of salinity in the watershed of Petronila Creek Above Tidal by plugging abandoned, non-compliant oil and gas wells and re-plugging improperly plugged wells.

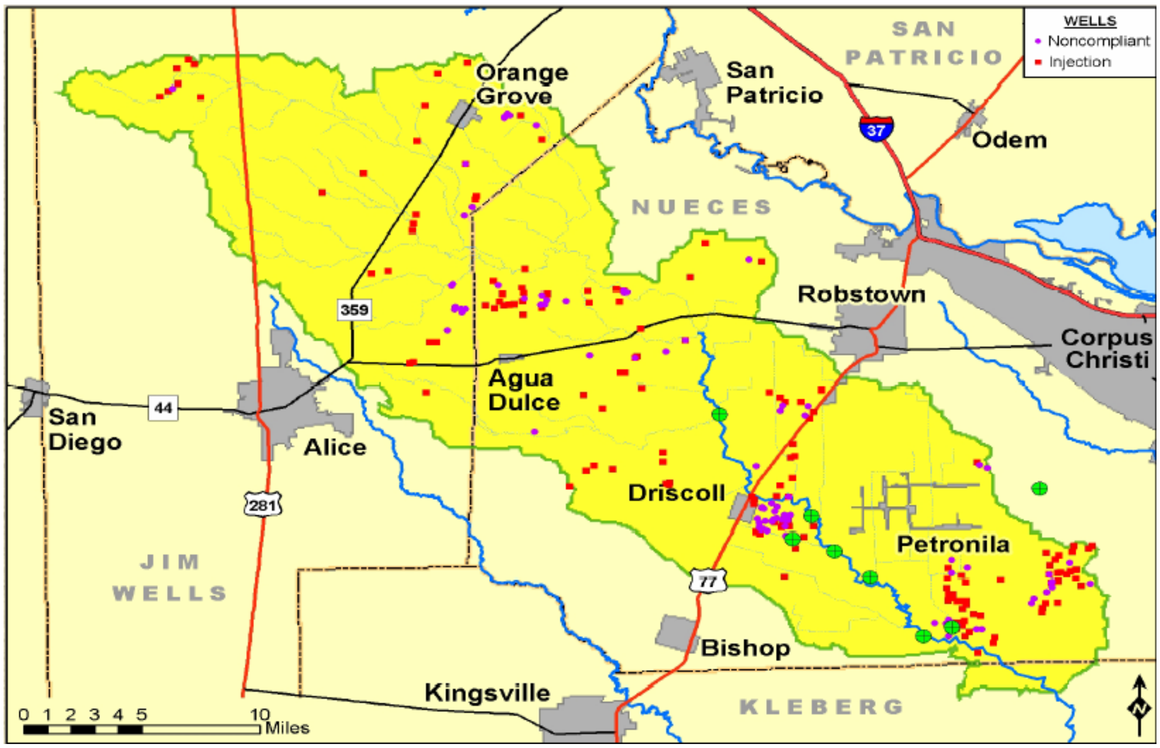


Figure 5: Non-Compliant Oil and Gas Wells and Injection Wells in the Watershed of Petronila Creek Above Tidal

Assessment of Pollutant Sources

The data used to assess the sources affecting Petronila Creek Above Tidal are discussed in the following sections. The inventory of data and information is outlined, along with monitoring, water quality, stream flow, and meteorological weather data.

Data and Information Inventory

A wide range of data and information were used in the development of the TMDLs for Petronila Creek Above Tidal. Categories of data used include the following:

1) Hydrographic data that describe the physical conditions of the stream, such as the network and connectivity of the stream reach, and the depth, width, slope, and elevation of the stream channel.
2) Watershed physiographic data that describe physical conditions such as topography, soils, and land use.
3) Data and information related to the use of, and activities in, the watershed that can be used in the identification of possible chloride, sulfate, and TDS sources.
4) Environmental monitoring data that describe stream flow and water quality conditions in the stream.

Water Quality Monitoring

The NRA is responsible for coordinating the Clean Rivers Program monitoring activities in the Nueces Rio-Grande Coastal Basin for inclusion in the TCEQ's Surface Water Quality Monitoring (SWQM) database. The TCEQ and the USGS also collect data within the basin.

Table 2: Monitoring Stations on Segment 2204

Station I.D. Number	Period of Record	
	From	To
13030	2003	2005
13032	2003	2005
13093	2003	2005
13094	1994	2005
13095	2003	2005
13096	2003	2005
13098	2003	2005
13099	1998	2005

Data collected at eight stations on Segment 2204 were used in the development of these TMDLs (Table 2). Field and chemical parameters included water temperature, pH, dissolved oxygen, specific conductivity, flow, TDS, chloride, and sulfate.

Water Quality Data

Review of the available water quality data reinforced early assessments that Petronila Creek contains moderate to high levels of TDS, chloride, and sulfate. Tables 3, 4, and 5 summarize the data collected on segment 2204, including the number of samples collected, exceedances of the water quality standard, and the observed concentration ranges for chloride, sulfate, and TDS. Figures 7, 8, and 9 display the data in charts depicting the high, low, and median values observed over the respective term of collection.

Stream Flow and Weather Data

Stream flow measurements are necessary to calibrate watershed and water quality models, calculate loadings of pollutants from point and nonpoint sources, characterize transport processes, and evaluate impacts of pollutant loadings. However, no recent source of continuous flow data is available for the watershed of Petronila Creek Above Tidal. Therefore, a paired watershed approach was used to develop a source of flow data for TMDL modeling. The basis of this approach was to develop a model for a hydrologically similar watershed where sufficient stream flow and other data were available. This model was then transferred to the watershed of Petronila Creek Above Tidal. Criteria used to evaluate the hydrologic similarity of the paired watersheds included mean annual precipitation and physiographic characteristics such as drainage area, main channel slope, main channel length, mean basin elevation, soil type distribution, and land use/land cover.

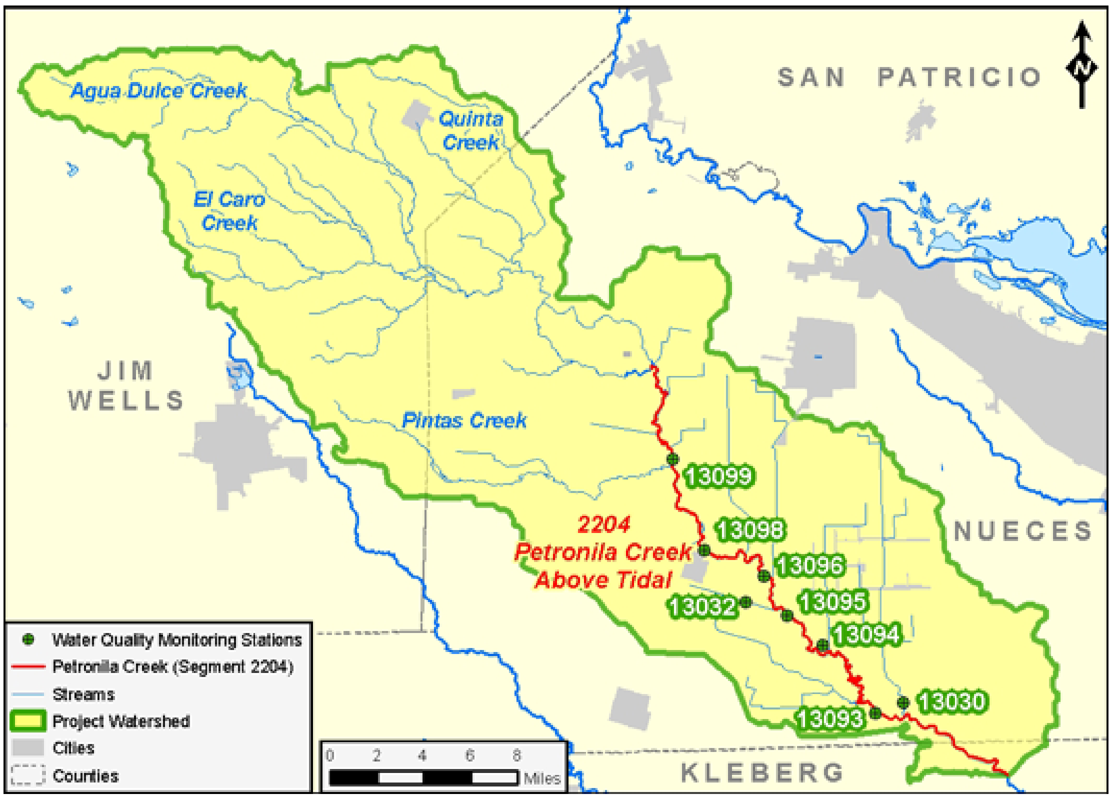


Figure 6. Water Quality Monitoring Stations Located on Segment 2204

Oso Creek, located within the Nueces-Rio Grande Coastal Basin in the watershed of Corpus Christi Bay, was chosen to simulate stream flow because of its hydrologic and physiographic similarities to the watershed of Petronila Creek Above Tidal. The Oso Creek watershed is also immediately adjacent to the Petronila Creek watershed.

The flow monitoring station for Oso Creek (USGS08211520) is located near Corpus Christi, Texas. Flow data for Oso Creek were retrieved for the period of 1973 to 2004 from USGS, and were used in model set-up, hydrological calibration, and validation. The calibrated hydrologic model was then used to develop the watershed of Petronila Creek Above Tidal TMDL.

Table 3: Summary of Chloride Data for Petronila Creek

Station I.D.	# of Samples	# of Exceedances	Data Range (mg/L)	Dates Collected
13030	17	10	60 - 30,000	1/27/2003 - 6/3/2005
13032	12	9	11 - 29,000	1/21/2003 - 6/2/2005
13093	16	11	14 - 8,800	1/27/2003 - 6/2/2005
13094	42	33	9 - 11,200	5/8/95 - 6/3/2005
13095	15	9	9 - 10,000	1/27/2003 - 6/2/2005
13096	21	13	7 - 11,000	10/17/95 - 6/3/2005
13098	14	1	3 - 5,800	5/9/2003 - 6/3/2005
13099	9	0	2 - 16	1/27/2003 - 6/2/2005

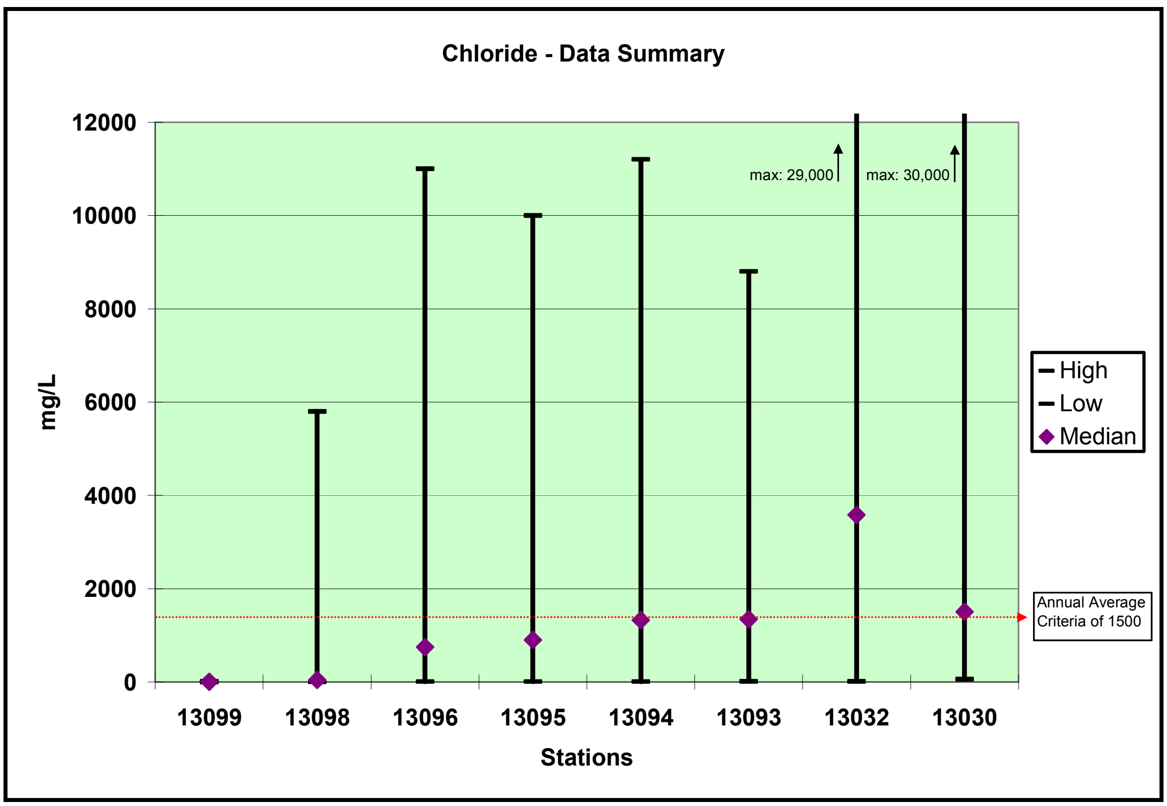


Figure 7: Summary of Chloride Data for Petronila Creek

Table 4: Summary of Sulfate Data for Petronila Creek

Station I.D.	# of Samples	# of Exceedances	Data Range (mg/L)	Date Collected
13030	17	10	42 - 4,170	1/27/2003 - 6/3/2005
13032	12	9	13 - 6,000	1/21/2003 - 6/2/2005
13093	17	11	8 - 1,570	1/27/2003 - 6/2/2005
13094	42	20	4 - 1,680	5/8/95 - 6/3/2005
13095	16	9	4 - 1,660	1/27/2003 - 3/22/2005
13096	21	11	3 - 2,000	1/24/96 - 6/2/2005
13098	14	0	3 - 400	5/9/2003 - 6/3/2005
13099	9	0	2 - 8	1/27/2003 - 6/2/2005

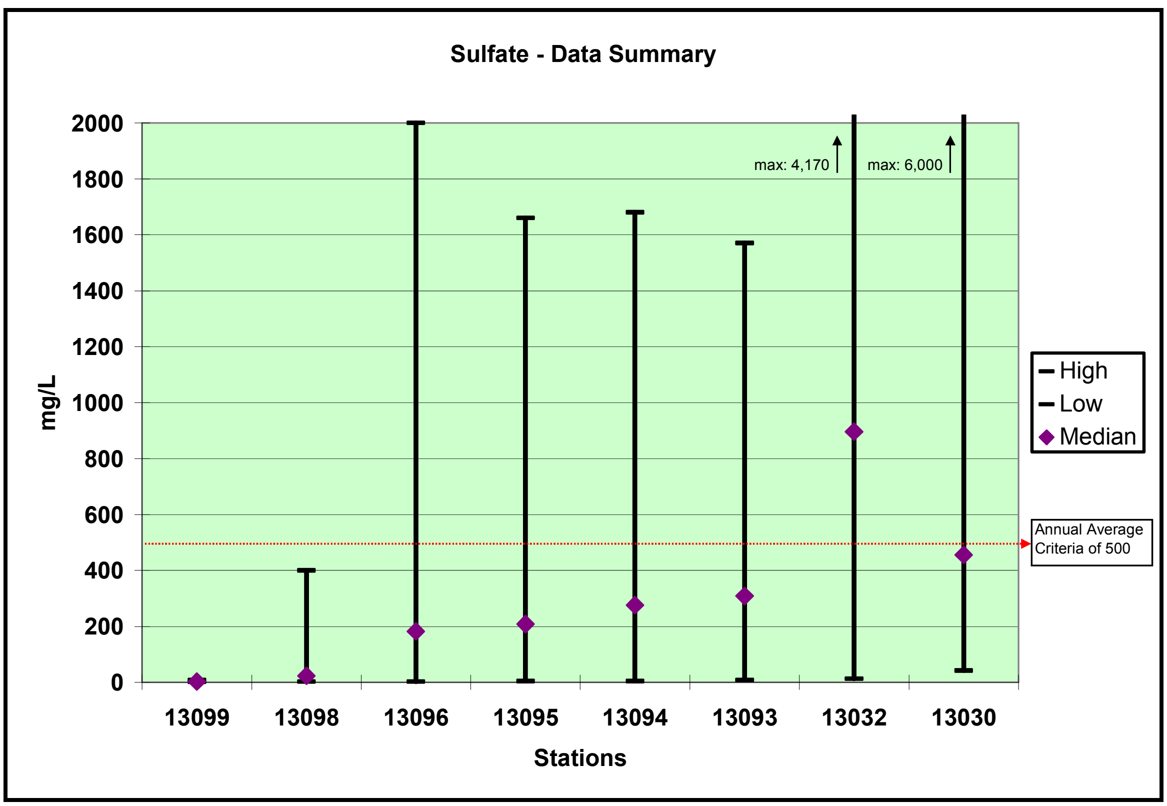


Figure 8: Summary of Sulfate Data for Petronila Creek

Table 5: Summary of TDS Data for Petronila Creek

Station I.D.	# of Samples	# of Exceedances	Data Range (mg/L)	Date Collected
13030	17	10	360 - 34,000	1/27/2003 - 6/3/2005
13032	12	9	260 - 32,800	1/21/2003 - 6/3/2005
13093	17	12	240 - 17,400	1/27/2003 - 6/2/2005
13094	45	34	140 - 20,200	4/25/94 - 6/3/2005
13095	15	9	130 - 17,400	1/27/2003 - 6/2/2005
13096	20	13	130 - 20,900	10/17/95 - 6/3/2005
13098	14	0	180 - 3,250	5/9/2003 - 6/3/2005
13099	12	0	110 - 240	11/4/97 - 6/2/2005

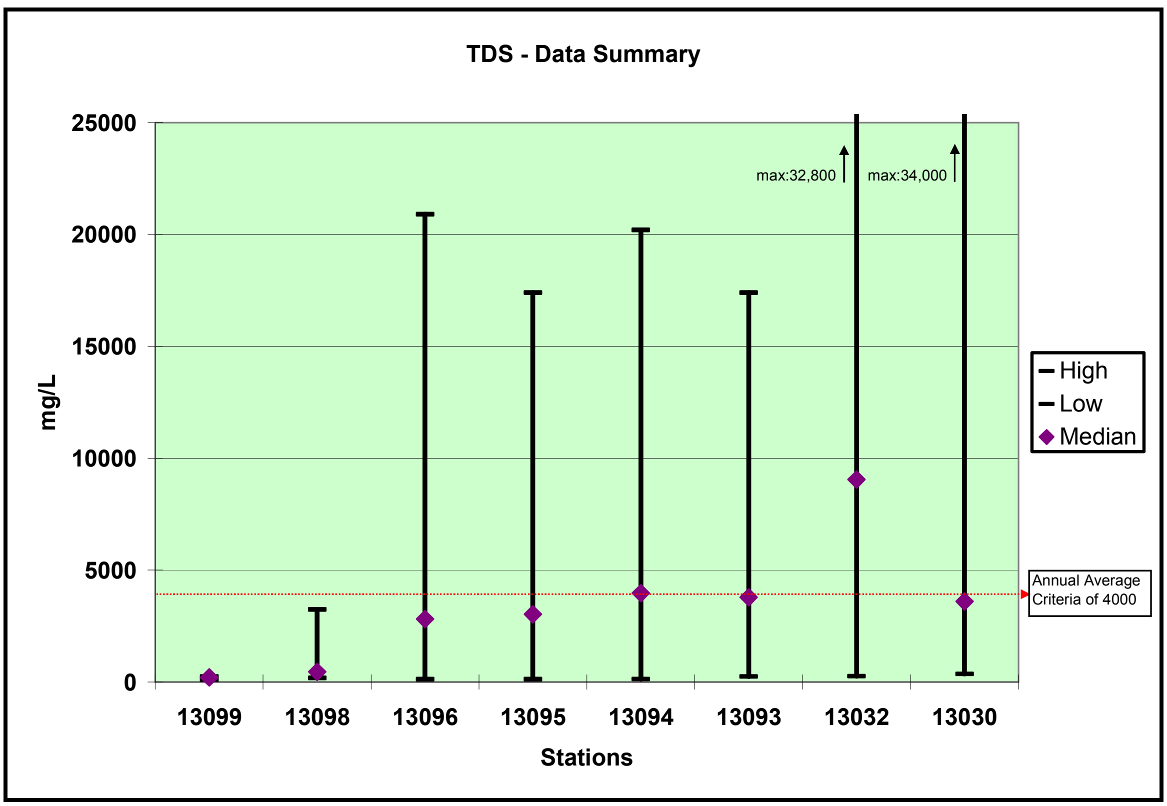


Figure 9: Summary of TDS Data for Petronila Creek

Hourly precipitation and weather data are used to simulate the hydrologic cycle in modeling. Precipitation and weather data collected at the Corpus Christi airport (east of the Petronila Creek watershed in Corpus Christi, Texas) were obtained from the National Climatic Data Center for use in the model.

The Critical Condition

Federal regulations in 40 CFR 130.7 (c) (1) require that TMDLs take into account the critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that water quality is protected during times when it is most vulnerable. The critical condition is considered the “worst case scenario” of environmental conditions in the watershed of Petronila Creek Above Tidal. If the TMDL is developed so that the water quality targets are met under the critical condition, then the water quality targets are most likely to be met under all other conditions. Critical conditions are important because they describe the factors that combine to cause a violation of water quality standards and help in identifying the actions that may have to be undertaken to meet water quality standards.

Chloride, sulfate, and TDS loadings result from sources that can contribute these pollutants during wet weather and dry weather. The critical conditions for the impaired segment of Petronila Creek were determined using the paired-watershed approach from the available instream water quality data collected by the TCEQ and from USGS streamflow data. Plotting chloride, sulfate, and TDS water quality data along with streamflow data revealed that the standard exceedances were occurring throughout the impaired segment, independent of the season, and mainly under low flow conditions (see Figures 10, 11, and 12). Since chloride, sulfate, and TDS loadings are based on an annual average and occur throughout the year, their impacts are a function of cumulative loading rather than particular events. Since it is appropriate to consider chloride, sulfate, and TDS loadings on an annual basis, pollutant loadings and TMDL allocation scenarios were developed based on average annual loads determined from a 10-year model simulation period.

Consideration of Seasonal Variations

Seasonal variations involve changes in stream flow and water quality as a result of hydrologic and climatic patterns. Seasonal variations were evaluated in the modeling approach for these TMDLs. This allowed the consideration of temporal variability in chloride, sulfate, and TDS loadings within the Petronila Creek impaired segment. Exceedances occur throughout the impaired segment independent of the season.

ENDPOINT IDENTIFICATION

TMDLs must identify a quantifiable water quality target for each constituent that causes a body of water to appear on the §303(d) list. For chloride, sulfate, and TDS, the primary water quality targets have been established through the *Texas Surface Water Quality Standards*.

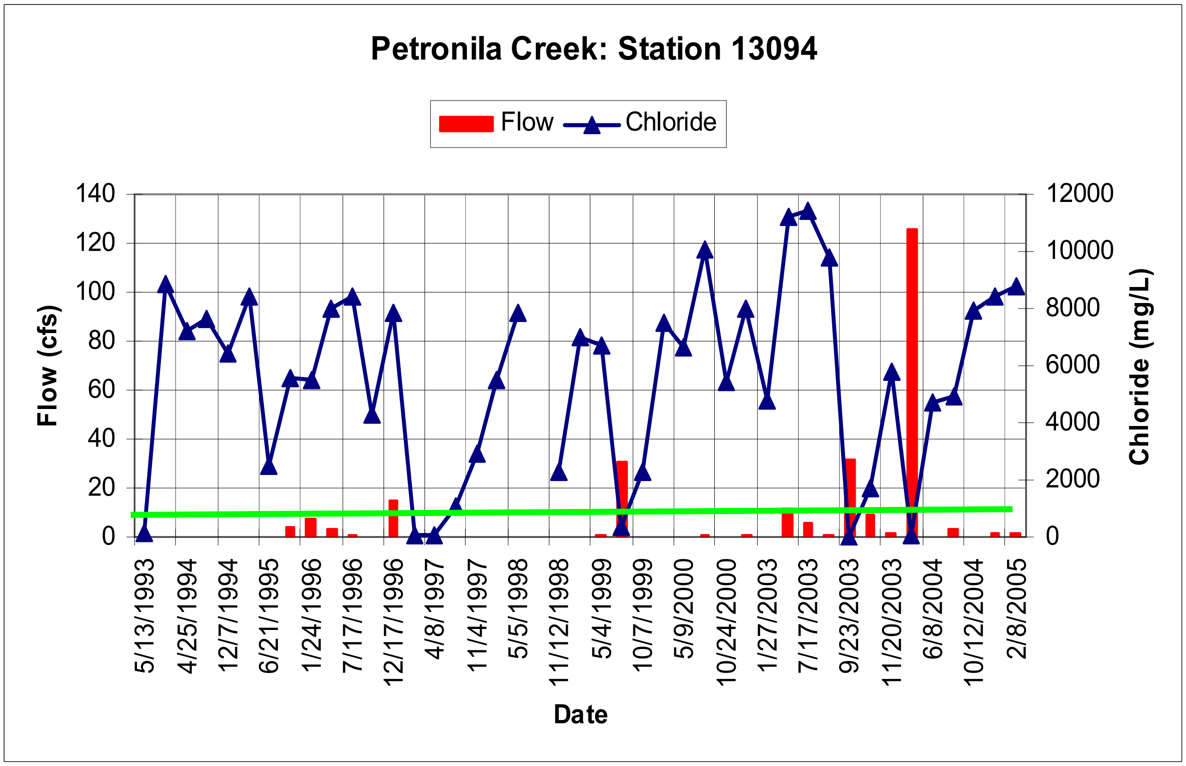


Figure 10: Flow and Chloride Concentrations at Station 13094

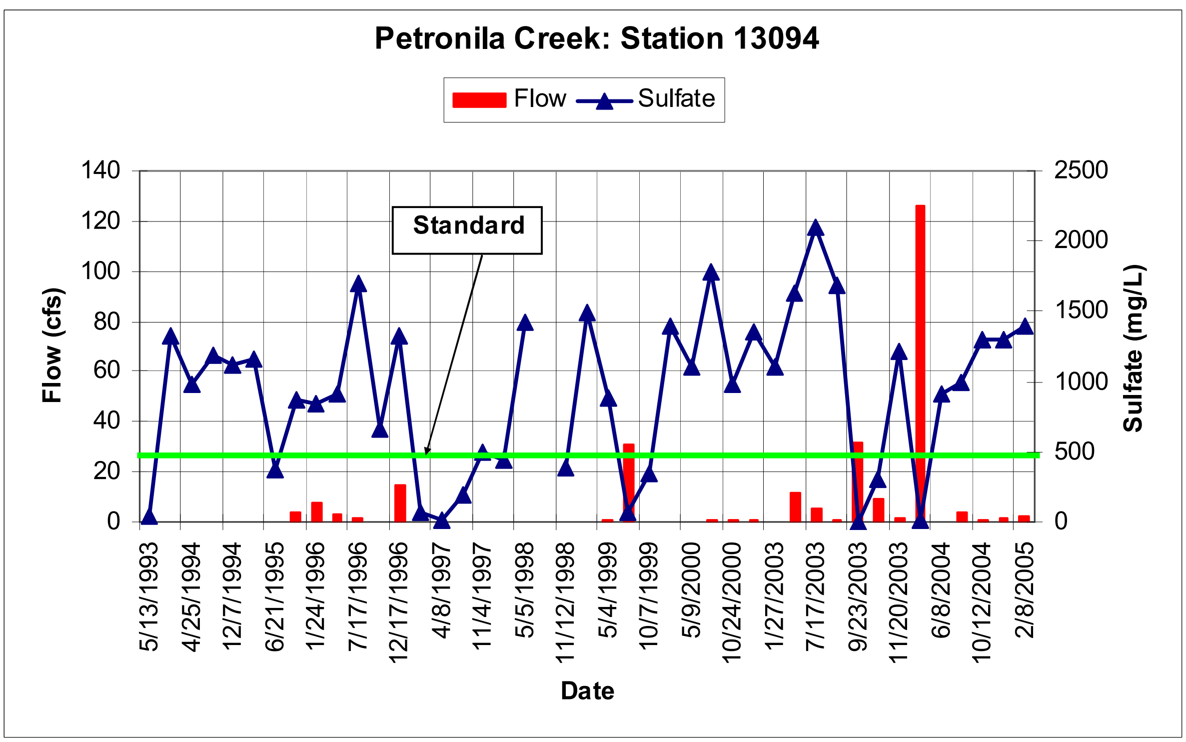


Figure 11: Flow and Sulfate Concentrations at Station 13094

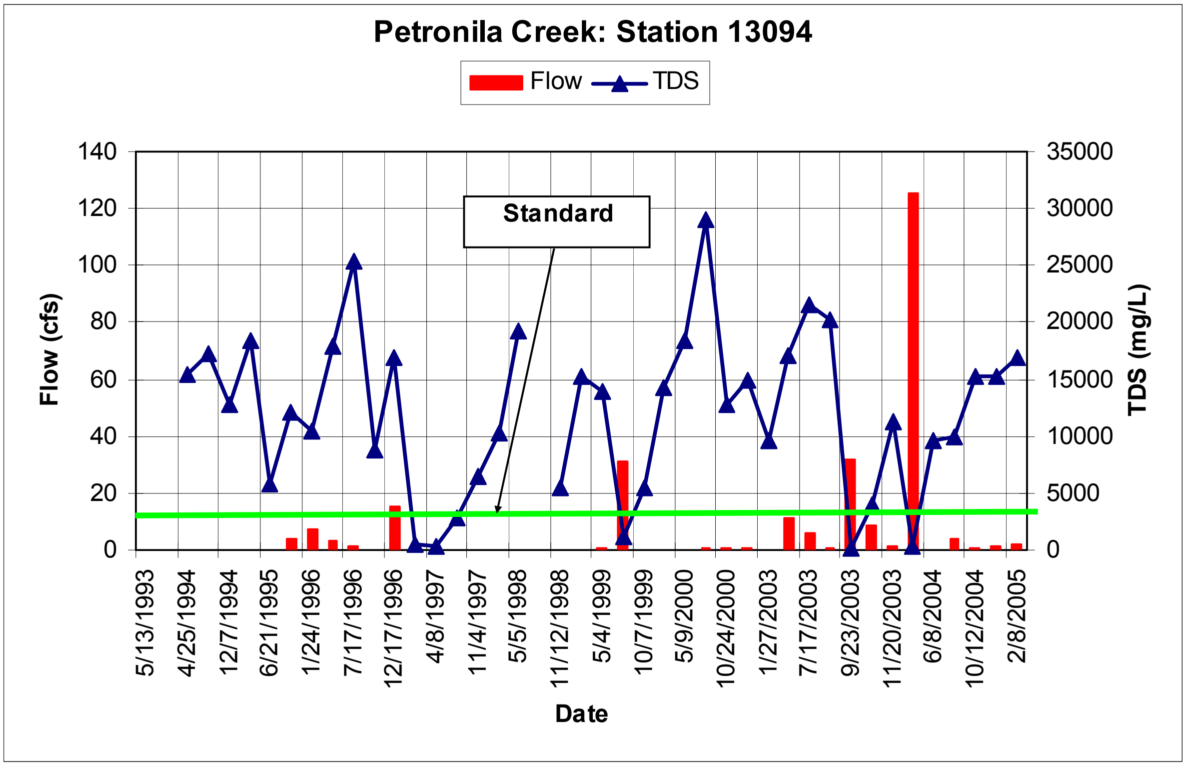


Figure 12: Flow and TDS Concentrations at Station 13094

Chloride

Texas water quality standards specify that the annual average chloride concentrations in the impaired segment of Petronila Creek should not exceed 1,500 mg/L.

Sulfate

Texas water quality standards specify that the annual average sulfate concentrations in the impaired segment of Petronila Creek should not exceed 500 mg/L.

Total Dissolved Solids

Texas water quality standards specify that the annual average TDS concentrations in the impaired segment of Petronila Creek should not exceed 4,000 mg/L.

Source Analysis

Pollutants may come from several sources, both point and nonpoint. The possible sources of salts in Petronila Creek Above Tidal are discussed in this section.

Point Source Dischargers

Point source pollutants come from a discernible, confined, and discrete conveyance, such as any pipe, ditch, channel, tunnel, conduit, well, container, or from concentrated animalfeeding operations, vessels or floating crafts from which pollutants are discharged to surface water bodies. Point sources are regulated by permits under the Texas Pollutant Discharge Elimination System (TPDES), which may include effluent limitations, monitoring, and reporting requirements. Storm water discharges from separate storm sewer systems of cities and those associated with industry and construction are also considered point sources of pollution.

The only regulated point sources with permit limits discharging to the impaired segment are six permitted municipal wastewater plants and industrial plants. The point sources present in the impaired segment are identified in Table 6.

Table 6: Permitted Dischargers with Permit Limits in Watershed of Petronila Creek Above Tidal

Permit #	Name of Facility	Flow (MGD)
WQ0010140-001	City of Agua Dulce	0.16
WQ0010592-001	City of Orange Grove	0.2
WQ0011541-001	Driscoll Plant, City of Driscoll	0.1
WQ0011583-001	Banquete Plant, Nueces CO WCID 5	0.1
WQ0011689-001	City of Coastal Bend Youth City	0.015
WQ0011754-001	Petronila Elementary	0.008

Produced Water

There has been significant oil and gas exploration and production activity in the study area. As of 2001, there were 1,875 documented oil and gas wells (EA Engineering et al, 2006). Currently active fields include the Clara Driscoll and North Clara Driscoll oil fields, which are bisected by Petronila Creek. Oil exploration is a major industry in the watershed. The production of oil is usually accompanied by the production of brine, which occurs in the same strata as the oil. During primary production of oil, the ratio of salt water to oil is usually less than 1:4 but as the well ages, the ratio of salt water to oil becomes closer to 1:1 and may be as high as 10:1. As the ratio increases, the well becomes unprofitable to operate and is either properly plugged or abandoned. Some of these abandoned wells occasionally have cracks and leaks that may eventually allow brine to reach the surface and contaminate ground water and surface water (Paine et al, 2005).

Brine Pits

Historically, operators disposed of brine in large, shallow, unlined pits where water would be lost due to evaporation and seepage. When brine evaporates, dissolved solids are left behind as salt crusts that can cause infiltration to the shallow subsurface and local ground water. Brine disposal pits were used extensively in areas of oil production until 1969, when a statewide ban was placed on their use.

Brine Injection

The practice of injecting brine into subsurface strata is used for both disposal of excess brine and for recovering oil from under-pressurized formations. Many disposal wells inject brine into formations immediately below shallow aquifers. This relatively shallow disposal presents a higher risk of migration into groundwater and surface water bodies at the point where the formation outcrops. Surface and subsurface contamination associated with injection wells are often traced to cracked casings, leaking boreholes, or wells that are not operated properly.

Phreatophytic Brush

The proliferation of invasive species of brush (phreatophytic brush) into the southwestern portions of the United States is a recognized problem in water management. Species of phreatophytic brush that are found in the Nueces-Rio Grande Coastal Basin are prickly pear, juniper, retama, huisache, and mesquite. Phreatophytic brush species have a high water consumption rate compared to most native vegetation and easily out-compete most native species in disturbed areas. Thus, there may be a correlation between decreased stream flows, higher ambient salinity, and increasing brush coverage.

Additional Salinity Sources

Additional potential sources of salinity in Petronila Creek include: the presence of primary saline pore water in Beaumont Formation strata that was deposited in a late Pleistocene coastal environment; salt particles blown inland and deposited by prevailing onshore winds; and extensive inland flooding of saline gulf and estuarine water during recurrent tropical storms.

Field Monitoring Surveys

Field surveys of the Petronila Creek watershed were conducted by EA Engineering Science and Technology (EA) from January 2003 through July 2005 to enhance understanding of the nature and extent of salinity loading in the watershed of Petronila Creek Above Tidal. Reconnaissance ground-based measurements supplemented available water quality data and confirmed that little salinization exists upstream from U.S. Highway 77, but that significant salinization occurs within a short distance of U.S. Highway 77 and continues to the downstream section surveyed. Local areas of elevated ground conductivity suggest that there are local sources of salinization that degrade surface water quality, including several sites near Driscoll and within the Driscoll Oil Field area.

Electromagnetic Induction (EM) Surveys

Geophysical instruments can also be used to non-invasively identify saline ground that might contribute to the elevated salinity of Petronila Creek. The electrical conductivity of the ground (McNeill, 1980) is generally dominated by electrolytic flow of ions in pore water. Because the salinity of water is strongly correlated to its electrical conductivity (Robinove and others, 1958), the electrical conductivity of soil and sediment is also strongly influenced by the salinity of pore water. As pore-water salinity increases, so does the electrical conductivity of the ground.

In order to better define the sources of chloride, sulfate, and TDS in the Petronila Creek impaired segment, the University of Texas Bureau of Economic Geology (BEG) conducted TCEQ-sponsored ground-based and airborne geophysical surveys using ground and airborne electromagnetic (EM) induction instruments to delineate the extent and intensity of salinization and identify salinity sources that degrade surface water quality in Petronila Creek downstream from U.S. 77.

EM methods employ a changing primary magnetic field created around a transmitter coil to induce current to flow in the ground, which in turn creates a secondary magnetic field that is sensed by the receiver coil (Paransis, 1973; Frischknecht and others, 1991; West and Macnae, 1991). The strength of the secondary field is a complex function of EM frequency and ground conductivity (McNeill, 1980b), but generally increases with ground conductivity and constant frequency. This section summarizes results of the BEG's EM surveys (Paine et al, 2005).

The BEG used evident lateral and vertical conductivity trends to interpret the extent and intensity of salinization, whether it has shallow or deep sources, and, by combining geophysical patterns with chemical surface water patterns, interpreted the likely source type. A Geonics EM31 ground conductivity meter was used to take ground conductivity measurements at 166 locations along Petronila Creek, accessible tributaries, and drainage ditches that flow into Petronila Creek and across adjacent fields between June 22 and 26, 2004. The instrument operates at a frequency of 9.8 kilohertz (kHzs), measuring apparent conductivity to a depth of about 3meters (horizontal dipole [HD] orientation) and 6meters (vertical dipole [VD] orientation). Measurements were taken in both the HD and the VD.

Aerial conductivity measurements were acquired in early February 2005 within a northwest-southeast oriented block measuring 3.7 miles by 15.5 miles centered on the axis and within a corridor centered on Petronila Creek, from a point above U.S. 77 to about 1.2 miles downstream from where Petronila Creek enters Kleberg County. The survey subcontractor, Geophex, provided the technical survey crew and their GEM-2A airborne instrument. Airlift Helicopters provided the flight crew and helicopter to tow the instrument.

The GEM-2A is an EM instrument that employs a single pair of transmitter and receiver induction coils in horizontal coplanar orientation that operate at multiple effective frequencies (and exploration depths) simultaneously (Won and others, 2003). Five primary frequencies: 450, 1350, 4170, 12,810, and 39,030 Hz yield exploration depths ranging from a few meters at the highest frequency to several tens of meters at the lowest frequency.

The BEG received final processed geophysical data from Geophex, the survey subcontractor, in mid-April 2005, and converted final processed data into images showing trends and variations in apparent conductivity laterally and with depth along and near the creek. Chemical analyses of the surface water flowing in the creek during the airborne survey depict a chemistry that changes from fresh meteoric water upstream from U.S. 77 to highly saline water below U.S. 77 that is (a) a mixture between two non-seawater sources (probably produced oilfield water), and (b) a mixture of seawater and another highly saline source (probably produced water).

Survey Results

The exploration depth of the airborne EM instrument is governed by instrument frequency and ground conductivity. The BEG explored at five frequencies ranging from 450 Hz (the deepest-exploring frequency at an average exploration depth of about 28 meters (92 feet) for this area) to 39 kHz (the shallowest-exploring frequency at an average exploration depth of about 2 meters (7 feet)). Apparent conductivity trends plotted from creek-axis data allow delineation of three areas of generally elevated apparent ground conductivity along the creek (Figure 13). From upstream to downstream, these include the Driscoll area, extending a total creek length of about 4.8 miles downstream from the U.S. 77 bridge to the FM 665 bridge; the Concordia area, extending a total creek length of about 5.6 miles from about 0.6 miles below the FM 665 bridge to about 1.2 miles below the FM 892 bridge; and the Luby area, extending from the FM 70 bridge to near the end of the survey about 5.2 miles farther downstream. These areas represent the stream reaches most likely to be contributing highly saline water that degrades water quality in Petronila Creek.

Driscoll Area

The Driscoll reach lies adjacent to the Clara Driscoll Oil Field south of the creek and the North Clara Driscoll Oil Field north of the creek (Figure 13). Elevated apparent conductivities are evident across the Clara Driscoll field at all frequencies and at the North Clara Driscoll field at low to intermediate frequencies, suggesting that oil field-related, near-surface salinization has occurred in these areas, probably largely from past surface discharge of produced water into pits and ditches (Figure 14).

Assuming that there has been no significant surface discharge of produced water for more than a decade, the most likely mechanism for infiltration of highly saline water into this creek reach is: (1) direct infiltration of produced water into the shallow subsurface from pits and drainage ditches; (2) lateral migration of saline water through sandy Beaumont Formation channels; and (3) discharge as local, shallow-source base flow into Petronila Creek in places along the 4.8-mile reach.

At the upstream end at U.S. 77, flow on February 8, 2005 (one day after the airborne survey was completed) was 0.1 cubic feet per second at a total dissolved solids (TDS) concentration of 2,460 mg/L. This translates to an incoming TDS load of 1327 pounds per day (lbs/day). At FM 665 at the end of the Driscoll, flow was 0.562 cubic feet per second with a TDS concentration of 15,100 mg/L at station 13096, translating to an outgoing salinity load of 45,772 lbs/day, an increase of about 44,445 lbs/day. This loading is predominantly attributed to the local base flow mechanism described above.

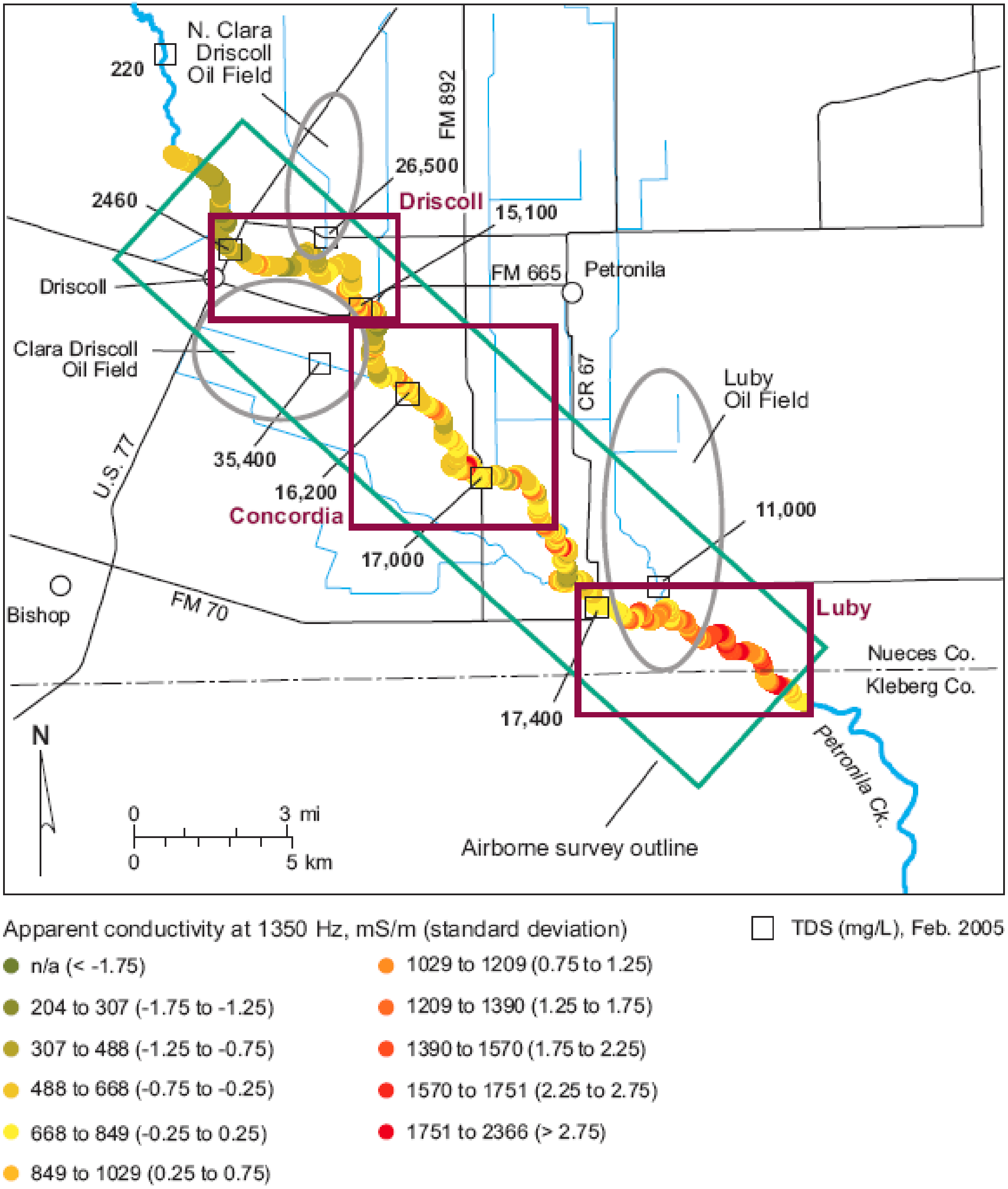
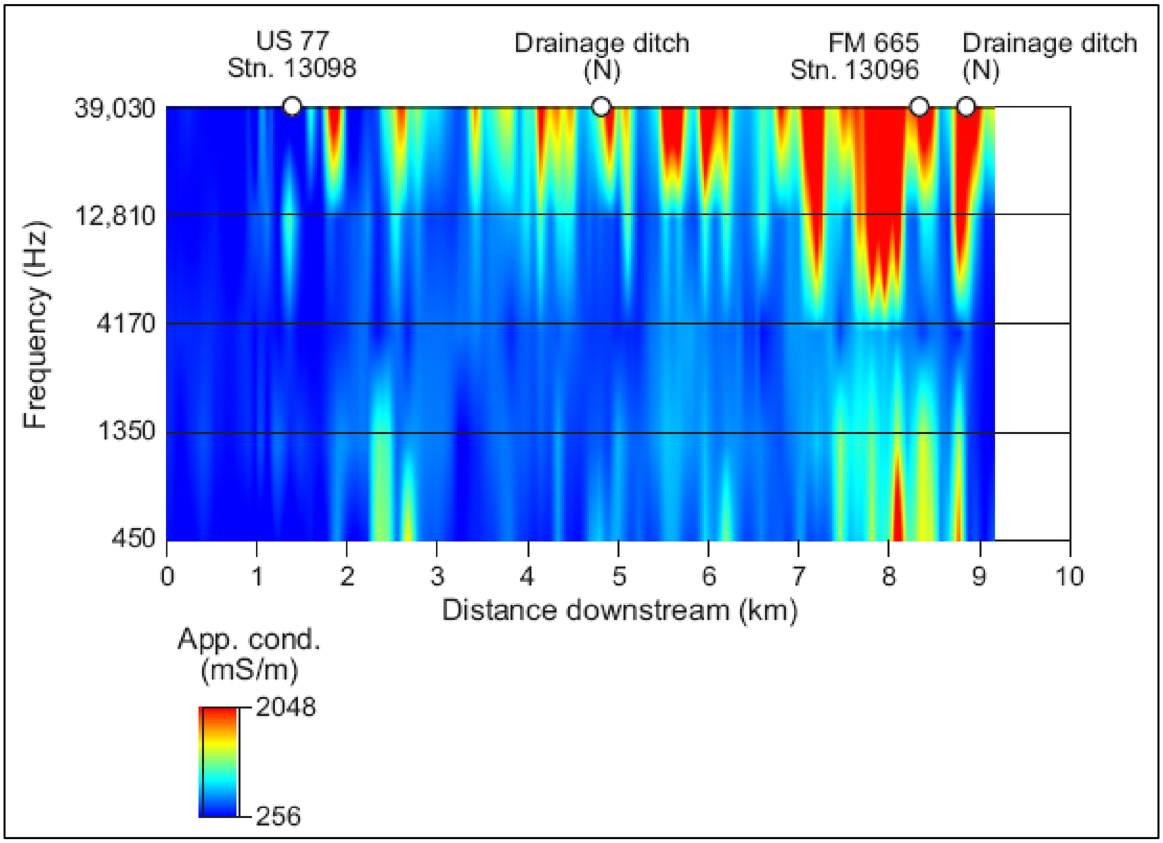


Figure 13: Areas of Elevated Conductivity Measured in Petronila Creek Impaired Reach

Concordia Area

The Concordia area encloses a 5.6-mile-long segment of Petronila Creek that begins about 0.6 miles downstream from FM 665 and continues to about 1.2 miles downstream from FM 892 (Figure 13). EM data shown on the pseudosection (Figure 15) indicate that the most conductive reach is about 3.7 miles long, extending from the upstream limit of the Concordia area to a point about 1.2 miles downstream from FM 892. Conductivities at the two highest frequencies are particularly high, implying highly conductive, near-surface strata beneath the creek. There are relatively few oil and gas wells within the

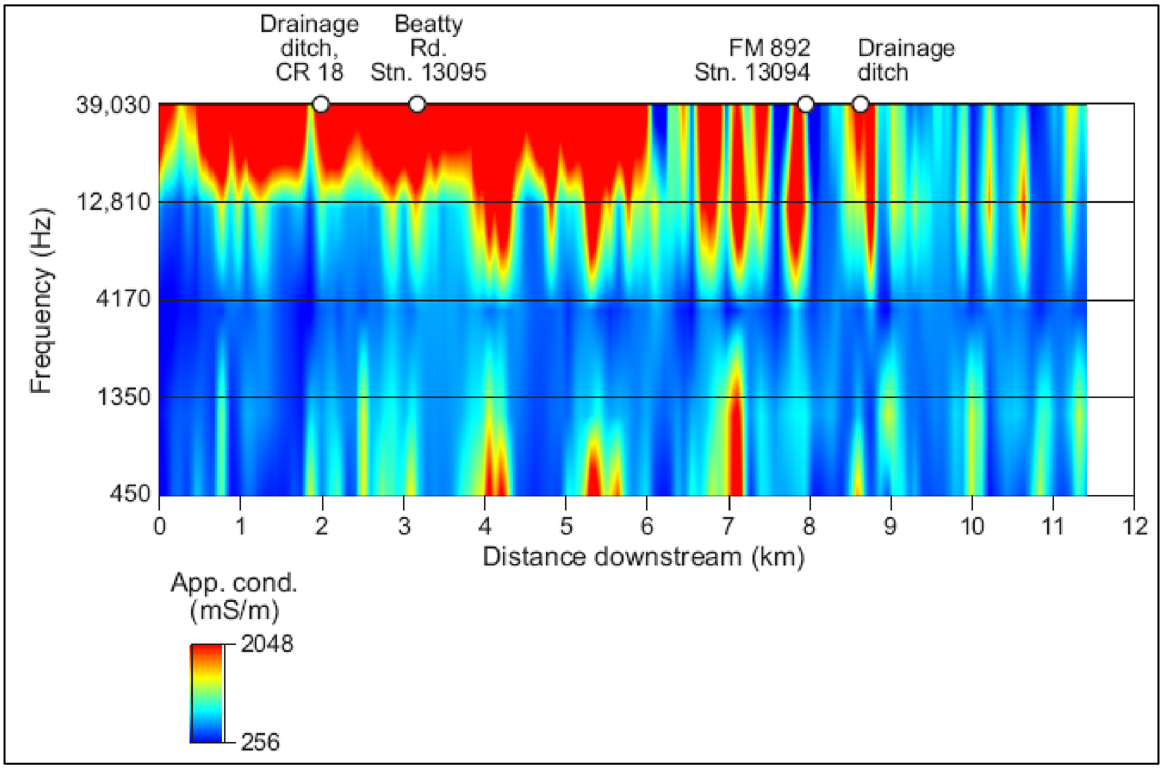
Concordia area, but there are at least two ditch-drainage systems that carried water produced from wells farther west across the area south of Petronila Creek. We interpret that the elevated conductivity south of Petronila Creek represents relatively shallow accumulations of saline produced water that was discharged into the drainage ditches when that practice was permitted and entered the subsurface along the ditches where they intersect the sandy Beaumont Formation channels. This water has migrated laterally toward Petronila Creek, providing locally sourced saline base flow to Petronila Creek.



Note: The shallowest-exploring frequency is along the top of the image and the deepest-exploring frequency is along the bottom.

Figure 14: Combined apparent conductivity pseudosection along the Driscoll reach using all frequencies acquired during the airborne stream-axis survey (UTBEG, 2005)

The BEG estimated salinity loading along the Concordia segment using EA's February 2005 sampling and analyses. Loading at the upstream end of the segment is represented by the 45,772 lbs/day TDS value calculated at FM 665 (station 13096). At the Beatty Road crossing (station 13095) within the upper part of the Concordia segment, flow had increased to 1.253 cubic feet per second at 16,200 mg/L TDS, representing a TDS load of 109,545 lbs/day, an increase of about 63,944 lbs/day above the value at FM 665.



Note: The shallowest-exploring frequency is along the top of the image and the deepest-exploring frequency is along the bottom

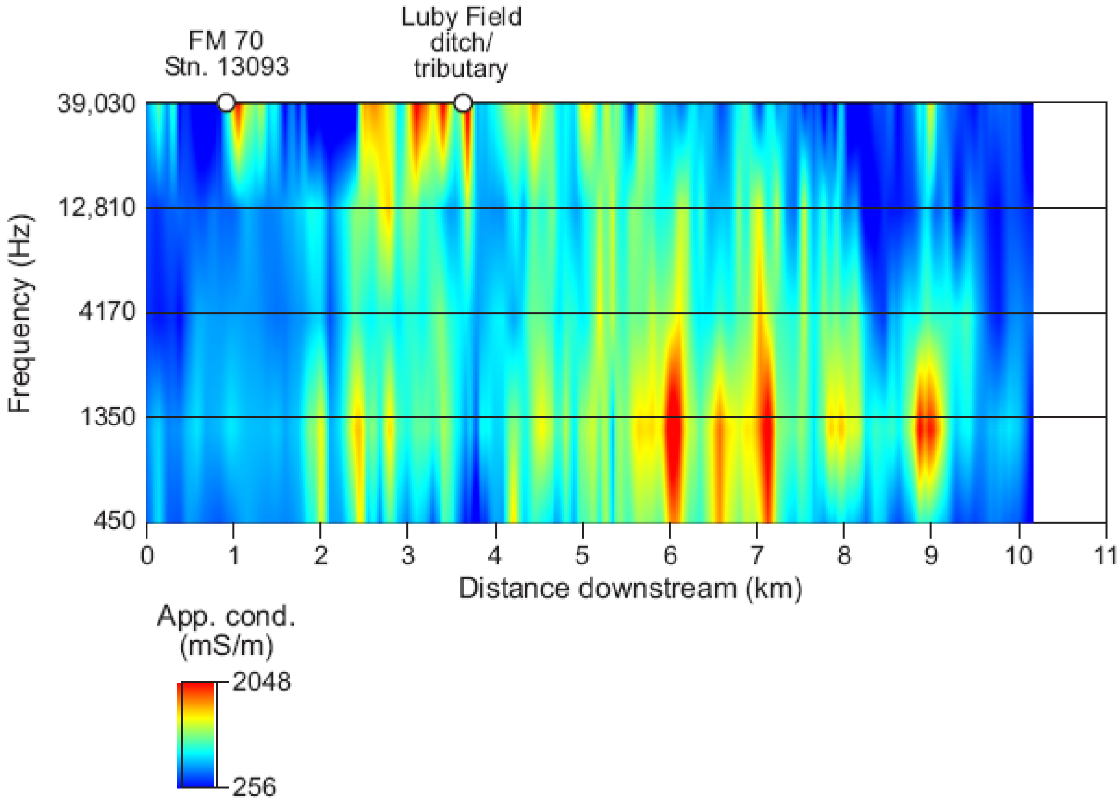
Figure 15: Combined apparent conductivity pseudosection along the Concordia reach using all frequencies acquired during the airborne stream-axis survey (UTBEG, 2005)

At FM 892 (station 13094) farther downstream within the Concordia segment, combining the flow of 1.974 cubic feet per second with the 17,000 mg/L TDS concentration translates to a TDS load of 181,003 lbs/day, an increase of more than 70,547 lbs/day from the Beatty Road crossing. Total loading increase along the Concordia segment was thus more than 134,481 lbs/day. Though these calculations were instantaneous and cannot realistically be used for meaningful annual loading calculations, the BEG interpreted that this increase is dominated by local-source, near-surface base flow from produced water that was once discharged into the two major drainage ditches crossing the area, entered the shallow subsurface along the ditches, and migrated toward the creek along sandy subsurface Beaumont Formation channels.

Luby Area

The Luby area differs from the Driscoll and Concordia areas in that the patterns are best developed in the lowest frequency (deepest exploring) data (Figure 16). Maps and sections produced from airborne geophysical data show a relatively distinct upstream boundary that crosses Petronila Creek near the FM 70 bridge and coincides with part of the Luby Oil Field.

Multi-frequency conductivity sections constructed from stream-axis conductivity profiles differ markedly from the Driscoll and Concordia sections, indicating relatively little evidence for shallow salinization and more pronounced elevated conductivity at the lower (deeper) frequencies. The BEG interpreted these data to suggest that this area may mark the upstream limit of the subsurface incursion of saline coastal water, rather than representing further significant addition of produced water to the stream environment.



Note: The shallowest-exploring frequency is along the top of the image and the deepest-exploring frequency is along the bottom.

Figure 16: Combined apparent conductivity pseudosection along the Luby reach using all frequencies acquired during the airborne stream-axis survey (UTBEG, 2005)

Minor amounts of produced water may reach this segment along drainage ditches from the Luby Oil Field area, but the elevated subsurface conductivities appear to be dominated by incursion of coastal saline water. There are insufficient data available to estimate possible TDS loading changes along this most downstream, coastal-influenced segment. At FM 70 (station 13093) at the upstream end of the segment, combining EA's February 2005 flow of 0.787 cubic feet with a TDS concentration of 17,400 mg/L translates to an incoming load of 73,861 lbs/day. The reduction in TDS load of more than 105,821 lbs/day from 181,003 lbs/day at the downstream limit of the Concordia segment to the Luby segment is thus likely caused by flow losses along the creek.

LINKAGE BETWEEN SOURCES AND RECEIVING WATERS

There has been significant oil and gas exploration and production activity in the watershed downstream of U.S. Hwy 77. As of September 2001, there were 1,875 documented oil and gas wells in Nueces County (EA Engineering et al, 2006). Active or once-active fields on or adjacent to the creek include the Clara Driscoll, North Clara Driscoll, and Luby oil fields. Records from the Railroad Commission of Texas indicate that 900 wells have been drilled within the boundary of the airborne geophysical survey. These include 359 active or plugged oil wells, 113 active or plugged gas wells, 215 active or plugged oil and gas wells, 187 dry holes, 16 injection or disposal wells, and 10 sidetrack wells.

Produced brine discharge into surface pits presumably ceased with the implementation of the Railroad Commission's no-pit order in 1969. The RRC no longer permitted discharge of produced water to area drainage ditches and streams beginning in 1987 (Shipley, 1991). Water produced from area oil fields is highly saline; Gaither (1986) reports a TDS concentration of 49,300 mg/L and chloride concentration of 28,904 mg/L in water produced from the Vicksburg Formation in the Clara Driscoll Oil Field. Shipley (1991) cites chloride concentrations of 36,500 to 55,700 mg/L in raw produced brines from the Petronila Creek area.

The past oil industry practice of discharging highly saline produced water at the surface into drainage ditches, pits, and Petronila Creek has been shown to have degraded surface-water quality and affected aquatic species in Petronila Creek (Shipley, 1991). In a study covering seven years during which produced brine was discharged directly or indirectly into the creek and one year of monitoring after permitted discharge ceased in 1987, Shipley (1991) showed that creek salinities remained high below U.S. 77 after discharge ceased, except at the most upstream station monitored, and pore-water salinities in creek-bottom sediments along the affected segment also remained high after discharge ceased, despite flushing storm events. Further, the chemical signature of saline water in Petronila Creek more closely matched that of discharged produced water than that of saline water in Baffin Bay downstream (Paine et al, 2005).

MARGIN OF SAFETY

The margin of safety (MOS) is a required component of the TMDL to account for any lack of knowledge concerning the relationship between effluent limitations and water quality. According to EPA guidance (*Guidance for Water Quality-Based Decisions: The TMDL Process, 1991*), the MOS can be incorporated into the TMDL using two methods:

- Implicitly incorporating the MOS using conservative model assumptions to develop allocations; or
- Explicitly specifying a portion of the TMDL as the MOS and using the remainder for allocations.

The MOS will be explicitly incorporated into this TMDL. An explicit margin of safety is more appropriate when there is some degree of uncertainty in input data and model results. In flow calibration, there was a good agreement between observed and simulated stream flows. However, model validation shows less robust flow calibration results, though still within acceptable range. Flow was calibrated using a reference station (paired watershed) in Oso Creek which introduces additional uncertainty. Consequently, a 5% explicit margin of safety was used to account for these uncertainties. Incorporating a MOS of 5% will require that allocation scenarios be designed to meet annual average sulfate, chloride, and TDS standards of 475, 1425, and 3800 mg/L, respectively (as compared to the segment-specific standards of 500, 1500, and 4000 mg/L).

POLLUTANT LOAD ALLOCATION

For Petronila Creek, the TMDL allocation analysis for chloride, sulfate, and TDS is the third stage in the overall TMDL development process. Its purpose is to develop the framework for reducing sulfate, chloride, and TDS loadings under the existing watershed conditions so water quality standards can be met. The TMDL represents the maximum amount of pollutant that the stream can receive without exceeding the water quality standard. The load allocations for the selected scenarios are calculated using the following equation:

$$TMDL = \sum WLA + \sum LA + MOS$$

Where

WLA = wasteload allocation (point source pollutant contributions);
LA = load allocation (nonpoint source pollutant contributions);
MOS = margin of safety; and
$\sum$ = summation.

Typically, there are several potential allocation strategies that would achieve the TMDL endpoint and water quality standards. Available control options depend on the number, location, and character of pollutant sources.

Allocation Scenario Development

Allocation scenarios that would reduce the existing sulfate, chloride, and TDS loads to meet the corresponding water quality standards were simulated using the Hydrological Simulation Program – FORTRAN (HSPF) model (Bicknell et al., 1993).

Wasteload Allocation

There are six permitted point source dischargers in the impaired reach of the Petronila Creek watershed. For this TMDL, the wasteload allocations for the dischargers were set equal to the water quality standards minus the MOS. The wasteload allocations are provided in Table 7. For this TMDL, the "existing condition" point source loads were calculated using the design flows and typical chloride, sulfate, and TDS concentrations ordinarily present in domestic wastewater effluent (50 mg/L, 30 mg/L and 105 mg/L, respectively) based on literature (Metcalf and Eddy, 1995). The allocated loads or percent reductions were calculated using the design flows and the water quality standards for chloride, sulfate, and TDS (1425 mg/L, 475 mg/L and 3800 mg/L, respectively) with five percent reserved for MOS. Table 7 shows the waste load allocations.

Load Allocation

The reductions of loading from nonpoint sources are incorporated into the load allocation, and include abandoned brine pits, produced water, and groundwater. A number of load allocation scenarios were run to identify various TMDL load allocations. First, a set of scenarios were designed and used to isolate and assess the reductions of chlorides. These scenarios, presented in Table 8, also apply to TDS since it is directly estimated from the chloride sources.

- Scenario 0 represents "base condition" loading, which shows no pollutant reduction of any of the sources, and point source contributions are computed based on the water quality standards. The base condition model is slightly different from the existing condition model. In the base condition model, the point source loads are computed based on design flows, the water quality standards, and the margin of safety. Point source loads in the existing condition model were computed using design flows and the typical concentrations of pollutants in the effluent. The non-point source loads for the base condition model are identical to those in the existing condition model.
- Scenarios 1 through 3 represent incremental reductions in loadings from abandoned brine pits and produced water. The intent is to assess the resulting effect of jointly controlling the abandoned brine pit and produced water sources of pollutants.
- Scenario 4 represents a complete reduction in loadings from the abandoned brine pits.
- Scenarios 5 through 8 represent an incremental reduction in loadings from the produced water in addition to a complete reduction in loadings from the abandoned brine pits.

Table 7: Petronila Creek Wasteload Allocation

Name of Facility	Existing Condition Loads Based on Avg Flow (lbs/day)			Allocated Loads Based on Design Flow (lbs/day)			Percent Reductions		
	Cl	SO_4	TDS	Cl	SO_4	TDS	Cl	SO_4	TDS
City of Agua Dulce	67	40	142	1903	634	5074	0	0	0
City of Orange Grove	83	50	177	2378	793	6342	0	0	0
Driscoll Plant, City of Driscoll	42	25	89	1189	396	3171	0	0	0
Banquete Plant, Nueces CO WCID 5	42	25	89	1189	396	3171	0	0	0
City of Coastal Bend Youth City	6	4	13	178	59	476	0	0	0
Petronila Elementary	3	2	7	95	32	254	0	0	0

Table 8: Load Allocation Scenarios for Chlorides and TDS in Petronila Creek

Scenario	Chloride, Sulfate and TDS Reduction in Loadings from Existing Conditions (%)		
	Abandoned brine Pits	Produced Water	Groundwater
0	0	0	0
1	25	25	0
2	50	50	0
3	75	75	0
4	100	0	0
5	100	50	0
6	100	75	0
7	100	78	0
8	100	88	0

Table 9: Petronila Creek Load Reduction Analysis

Scenario Number	Reduction in Loadings from Existing Conditions (%)			Percent of Time that Simulated Annual Average Exceeded the Water Quality Standard		
	Abandoned Brine Pits	Produced Water	Groundwater	Chlorides	Sulfates	TDS
0	0	0	0	100	100	100
1	25	25	0	100	100	100
2	50	50	0	100	100	100
3	75	75	0	100	5	98
4	100	0	0	100	100	100
5	100	50	0	100	100	100
6	100	75	0	100	5	98
7	100	78	0	100	0	71
8	100	88	0	0	0	0

For the hydrologic period spanning from January 2000 to December 2004, the sulfate, chloride, and TDS simulated concentrations were compared against the corresponding standards to estimate the number and frequency of exceedances. Table 9 summarizes the results for all the scenarios.

The following conclusions can be made:

1) Under the base condition (Scenario 0) loadings, the water quality standards were exceeded 100% of the time for chloride, sulfate and TDS ;
2) Elimination of loadings from the abandoned brine pits (Scenario 4) would result in no reduction in the percent exceedance of the water quality standards;
3) Elimination of loadings from the abandoned brine pits and a reduction of 75% from the produced water (Scenario 6 for) would result in a 100 percent ex-

ceedance of the chloride standard, 5% exceedance of the sulfate standard, and 98% exceedance of the TDS standard; and

4) To meet the water quality standard for sulfate a complete (100%) load reduction from the abandoned brine pits and a 78% load reduction from produced water is required (Scenario 7).
5) To meet the water quality standard for chlorides and TDS a complete (100%) load reduction from the abandoned brine pits and an 88% load reduction from the produced water is required (Scenario 8).

Scenario 7 was used to derive the sulfate load allocation plan. Scenario 8 was used to derive the chloride and the TDS load allocation plans.

TMDL Summary

Based on the analysis of the load allocation scenario, a TMDL allocation plan to meet the respective water quality standard goals requires:

- 100% reduction of loading from abandoned brine pits, and;
- 88% reduction of loading from the produced water.
- Overall, the loading from nonpoint sources of chloride and TDS must be reduced by 88% and the loading of sulfate must be reduced by 78% to meet the goal.

Figures 17 through 19 show the modeled chloride, sulfate, and TDS concentrations at station 13093 with the applicable water quality standards. Station 13093 is located at the downstream end of Petronila Creek, and is the most appropriate location for an index site to gage the future trends of salinity in Petronila Creek. These plots show that the water quality standards are not violated under the TMDL allocation scenario. A summary of the sulfate, chloride, and TDS TMDL allocation loads for Petronila Creek is presented in Table 10.

TMDL Expressions

The total load allocations, wasteload allocations, and margins of safety for chloride, sulfate and TDS are summarized in Tables 11 and 13. The background chloride, sulfate and TDS loads are included in groundwater and surface runoff contributions and explicitly considered in LA allocations. The sum of WLA and LA is divided by 0.95 to obtain the TMDL. The margin of safety (MOS) is calculated by subtracting WLA and LA from the TMDL.

PUBLIC PARTICIPATION

The TCEQ maintains an inclusive public participation process. From the inception of the investigation, the project team sought to ensure that stakeholders were informed and involved. The project team also recognized that communication and comments from stakeholders in the watershed would strengthen the project and its implementation actions.

In accordance with requirements of law promulgated in 2001 under TX House Bill 2912, an official steering committee of stakeholders was established and notices of meetings were posted on the TCEQ calendar and in the *Texas Register*. Two weeks prior to sched-

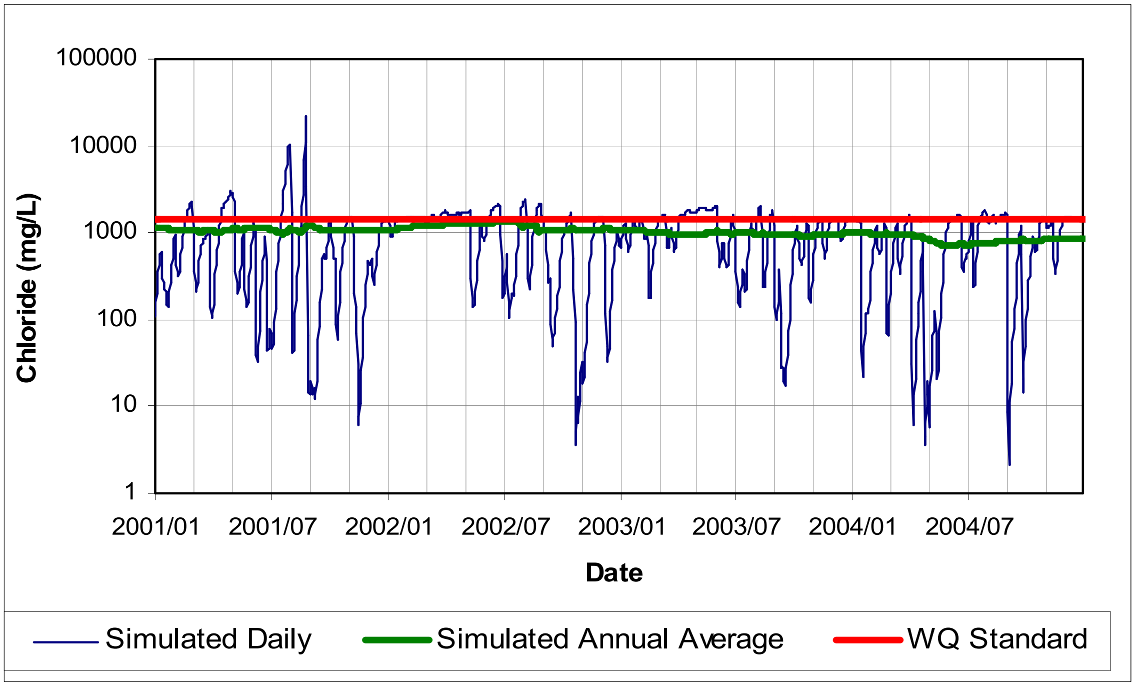


Figure 17: Simulated Chloride Concentrations at Station 13093 under TMDL Allocation

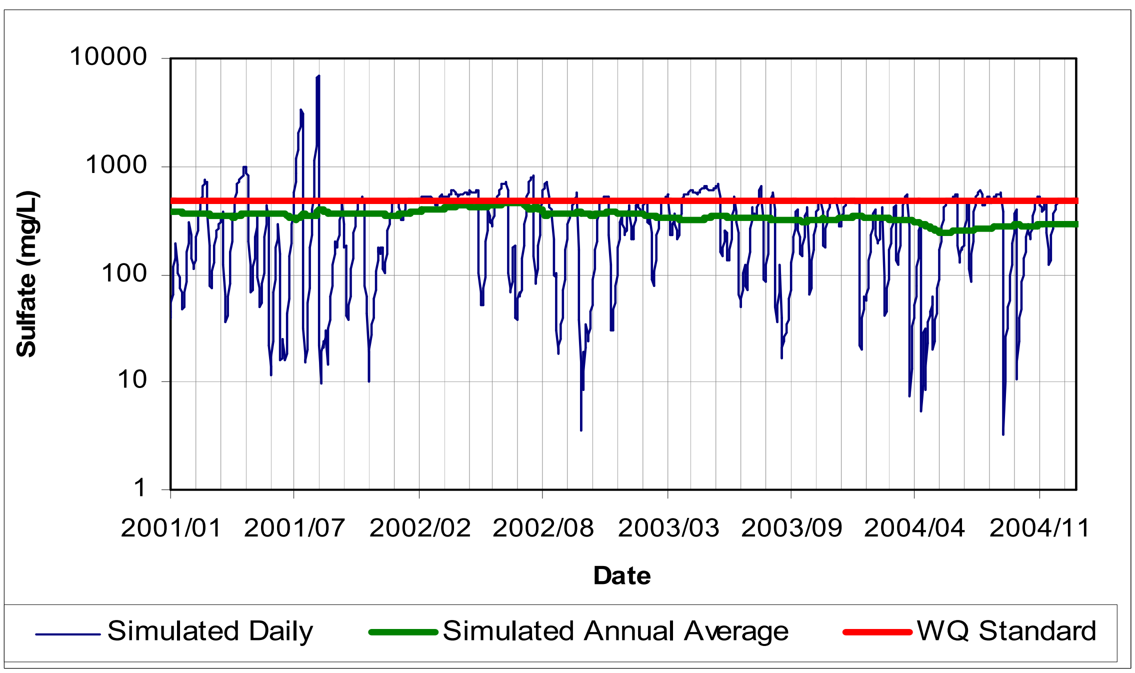


Figure 18: Simulated Sulfate Concentrations at Station 13093 under TMDL Allocation

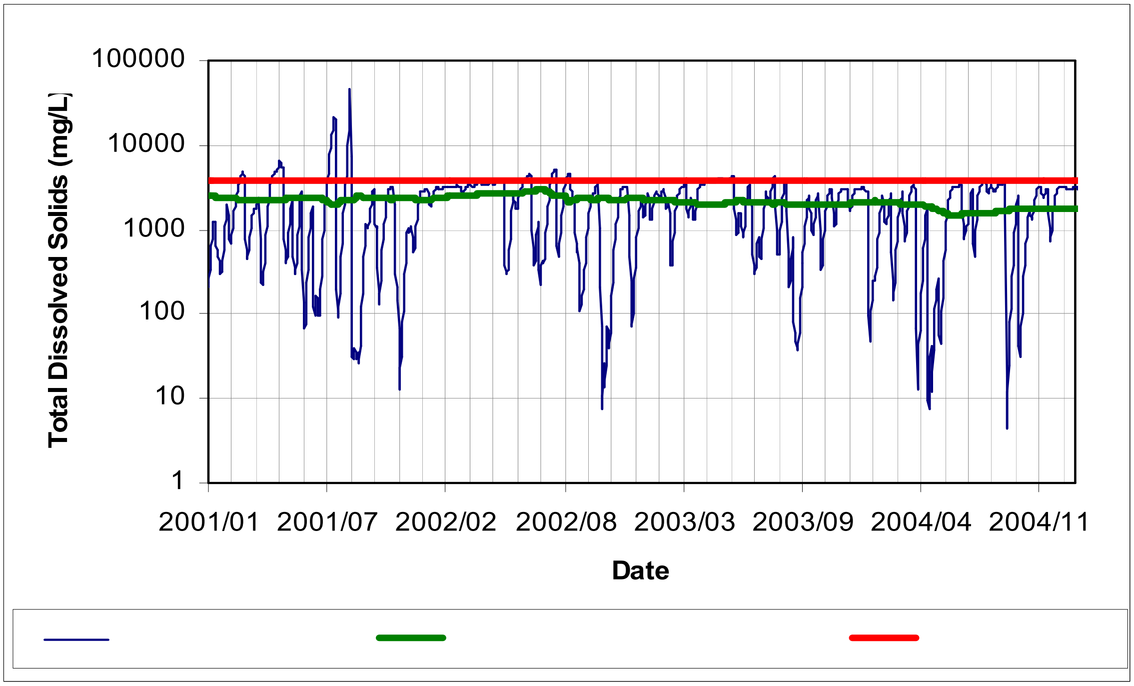


Figure 19: Simulated TDS Concentrations at Station 13093 under TMDL Allocation

Table 10: TDS, Chloride, and Sulfate TMDL Allocation Load Distributions by Source

Source	Annual Average Loads (lbs/Year)					
	Chlorides	**% Total**	**Sulfates**	**% Total**	**TDS**	**% Total**
Abandoned Brine Pits	0.00E+00	0.00%	0.00E+00	0.00%	0.00E+00	0.00%
Produced Water	3.78E+07	85.25%	8.98E+06	46.09%	8.04E+07	90.69%
Groundwater	5.17E+04	0.12%	8.56E+05	4.39%	1.10E+05	0.12%
Other Background Sources	1.74E+06	3.92%	8.67E+06	44.50%	3.70E+06	4.17%
Point Sources	2.53E+06	5.71%	2.31E+03	0.01%	1.85E+04	0.02%
Margin of Safety*	2.22E+06	5.00%	9.74E+05	5.00%	4.43E+06	5.00%
Total	**4.43E+07**	**100%**	**1.95E+07**	**100%**	**8.87E+07**	**100%**

*Margin of safety taken as 5% of all the allocations (see Margin of Safety)

Table 11: Chloride TMDL

TMDL (lbs/year)	WLA (lbs/year)	LA (lbs/year)	MOS (lbs/year)
4.43E+07	2.53E+06	3.96E+07	2.22E+06

Table 12: Sulfate TMDL

TMDL (lbs/year)	WLA (lbs/year)	LA (lbs/year)	MOS (lbs/year)
1.95E+07	2.31E+03	1.85E+07	9.74E+05

Table 13: TDS TMDL

TMDL (lbs/year)	WLA (lbs/year)	LA (lbs/year)	MOS (lbs/year)
8.87E+07	1.85E+04	8.42E+07	4.43E+06

uled meetings, media releases were initiated and steering committee stakeholders were formally invited to attend. To ensure that absent stakeholders and the public were informed of past meetings and pertinent material, a project web page was established to provide meeting summaries, presentations, ground rules, and a list of official steering committee stakeholders.

Throughout the term of the project, from 2002 to 2006, a total of seven meetings were held in Robstown, in Nueces County. Based on interest and attendance, meetings were held in both the afternoon and evening. The objectives of the first stakeholders meeting were to:

- Introduce the project team and summarize the public participation process.
- Define what the project was intended to accomplish.
- Provide historical monitoring data, information, issues, and potential sources.

During the first meeting in September of 2002, the project team received and responded to a number of questions and comments which were taken into account when developing the sampling plan. The objectives of the second stakeholders meeting were to:

- Inform the stakeholders on the status of work being performed on the project.
- Provide information on the TMDL stakeholder process; specifically, involvement, consultation, and collaboration.
- Provide information on the monitoring plan and monitoring schedule.
- Provide information on of the project's phases; specifically, historical data review, data collection, modeling, approval, and implementation.

During the second meeting in December of 2003, the project team received a number of constructive comments and suggestions. The objectives of the third stakeholders meeting were to:

- Inform the stakeholders on the status of work being performed on the project.
- Provide a survey questionnaire to assist in evaluating how effective the information about the project is being understood by the stakeholders and the public
- Provide information and data to summarize results.

- Inform stakeholders about a prospective study through the BEG to conduct electromagnetic surveys on Petronila Creek.
- Provide information on the selected model, the Hydrologic Simulation Program Fortran (HSPF), and its process.

During the third meeting in April of 2004, the project team received a number of informative comments and suggestions. The objectives of the fourth stakeholders meeting were to:

- Inform the stakeholders on the status of work being performed on the project.
- Provide information about Phase I of the BEG electromagnetic conductivity survey study.
- Provide an update on the status of the modeling phase of the project.

During the fourth meeting in December of 2004, the project team received a number of questions and comments concerning the project and the BEG study. The objectives of the fifth stakeholders meeting were to:

- Provide information on the stakeholder goals and the public participation process.
- Provide a re-cap of the TMDL process.
- Present results of the airborne geological survey.

During the fifth meeting in June of 2005, the project team received a great deal of comments and questions. The BEG electromagnetic conductivity survey results were posted on the project web page. The objectives of the sixth stakeholders meeting were to:

- Summarize the last three years of progress on the TMDL project.
- Present a re-cap of data including the most recent sample collection.
- Present an abbreviated version of results from the airborne geophysical survey performed in January 2005, and make interpretations about the mechanisms of the contamination.
- Present a re-cap of the TMDL process, model, and draft TMDL.
- Provide an overview of Texas Watch and proposed education and outreach for the watershed to address illegal dumping.
- Speak about a RRC project to address salinity; specifically, abatement practices and remediation.

During the sixth meeting in July of 2005, the project team received a great deal of comments concerning the project, specifically concerning the RRC and Texas Watch. The objectives of the seventh stakeholders meeting were to:

- Provide information on the draft TMDL and load allocation.
- Provide information on Texas Watch and progress toward education and outreach concerning illegal dumping.

IMPLEMENTATION AND REASONABLE ASSURANCES

The TMDL development process involves the preparation of two documents:

1) a TMDL, which determines the amount of pollutant a water body can receive and continue to meet applicable water quality standards, and
2) an implementation plan, which is a detailed description and schedule of regulatory and voluntary management measures necessary to achieve the pollutant reductions identified in the TMDL.

It is the policy of the TCEQ to develop implementation plans for all TMDLs adopted by the commission, and to assure the plans are implemented. Implementation plans are not subject to EPA approval.

During TMDL implementation, the TCEQ works with stakeholders to develop the management strategies needed to restore water quality to an impaired water body. This information is summarized in a TMDL implementation plan (I-Plan), which is separate from the TMDL document. Preparation of an I-Plan is critical to ensure water quality standards are restored and maintained.

Several implementation activities have already been initiated during the later phase of the TMDL project to achieve pollutant reductions.

1) The EPA has awarded a nonpoint source grant through the TCEQ to the RRC for the investigation of the nature and extent of known salinity contamination thought to be contributing to water quality problems in Petronila Creek, the development of remediation and/or abatement alternatives or BMPs, and the implementation of the BMPs.
2) The Nueces River Authority, Nueces County, Coastal Bend Council of Governments, and Texas Watch will coordinate restoration actions to remove refuse that has been illegally dumped in the watershed, community river-cleanup events, and development of education outreach and media exposure.
3) The TCEQ Continuous Water Quality Network and Nueces River Authority will deploy a continuous monitor to measure specific conductivity hourly at water quality station 13093, Petronila Creek at FM 70. A link to continuous water quality data will be provided to the RRC to assist in enforcing oil and gas well compliance in the watershed.

Preparation of the implementation plan for Petronila Creek will begin upon commission approval of the TMDL. The I-Plan will detail any activities such as mitigation measures, permit actions, best management practices, and additional sampling and monitoring determined to be necessary to restore water quality. Additional sampling at appropriate locations and frequencies will allow tracking and evaluation of progress toward the targeted and primary endpoints. These steps will provide reasonable assurances that the regulatory and voluntary activities necessary to achieve the pollutant reductions will be implemented.

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