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Water-Quality Assessment of the Trinity River Basin, Texas—Nutrients in Two Coastal Prairie Streams Draining Agricultural Areas, 1994–95

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Introduction

In 1991, the U.S. Geological Survey (USGS) began nationwide implementation of the National Water-Quality Assessment (NAWQA) Program. Long-term goals of NAWQA are to describe the status of and trends in the quality of a large, representative part of the Nation's surface- and ground-water resources and to provide a sound, scientific understanding of the primary natural and human factors affecting the quality of these resources (Leahy and others, 1990). The Trinity River Basin in east-central Texas (fig. 1) was among the first 20 hydrologic areas, called study units, to be assessed by this program. The first intensive data-collection phase for the Trinity River Basin NAWQA began in March 1993 and ended in September 1995. Streams in the Trinity River Basin were assessed by sampling water, bed sediment, and tissue of biota and characterizing the aquatic communities and their habitat. Aquifers were assessed by sampling water from wells.

The coastal prairie is a small part of the Trinity River Basin, but it is environmentally important because of its proximity to Galveston Bay and the extensive use of agricultural chemicals on many irrigated farms. Galveston Bay (fig. 1) was selected by Congress as an estuary of national significance and was included on a priority list for the National Estuary Program. The Trinity River is especially important because its watershed dominates the total Galveston Bay drainage area and because its flow contributes substantial amounts of freshwater and water-quality constituents to the bay. Historically, measurements of the quantity and quality of water entering Galveston Bay from the Trinity River Basin have been made using data from a station about 113 kilometers (70 miles) upstream from Trinity Bay, an inlet bay to Galveston Bay.

With a focused objective of providing additional water-quality information in the intervening coastal prairie area and an overall objective of improving the understanding of the relations between farming practices and stream quality in the Trinity River Basin, a special study was conducted. This report provides a description of the occurrence and concentrations of nutrients in two streams in this intervening area. An earlier report by Brown (1996) describes the occurrence and concentrations of pesticides in these two streams. An overall analysis of nutrient data collected during 1974–91 in the Trinity River Basin is given by Van Metre and Reutter (1995).

Study Area

The extreme southern part of the Trinity River Basin is known as the coastal prairie and has almost level relief, clay-rich soils, and a subtropical climate. The area receives an average of 134 centimeters (53 inches) of rainfall per year. During calendar year 1994, 152 centimeters (60 inches) of rain fell at Anahuac and 178 centimeters (70 inches) fell in the Dayton area (National Oceanic and Atmospheric Administration, 1994). The coastal prairie is the only area within the river basin where there is extensive irrigation of farmlands. Historically, the coastal prairie has been a major producer of rice, cattle, oil, and natural gas. Because of the water requirements for growing rice and because the area is flood prone, a complex network of water-delivery canals and drainage canals has been built. These canals along with roadways have greatly altered the natural drainage of the flat terrain.

Two watersheds, East Fork Double Bayou and West Prong Old River (or simply East Fork and West Prong), were selected to characterize the quality of water draining agricultural areas of the coastal prairie. The location of these watersheds is shown in figure 1. The drainage areas and major crops are listed in table 1. In 1994, the two watersheds had more than one-half of their area in cropland, pasture, and rangeland. However, the area is in a transition because of a decline in the agricultural economy. The result has been a decline in cropland and an increase in abandoned farms, pasture, rangeland, industry, and home sites.

East Fork is on the east side of the Trinity River, drains directly into Trinity Bay, has clay soils, and is the larger watershed. Rice is the dominant crop. Cattle are raised in the pasture areas, especially in the headwaters area. West Prong drains into the Trinity River from the west and has soils ranging from clay

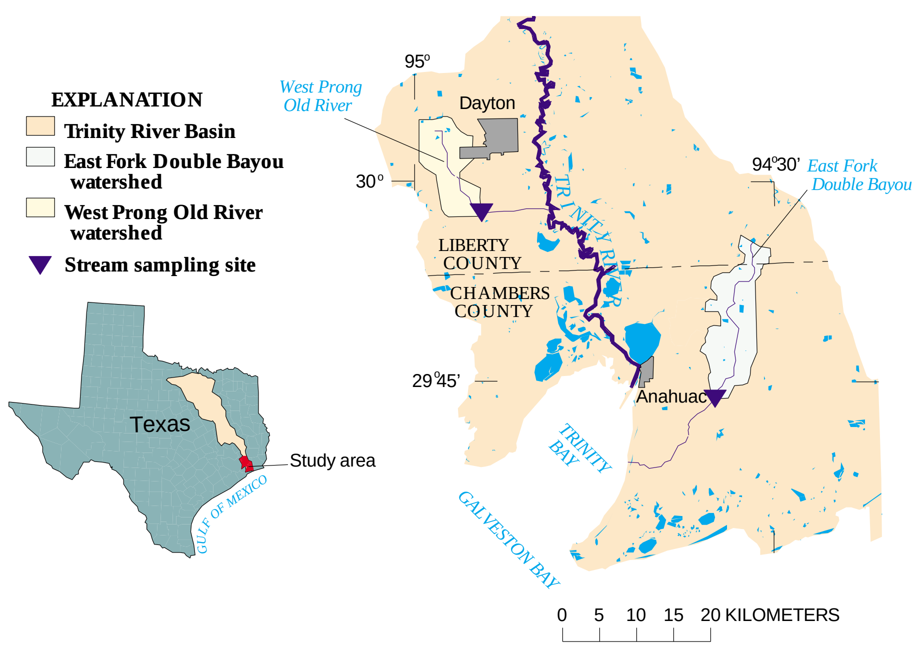

Figure 1. Location of Trinity River Basin, coastal prairie study area, and stream sampling sites.

Table 1. Watershed drainage areas and major crops

[km^2, square kilometers]

Watershed	Drainage area (km^2)	Crops (percentage of watershed area)		
		Rice	Sorghum	Soybeans
East Fork	112	10.5	0	0
West Prong	75	5.6	5.9	20

loam to clay. The West Prong watershed has a higher percentage of land in crop production and a greater variety of crops (mostly rice, sorghum, and soybeans) than the East Fork watershed. Other agricultural activities in the West Prong watershed include growing hay, turf, and nursery plants and cattle ranching. Rice is planted between April and mid-June, depending on the weather and variety. Sorghum is planted as early as the first part of March, and soybeans are planted in the May-to-June timeframe. Fertilizer generally is applied during April to July but varies with the crop, planting schedule, and weather. Most of the applications are in May and June when plants are in the stage of vigorous growth.

Detailed crop acreage was obtained by use of aerial photographs of the watersheds taken during the sampling period and by assistance from Consolidated Farm Service Agency (CFSA) officials in Liberty and Chambers Counties. The aerial photographs were originally printed at a scale of 1:24,000, and the watershed boundaries and crop information from the CFSA were overlain on the photograph (Zey, 1995). The three crops identified through the CFSA account for most of the cropland in the watersheds. Figure 2 shows the aerial photographs overlain with the watershed boundaries, streams, canals, and crops.

Sampling

Water samples were collected at a downstream site in each of the two watersheds from March 1994 through February 1995. Sampling frequency varied from weekly during part of the growing season (May and June) to once every 2 months during the winter. A total of about 20 samples from each site was available for analysis. Additional samples were collected to ensure consistent, reproducible results.

Water samples were analyzed at the USGS National Water-Quality Laboratory. In addition to nutrient analyses, laboratory analyses included major inorganic ions, pesticides, and suspended sediment. Field measurements included stream stage and discharge, water temperature, pH, dissolved oxygen, and specific conductance. Stream stage was measured three times per week at each site from April through September. These stage data were used to estimate discharge with a linear-regression equation that was calculated from paired stage and discharge measurements.

Nutrients in Two Coastal Prairie Streams

Nutrients in streams include several species of nitrogen and phosphorus. Their concentrations are affected by many environmental and human factors, such as season, rainfall, runoff, instream processes, soil types, land use, and proximity to sources.

Concentrations

The distribution of concentrations for total (dissolved plus suspended sediment) ammonia plus organic nitrogen, nitrate, and total nitrogen (nitrogen compounds) and for dissolved and

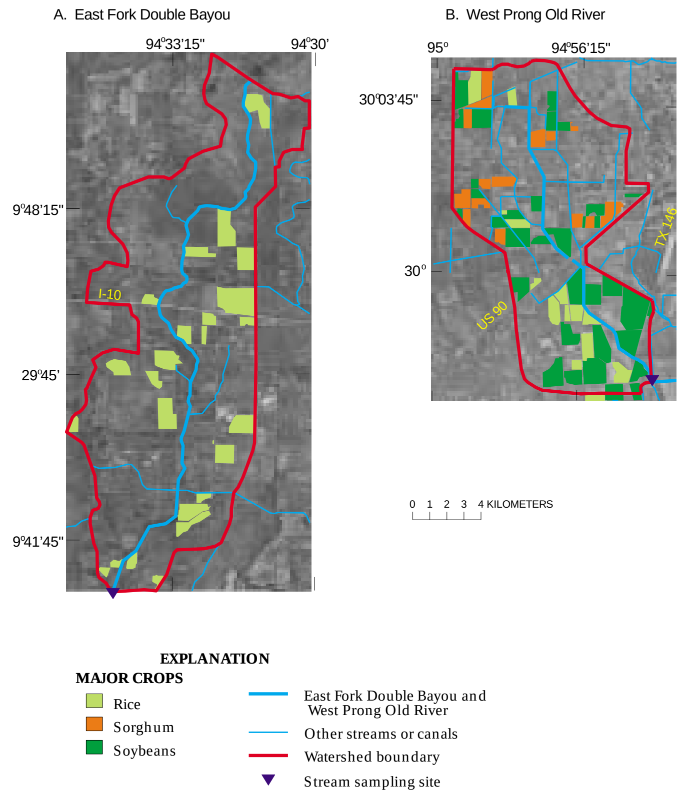

Figure 2. Aerial photographs overlain with watershed boundaries, streams, canals, and major crops, March 1994–February 1995.

total phosphorus are shown in figure 3. Concentrations of total ammonia plus organic nitrogen [known as total Kjeldahl nitrogen (TKN)] in both streams were less than 1.0 mg/L (milligram per liter) for 75 percent of the samples from both streams. Nitrate concentrations as nitrogen were less than 0.15 mg/L for more than one-half the samples from both streams. Concentrations of total nitrogen equal to or less than 1.0 mg/L occurred in 50 percent of the samples from East Fork and 75 percent of the samples from West Prong. The maximum concentration of total nitrogen of all samples was 4.8 mg/L from East Fork. Total nitrogen is generally composed of more than 80 percent TKN.

Concentrations of total phosphorus were less than 0.1 mg/L for about 80 percent of the samples from East Fork and 75 percent of the samples from West Prong. The maximum total phosphorus concentration of all samples was 0.35 mg/L from West Prong. At the median concentration, dissolved phosphorus makes up about one-half the total phosphorus from both streams.

On the basis of these samples, concentrations of nitrogen compounds were greater in East Fork where rice is the dominant crop, and concentrations of phosphorus compounds were greater in West Prong where there is more of a variety of crops. For nitrate, the maximum concentration of all the samples was 4.8 mg/L, which is less than one-half of the U.S. Environmental Protection Agency (1996) Maximum Contaminant Level for drinking water. To avoid excessive algae and other aquatic plant growth, the U.S. Environmental Protection Agency (1986) recommends that total phosphorus be less than 0.1 mg/L in streams except where they enter lakes and reservoirs; there, the concentrations should be less than 0.05 mg/L. About 20 percent of the samples contained more than 0.1 mg/L of total phosphorus, but about 80 percent contained more than 0.05 mg/L of total phosphorus.

Relation to Seasons

The seasonality of nutrient concentrations is shown by graphing the concentrations of total nitrogen and total phosphorus over time for the two sites (fig. 4). The data plots show that concentrations of total nitrogen and total phosphorus have seasonal highs during May and June. The seasonal pattern of total nitrogen shows an increase from an average of 0.8 mg/L during March, April, and July–February to 1.5 mg/L during May and June. For the same time periods and sampling sites, the average concentrations of total phosphorus increased from 0.07 to 0.12 mg/L. The seasonally high concentrations followed a number of small runoff events and one large runoff event in early May. Runoff events in August and September did not seem to cause a subsequent change in nutrient concentrations. A small runoff event in October appears to have caused an increase in phosphorus concentrations at both sites, but the sampling was too infrequent to identify a pattern. These seasonally high patterns of nutrient concentrations in the two streams generally coincide with the timing of fertilizer applications.

Loads

Whereas constituent concentrations define the levels of the nutrients in the stream, constituent loads define the total amount of nutrients being transported by the streams for a given period. The annual loads (March 1994–February 1995) of total nitrogen and total phosphorus for the two streams were estimated using the "unbiased stratified ratio estimator" method (Thomann and Mueller, 1987). This method uses the concentrations and discharges measured during sampling along with the mean discharge for the period to determine the load. It also allows for the data to be divided into two or more seasons to account for variable flow or concentrations. In this case, May and June were selected to represent one season when concentrations are typically higher, and the remaining months represent a second season when concentrations are typically lower.

Estimates of fertilizer applications were made for the three major crops grown in the coastal prairie area. These estimates were made by multiplying the area planted for a given crop in each watershed by application rates used by the Texas Agricultural Extension Service as typical applications for estimating crop-production costs (Texas Agricultural Extension Service, 1991). No estimates were made for fertilizers applied by homeowners and farmers growing crops such as hay, fruits, nuts, and turf because these amounts are believed to be insignificant in comparison to the application of fertilizers to the three major crops.

As shown in table 2, loads of total nitrogen and total phosphorus for East Fork were about 20 and 12 percent of the fertilizer applications to the major crop in the watershed, which is rice. For West Prong, loads of total nitrogen and total phosphorus were about 13 and 9 percent of fertilizer applications to the major crops (rice, sorghum, and soybeans) in this watershed. The percentage of fertilizers lost to the stream from the fields

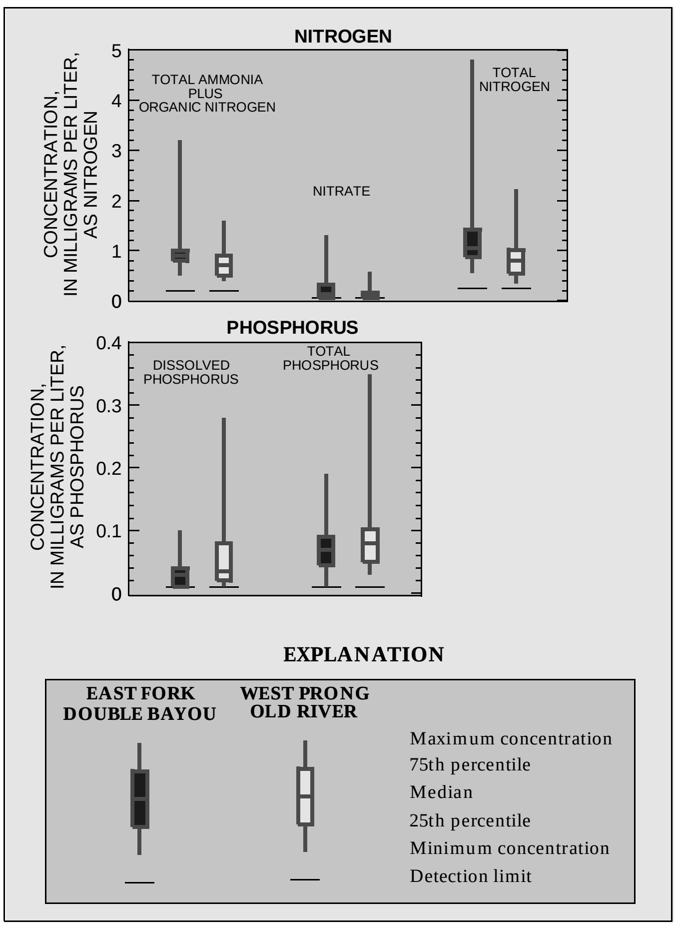

Figure 3. Distribution of nutrient concentrations, March 1994–February 1995.

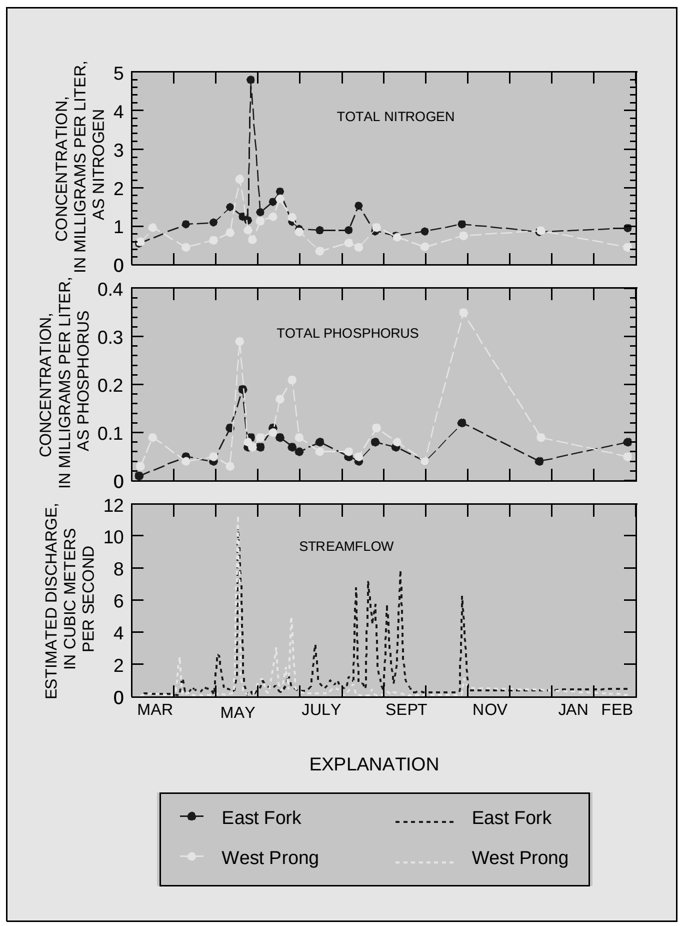

Figure 4. Seasonal pattern of nutrient concentrations and streamflow, March 1994–February 1995.

growing these major crops would be somewhat less than the amounts shown in table 2 because there are other sources of nutrients in streams such as fertilizer applied to other crops, landscape plants, and lawns and also manure from livestock.

Table 2. Estimated fertilizer applications to major crops and estimated loads of nutrients in two coastal prairie streams, March 1994–February 1995

[kg/yr, kilograms per year]

Stream/nutrient	Estimated fertilizer application to major crops (kg/yr)	Estimated nutrient load—all sources (kg/yr)	Percentage of fertilizer applications leaving watersheds by streams
East Fork			
Total nitrogen	210,000	42,000	20
Total phosphorus	28,000	3,500	12
West Prong			
Total nitrogen	120,000	16,000	13
Total phosphorus	28,000	2,600	9

Summary

Water-quality samples were collected from East Fork Double Bayou and West Prong Old River in the coastal prairie area immediately upstream from Trinity Bay from March 1994 to February 1995. Rice is grown in the East Fork Double Bayou watershed; and rice, sorghum, and soybeans are grown in the West Prong Old River watershed. Results of sampling include the following:

- Total nitrogen concentrations were equal to or less than 1.0 mg/L in 50 percent of the samples from East Fork and in 75 percent of the samples from West Prong. Nitrate as nitrogen was less than 0.15 mg/L in more than one-half the samples from both streams. Total nitrogen generally comprised more than 80 percent total ammonia plus organic nitrogen.
- Total phosphorus concentrations were less than 0.1 mg/L for about 80 percent of the samples from East Fork and for about 75 percent of the samples from West Prong. At the median concentration from both streams, dissolved phosphorus made up about one-half of the total phosphorus.
- Total nitrogen and total phosphorus exhibited a seasonality with higher concentrations occurring in May and June. However, the average concentrations from the two streams during these 2 months were less than two times the concentrations during other times of the year. These seasonally high patterns of nutrients in the two streams generally coincided with the timing of fertilizer applications.
- Loads of total nitrogen in the two streams ranged from 13 to 20 percent of the fertilizer applied to major crops in the associated watersheds. Loads of total phosphorus ranged from 9 to 12 percent of the fertilizer applied to major crops. The percentage of fertilizers lost to the streams from the fields growing these major crops would be somewhat less than these amounts because there are other sources of nutrients in streams.

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Information on technical reports and hydrologic data related to the NAWQA Program can be obtained from:

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In 1991, the U.S. Geological Survey, U.S. Department of the Interior, began a National Water-Quality Assessment (NAWQA) Program. The long-term goals of the NAWQA Program are to describe the status of and trends in the quality of a large representative part of the Nation's surface- and ground-water resources and to identify the major factors that affect the quality of these resources. In addressing these goals, NAWQA will produce water-quality information that is useful to policymakers and managers at Federal, State, and local levels.

Studies of 60 hydrologic systems that include parts of most major river basins and aquifer systems are the building blocks of the national assessment. The 60 study units range in size from less than 1,000 to more than 60,000 square miles and represent 60 to 70 percent of the Nation's water use and population served by public water supplies. Twenty investigations began in 1991, 15 investigations began in 1994, and 20 are scheduled to begin in 1997.