UNITED STATES DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
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The Woodlands, TX 77385

To: Caimee Schoenbaechler, Texas Water Development Board

From: Michael Lee, Zulimar Lucena

U.S. Geological Survey, Oklahoma-Texas Water Science Center

Subject: Progress Summary of Coastal Inflows Project

Dear Ms. Schoenbaechler,

The attached memo is a summary of the progress for the Coastal Inflows Project activities undertaken during agreement #1900012323. In general, the overall project goal was to provide new data to the scientific community and stakeholders regarding freshwater inflows, sediment, and nutrient concentrations and loads entering Texas bays and estuaries across a range of hydrologic conditions for select rivers.

This project started as a data collection program on the Trinity River Basin in 2009 evaluating freshwater inflow, suspended-sediment and nutrients entering Galveston Bay. It has grown into a monitoring network used for quantifying freshwater inflow, nutrient and suspended-sediment entering various Texas bays and estuaries. In addition to the collection of discrete samples, the data collection program includes the application of the sediment acoustic index method for computing continuous suspended-sediment concentrations. The monitoring network includes the following basins: Trinity River, Colorado River, Guadalupe-San Antonio River, and Nueces River. Each of the basins are at a different level of maturity, ranging from the initial demonstration of capabilities to having established real time suspended-sediment concentration estimates that are published on the USGS website. Further, leveraging other USGS program activities has seen this effort expand into the San Jacinto River and additional stations in the Trinity River in 2022.

The USGS thanks Texas Water Development Board for their continued collaboration on this important project. The data collected from this project is instrumental for the stewardship of Texas bays and estuaries. The status of each basin is further discussed below.

In cooperation with the Texas Water Development Board

Progress Summary for Texas Water Development Board Agreement #1900012323

U.S. Department of the Interior
U.S. Geological Survey

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Background

Estuarine ecosystems depend on freshwater inflows to maintain adequate salinity, nutrients, and sediment levels to support healthy ecosystem function and diverse biological communities. The delivery of freshwater into estuaries may be affected by alterations in the river course, including channelization and dam construction, resulting in changes in sedimentation patterns and biogeochemistry (Sklar and Browder, 1998). In Texas, the quantity of water flowing to the bays and estuaries is often influenced by withdrawals, diversions, and retention. The volume and timing of freshwater inflow typically influence nutrient and sediment loading into estuaries, affecting ecosystem communities (Sklar and Browder, 1998; Kimmerer, 2002). Periods of high flow in streams and rivers flowing into a coastal ecosystem are usually caused by local precipitation or releases from upstream reservoirs in response to precipitation upstream in the basin. The increase in rain and resultant flooding can increase sediment erosion and nutrient runoff into coastal rivers and consequently increase sediment and nutrient input into estuaries and bays.

Previous studies between the United States Geological Survey (USGS) and the Texas Water Development Board (TWDB) evaluated the sediment and nutrient concentration input of the Trinity River into Galveston Bay (beginning in 2009), the Guadalupe River into the San Antonio Bay System (beginning in 2012), the Colorado River into Matagorda Bay (beginning in 2013), and the Nueces River into the Nueces Bay System (beginning in 2016). In these river studies, the concentrations of suspended sediment, total nitrogen, and total phosphorus were compared to river discharge and turbidity measured at the time the discrete water-quality samples also were collected.

The previous work in these four river systems suggests that sediment and nutrient concentration response to hydrologic conditions vary among the river basins and according to the cause of increased flows (*e.g.*, reservoir releases versus local precipitation events). Variations in nutrient and sediment loading response to the bays can be event-specific and/or basin-specific; however, the data thus far supports the idea that large pulses of nutrients and sediments are transported to the bays during peak inflow periods. Therefore, the timing and supply of sediment and nutrients have the potential to significantly affect bay health and fisheries resources.

Results from these previous studies revealed a possible correlation between the concentrations of suspended sediment with in-situ measurements during periods of high flow at all stations. Additionally, a correlation between measures of turbidity and the strength of the returned pulse signal (backscatter) from an acoustic Doppler velocity meter (ADVM) suggests that backscatter data may be used as a proxy for suspended sediment concentration and potentially as a proxy to estimate certain nutrient concentrations. Results from these studies indicated that it may be possible to better understand the extent of sediment and nutrient loading to the bays using a combination of select discrete measurements of water-quality data with continuous measures of stream discharge and surrogate measures of sediment and nutrient concentrations.

The purpose of this study was to provide additional data and information to further the understanding of the variability of nutrient and sediment concentrations and loads entering select Texas bays and estuaries across a range of hydrologic conditions in four major river systems: Trinity River, Colorado River, Guadalupe-San Antonio River, and Nueces River. The objectives described herein build on previous work between the USGS and TWDB that evaluated the sediment and nutrient concentration input into Texas bays and estuaries. Data and information from this project can be used by scientists and stakeholders of the environmental flows process to validate or refine freshwater inflow standards.

Project methodology

Methodologies that are standard across all river systems are outlined within this section. Methods associated with a project task unique to a specific river system are described in more detail below in the relevant Objective Section.

Streamflow data collection

Streamflow is the volume of water passing an established reference point in a stream at a given time. Streamflow measurements were made using an acoustic Doppler current profiler (ADCP) as described in Mueller and others (2009). Additionally, the application of the index velocity method for computing continuous records of discharge is being evaluated or developed at each site. In the index velocity method, continuous records of stage and velocity are used to compute discharge records using two ratings developed from concurrent measurements of stage, velocity, and discharge. The index velocity method can be used at locations where stage-discharge methods are used, but it is especially appropriate when more than one specific discharge can be measured for a specific stage (Levesque and Oberg, 2012), such as tidally influenced areas.

The index velocity method uses an acoustic Doppler velocity meter (ADVM) to measure water velocity. It has been found that additional measurements made by ADVMs can be used to monitor suspended-sediment transport (Landers and others, 2016). Acoustic waves passing through a water-sediment mixture will scatter and attenuate as a function of fluid, sediment, and acoustic instrument characteristics. Acoustic backscatter, which is typically measured and recorded by ADVMs as a quality-assurance parameter, relates functionally to the characteristics of the sediment mixture (concentration, size, shape, and density). As a result, the backscatter measurement may be related to suspended-sediment concentration. ADVM technology is low maintenance and sturdy over a range of hydrologic conditions, and measured variables can be modeled to estimate suspended-sediment concentration, load, and duration of elevated levels on a real-time basis. The ADVMs installed at each site can estimate river discharge and provide a backscatter signal for estimating suspended sediment concentrations. The data are recorded in 15-minute intervals and then transmitted to the GOES satellite for display on the web and storage in the USGS National Water Information System (NWIS) database. The data are then used to continue developing index-velocity ratings and acoustic backscatter surrogate methodology for each major river.

Water-quality sample collection and analysis

Water-quality samples were collected and processed following standard USGS sampling methods as described in the National Field Manual for the Collection of Water-Quality Data (U.S. Geological Survey, variously dated). Water-quality and suspended-sediment samples were collected from a boat by either the equal discharge increment (EDI) or the multiple grab sample method (Edwards and Glysson 1999; U.S.

Geological Survey, variously dated). The EDI method allows the collection of an isokinetic depth-integrated sample that represents the discharge-weighted concentrations of the stream cross section being sampled. When measured mean water velocity exceeded 2.0 feet per second (ft/s), EDI samples were collected using a cable-suspended US DH–2 sampler after dividing a cross-section into five sections, each representing equal volumes of stream discharge. When measured mean water velocity was less than 2.0 ft/s, non-isokinetic grab samples were collected at the center of five equal width sections using a weighted bottle sampler (U.S. Geological Survey, variously dated). Field properties (water temperature, specific conductance, pH, dissolved oxygen concentration, and turbidity) were also measured at the sampling sites using a water-quality multi-probe instrument at the time of sampling.

Water-quality samples were composited in a polyethylene churn splitter, and sub-samples for whole-water analysis were drawn while churning at a standard rate. The churn splitter was used to allow for subsamples to be drawn while maintaining a uniform distribution of suspended material in the composite sample. Water samples for filtered nutrients were passed through a 0.45-micrometer (µm) pore-size filter pre-rinsed with deionized water. Whole-water (unfiltered) nutrient samples were preserved using 1 milliliter (mL) of 4.5N sulfuric acid.

Samples for nutrient analysis were chilled and shipped overnight to the National Water Quality Laboratory in Lakewood, CO. Nutrients samples were analyzed for selected parameters, including total phosphorus, orthophosphate, total nitrogen, total dissolved nitrogen, ammonia plus organic nitrogen, dissolved ammonia, nitrate plus nitrite, and nitrite. Methods for nutrient analysis are documented in Fishman (1993), U.S. Environmental Protection Agency (1993), Patton and Truitt (2000), and Patton and Kryskalla (2003, 2011). Suspended-sediment samples were shipped to the USGS Kentucky Water Science Center Sediment Laboratory or the USGS New Mexico Water Science Center Sediment Laboratory and analyzed for suspended-sediment concentration and particle size with methods described in Guy (1969).

Because stable isotopes of nitrate have been used as environmental tracers for examining sources of nitrate (Chang and others, 2002; McSwain and others, 2014), isotope samples were also collected as part of this study. Isotopic analysis of nitrate can aid in distinguishing atmospheric and synthetic fertilizer sources from organic fertilizer (animal manure) and septic sources. Isotopic analyses also can provide information on geochemical influences on nitrate in surface water, such as denitrification. The minimum concentration of nitrate needed in a sample to complete this analysis while maintaining a reasonable level of uncertainty is 0.06 mg/L. Samples were collected, frozen, and shipped to the Reston Stable Isotope Laboratory in Reston, VA. Methods for isotope analysis are documented in Coplen and others (2012).

Quality assurance and quality control

Quality assurance and quality control measures were followed to ensure the quality and completeness of the data generated during the project and assess the bias and variability of environmental samples collected. Quality control (QC) samples were collected to help identify potential sources of measurement bias and variability that could be introduced by the collection and analytical processes needed to interpret the environmental data. QC samples included field blanks and replicates. Field blanks collected in each basin are used to assess the potential contamination assocaited to sampling equipment, sample collection methods, and sample processing procedures. Split replicate samples were also collected and prepared by dividing a single volume of water into multiple samples. Split replicates are used to assess the variability associated with sample splitting and filtering and laboratory analysis. Replicate samples were compared by computing relative percent difference (RPD); the larger the RPD, the greater the variability in sample-replicate pairs. All QC data collected as a part of this project are included in Appendix 1 (Tables 1-1 and 1-2).

Project results

The results below are organized to correspond with the "Project Objectives" designated for each river basin within TWDB Agreement #1900012323. Since each river basin is at a different level of project maturity, task numbers do not necessarily correspond to the same effort within each river basin.

Objective 1: Trinity River – Galveston Bay

USGS, in cooperation with the TWDB, has been collecting data on the relationship between river flow, turbidity, suspended sediment concentrations, and nutrient concentrations in inflow to Galveston Bay since 2009. In 2014, in cooperation with the Trinity-San Jacinto Basin and Bay Area Stakeholder Committee, the USGS installed an index velocity meter two miles upstream of the saltwater barrier (USGS station 08067252, Trinity River at Wallisville, TX). A rating to determine real-time discharge and a suspended sediment surrogate model were developed to provide a continuous record of streamflow and suspended sediment concentrations and loads along the main channel of the Trinity River. Since 2016, USGS has also monitored the streamflow and water quality of Old River Lake. During events in which streamflow exceeds approximately 20,000 ft^3/s, water in the main channel of the Trinity River overflows into the Old River system. During 2019–21 the USGS continued data collection efforts to better understand the delivery of freshwater, nutrients, and sediment from the lower Trinity River Basin into Galveston Bay.

Objective 1a: Operation and maintenance of index-velocity streamgage

The streamgage at USGS station 08067252 Trinity River at Wallisville, TX was installed in 2014 as part of a previous study and later relocated in June 2017 due to bank scouring. USGS continued the operation and maintenance of this index-velocity gage during this study through support from the U.S. Army Corps of Engineers until December 23, 2019, when additional bank scouring required removal of the streamgage. In February 2020, the streamgage was relocated approximately 0.75 river miles upstream to the Interstate 10 bridge (Figure 1) and assigned a new USGS station number: 08067250 Trinity River at IH 10 near Wallisville, TX (hereinafter referred to as the "Wallisville site").

Figure 1. USGS streamgage 08067250 Trinity River at IH 10 near Wallisville, TX.

During a previous study, a suspended sediment surrogate was developed from acoustic backscatter data collected by the ADVM at the Wallisville site (Lucena and Lee, 2017). The surrogate allowed the computation of suspended sediment concentrations and loads every 15-minutes and provides a continuous record of suspended sediment data. Three suspended-sediment samples were collected in March–December 2019 to validate the surrogate equation. Suspended sediment time-series from the Wallisville site were published on NWIS until removal of the gage at station 08067252 Trinity River at Wallisville, TX on December 23, 2019.

The relocation of the streamgage in 2020 resulted in the need to develop a new regression equation to estimate suspended-sediment concentrations due to changes in the ADVM, instrument configuration, and cross-section characteristics. During February 2020–December 2021, the USGS started developing a new calibration dataset for a regression equation and collected six suspended-sediment samples at station 08067250 Trinity River at IH 10 near Wallisville, TX. The discharge at which these samples were collected are shown in Figure 2. Most of the samples were coincident with water-quality samples collected for Objective 1c. Data from these samples are available on NWIS and the USGS Texas Coastal Science Webpage. The USGS will continue collecting data to develop a calibration dataset for a new suspended-sediment regression equation. After sufficient suspended-sediment samples are collected and a new equation is developed, continuous suspended-sediment concentration data will be available from the date the streamgage was installed (February 21, 2020). Continuous suspended-sediment concentration data from the previous location can be found on NWIS.

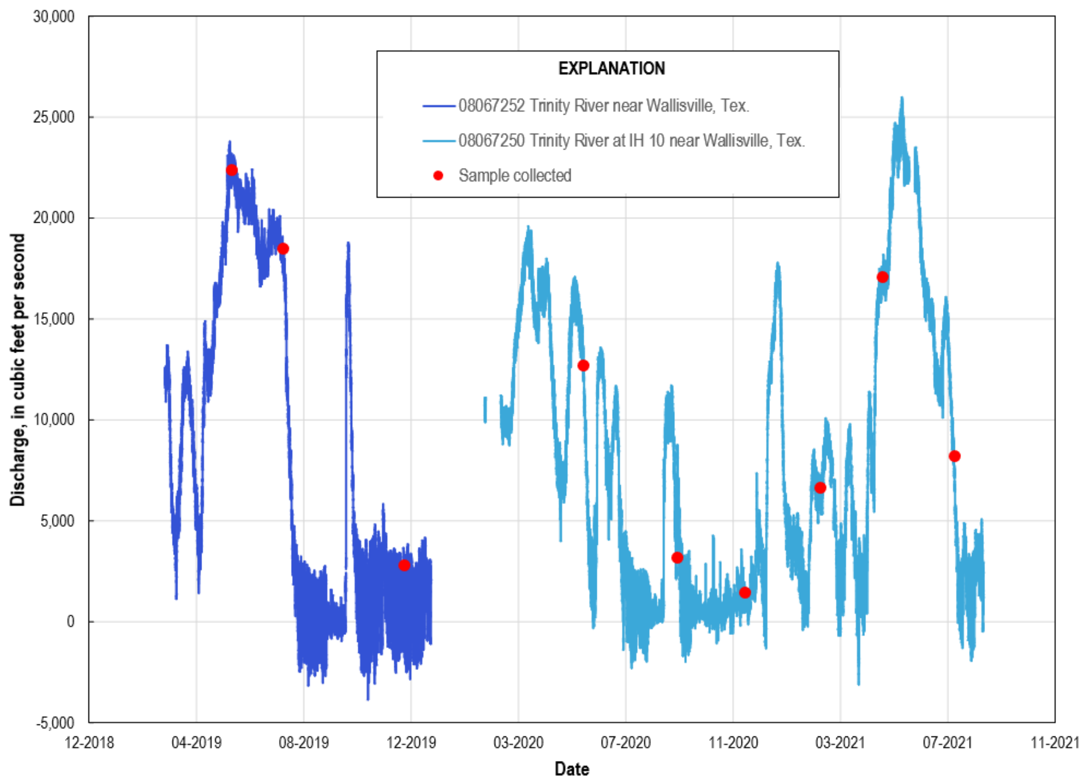

Figure 2. Instantaneous discharge and discrete water-quality and suspended-sediment samples collected at USGS stations in the lower Trinity River, TX, March 2019–August 2021.

Objective 1b: Continue evaluating the influence of the Old River system in the delivery of freshwater to Galveston Bay

Previous studies by the USGS in cooperation with TWDB indicated that water from the main channel of the Trinity River flows out of the main channel into distributary channels in the delta of the Trinity River, including the Old River Lake during high-flow events (Lucena and Lee, 2017). In 2016, to better understand the role of the Old River Lake and its distributary channels in the delivery of freshwater to Galveston Bay, the USGS started monitoring streamflow in selected locations in the delta of Trinity

River. The locations where discharge measurements were made are 08067230 are Old River Lake near Wallisville, TX (hereinafter referred to as the “Old River Lake site”), 08067256 Old River Cutoff at Buckeye Island near Anahuac, TX (hereinafter referred to as the “Old River Cutoff site”), and the Wallisville site (Figure 3, Table 1). During 2016–2019 the USGS made 11 streamflow measurements at the locations listed in Table 1. Results from these measurements, as summarized in a USGS Scientific Investigations Report by Lucena and Lee (2022), indicate that during events in which discharge at the upstream station 08067000 Trinity River at Liberty, TX (hereinafter referred to as the “Liberty site”) site exceeds approximately 20,000 ft^3/s, a large portion of the water flowing in the main channel of the Trinity River is likely diverted into surrounding distributary channels, including Old River Lake, before reaching Galveston Bay. In March 2019–August 2021 the USGS monitored these stations during three high-flow periods to collect supplemental data. The results from these measurements are shown in Table 2.

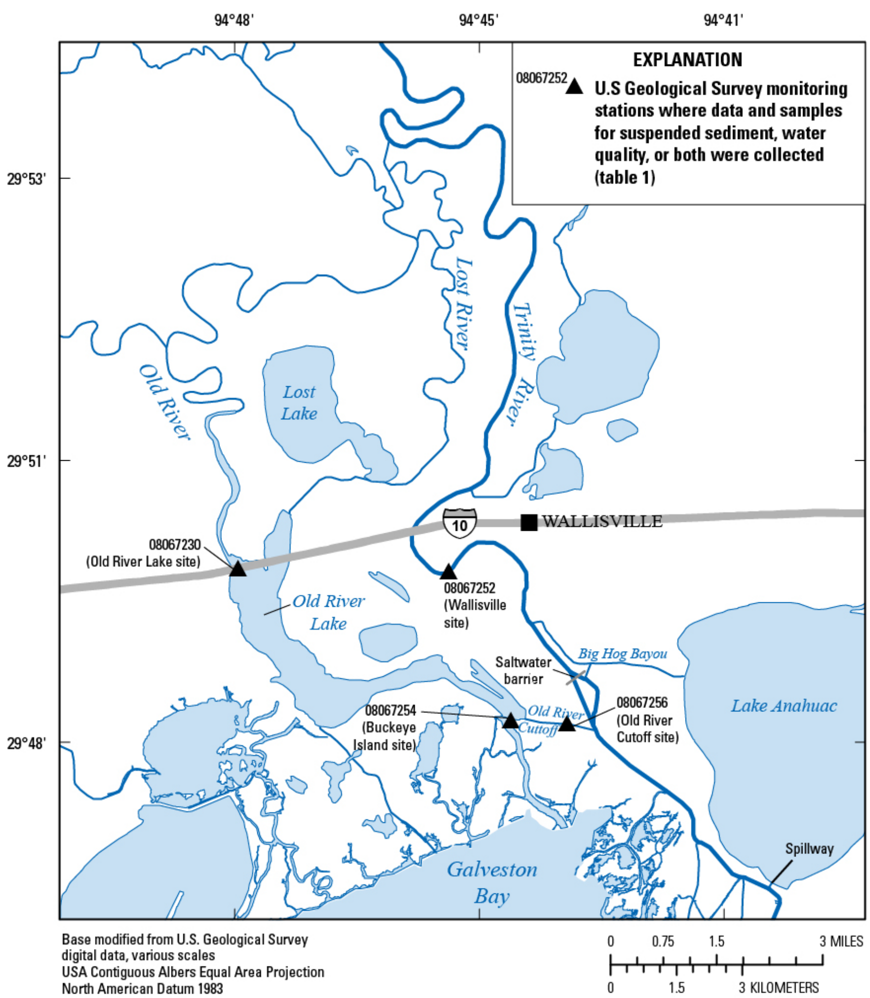

Figure 3. Map of USGS monitoring stations in the delta of the Trinity River.

Table 1. USGS stations with streamflow measurements and/or water-quality and sediment samples in the lower Trinity River Basin.

Station number	Station Name	Short name	Streamflow measurement (Y/N)	Water-quality sample collected (Y/N)
08067250	Trinity River at IH-10 near Wallisville, TX	Wallisville site	Y	Y
08067230	Old River Lake near Wallisville, TX	Old River Lake site	Y (if possible)	Y
08067254	Old River at Buckeye Island near Anahuac, TX	Buckeye Island site	N	Y
08067256	Old River Cutoff at Buckeye Island near Anahuac, TX	Old River Cutoff site	Y	N

Table 2. Summary of computed and instantaneous streamflow measurements at USGS monitoring stations in the lower Trinity River Basin, 2019–21.

	Discharge, in cubic feet per second (ft^3/s)					
	Liberty site[1]	Wallisville site	Old River Lake site	Old River Cutoff site	Sum of Wallisville site and Old River Lake site streamflow	Difference in streamflow between the Liberty site and the sum of Old River Lake site and Wallisville sites
5/14/2019	66,000	20,960	41,740	--	62,700	-3,300
5/10/2021	28,000	15,931	6,832	9,195	22,763	-5,237
7/29/2021	12,000	8,220	2,610	--	10,830	-1,170

[1]The streamflow values at the Liberty site shown in table were estimated based on estimated water travel times between the Liberty site and the Old River Lake and Wallisville sites.

Because of the potential role of the Old River Lake as a primary pathway for freshwater inflow into Galveston Bay during high flow events, the USGS installed a stage sensor at the Old River Lake site on August 19, 2019, to assess the feasibility of developing a streamflow rating at this site during high-flow conditions. Because of equipment malfunction, data loss occurred from January 13, 2021 to April 27, 2021. During baseflow conditions, stage at the Old River Lake site followed a pattern consistent with tidal currents (Figure 4*A*). During a high-flow event from March 21, 2020 to May 10, 2020, in which the peak discharge at the upstream station at the Liberty site was approximately 38,000 ft^3/s, stage data continued to show the effect of tidal currents (Figure 4*B*). The effect of tidal currents can also be observed in stage data collected during the event with the highest flow between August 19, 2019 and December 31, 2021 (Figure 4*C*). During this event, which occurred from May 2, 2021 to July 4, 2021, peak streamflow at the Liberty site was approximately 55,000 ft^3/s. Because the effect of tidal currents can be observed in stage data at the range of flows measured throughout the duration of this study, it is likely that a stage-discharge rating cannot be developed at the Old River Lake site. The USGS will continue collecting stage data at this site to assess if higher flows can attenuate the tidal signal in stage data; however, because the Old River Lake is an important pathway for freshwater, nutrients, and sediment at flows equal to or higher than approximately 40,000 ft^3/s (Lucena and Lee, 2022), alternative methods for measuring streamflow, such as the index-velocity method, may need to be assessed to appropriately monitor streamflow at the Old River Lake site.

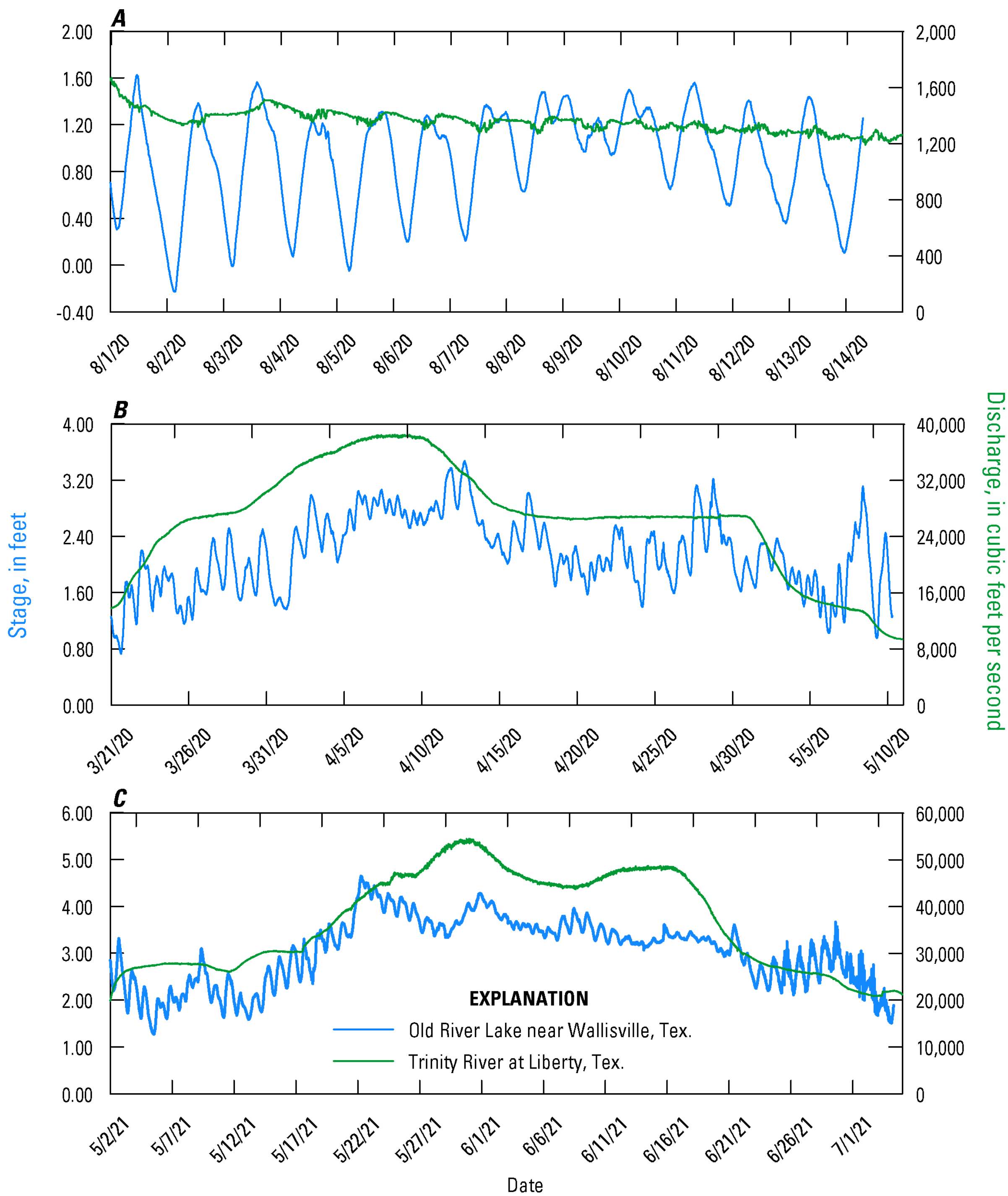

Figure 4. Stage at USGS station 08067230 Old River Lake near Wallisville, TX and discharge at 08067000 Trinity River at Liberty, TX on *A*, August 1–August 15, 2020 (baseflow conditions), *B*, March 21–May 10, 2020 (high-flow event), and *C*, May 2–July 4, 2021 (high-flow event).

Objective 1c: Collection of water-quality samples in the lower Trinity River Basin

In a previous study during 2016–19, the USGS collected water-quality samples at various locations in the delta of the Trinity River (Table 1) to evaluate the influence of freshwater diversions from the main channel of the Trinity River into Old River Lake in nutrient and suspended-sediment concentrations and loads. Results from these samples are presented in USGS Scientific Investigations Report “Distribution of Streamflow, Sediment, and Nutrients Entering Galveston Bay from the Trinity River, 2016-2019” (Lucena and Lee, 2022). Lucena and Lee (2022) found that Old River Lake and associated tributary and distributary channels likely play an important role in delivering nutrients and suspended sediment from the Trinity River Basin to Galveston Bay. In March 2019–December 2021, the USGS continued collecting samples in the Old River Lake and Buckeye Islands sites to acquire supplemental data. Four samples were collected at the Old River Lake site, nine samples were collected at the Wallisville site, and two samples were collected at the Buckeye Island site (samples were collected at this site only when streamflow at the Wallisville site exceeded 20,000 ft^3/s). Data from these samples are available on NWIS and on the USGS Texas Coastal Science Webpage. Summary statistics for selected water-quality constituents are shown in Appendix 1 (Table 1-3).

In addition to nutrient and suspended-sediment samples, the USGS collected samples to determine the δ15N and δ18O of dissolved nitrate in water. Due to method detection limits and analysis uncertainty, samples for these isotopes can only be analyzed when nitrate concentrations exceeded 0.06 milligrams per liter (mg/L). Nitrate concentrations for five samples at the Wallisville site, two samples at the Old River Lake site, and two samples at the Buckeye Island site exceeded 0.06 mg/L. Data from these samples are available on NWIS and the USGS Texas Coastal Science Webpage. Common fields of $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$ values derived from typical source signatures, as defined by Kendall and others (2007), are displayed in Figure 5. Boxes outlined in the graph indicate potential sources of nitrate, assuming there has been minimal cycling of nitrogen. Source identification is also affected by various factors. If mixing between water from two or more nitrate sources occurs, isotope values may plot between the typical source boxes. Additionally, in situ microbial transformation processes, such as denitrification, can cause the values of $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$ to increase through the loss of $_{14}N$ and $_{16}O$ due to fractionation complicating source determination (Kendall and others, 2007).

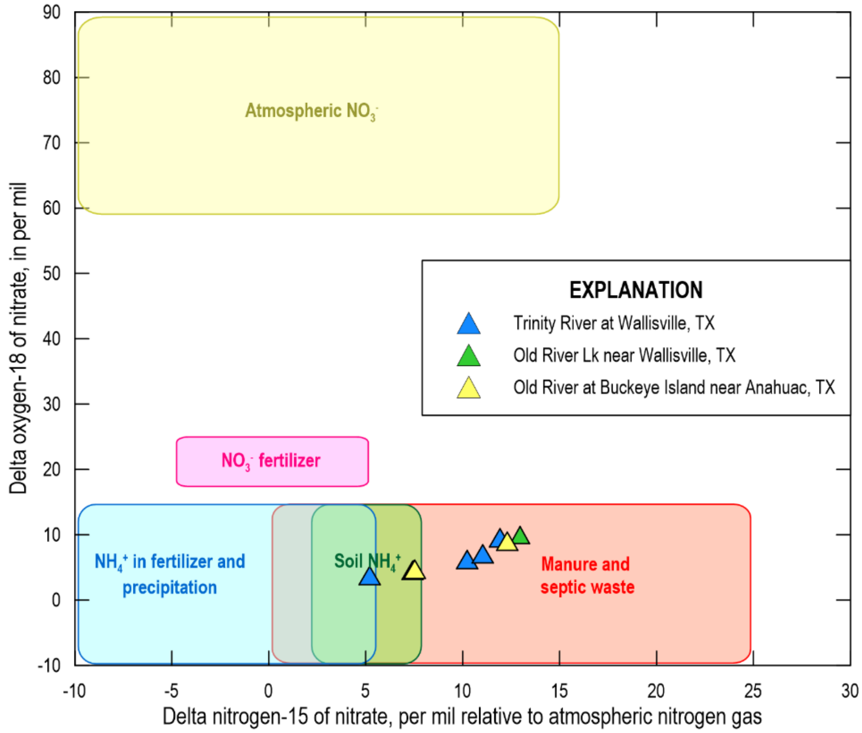

Figure 5. Nitrogen-15 and oxygen-18 isotope results and common source boxes, as defined by Kendall and others (2007) from samples collected at USGS monitoring stations in the lower Trinity River basin.

Objective 1d: Evaluation and inventory of data collected by USGS in the lower Trinity River

The USGS operates streamflow and discrete water-quality stations in the Trinity River below Lake Livingston. These stations provide data useful for assessing flow patterns in the river basin as water travels from Lake Livingston to Galveston Bay. A table listing each station and associated data collected in the lower Trinity River is included (Table 3).

Hydrographs from selected stations in the lower Trinity River Basin from March 2019 to December 2021 are shown by calendar year in Figure 6. A description of the hydrographic patterns observed in the lower Trinity River Basin are included in Lucena and Lee (2017) and Lucena and Lee (2022).

Table 3. Summary of USGS monitoring stations in the lower Trinity River Basin.

[NA; not applicable]

USGS station number	Station name	Type of data collected	Cooperating agency	Period of record
08066250	Trinity River near Goodrich, TX	• Streamflow • Stage	• Trinity River Authority	1989-2022
		• Project based water-quality samples	• Galveston Bay Estuary Program • Houston Advanced Research Center	2014-2022
08066500	Trinity River at Romayor, TX	• Streamflow • Stage	• NA	1988-2022
08067000	Trinity River at Liberty, TX	• Streamflow • Stage	• U.S. Army Corps of Engineers	1991-2022
		• Discrete water-quality samples	• City of Houston	2012-2022
08067070	CWA Canal near Dayton, TX	• Streamflow • Stage	• City of Houston • Coastal Water Authority	2007-2022
08067100	Trinity River near Moss Bluff, TX	• Stage • Continuous temperature and specific conductance	• U.S. Army Corps of Engineers	2007-2022 2013-2022
08067118	Lake Charlotte near Anahuac, TX	• Stage • Continuous temperature and specific conductance	• U.S. Army Corps of Engineers	2011-2022 2007-2022
08067215	Old River Cutoff near Moss Bluff, TX	• Stage • Continuous temperature and specific conductance	• U.S. Army Corps of Engineers	2007-2022 2013-2022
08067250	Trinity River at IH 10 near Wallisville, TX	• Streamflow • Stage	• U.S. Army Corps of Engineers	2020-2022

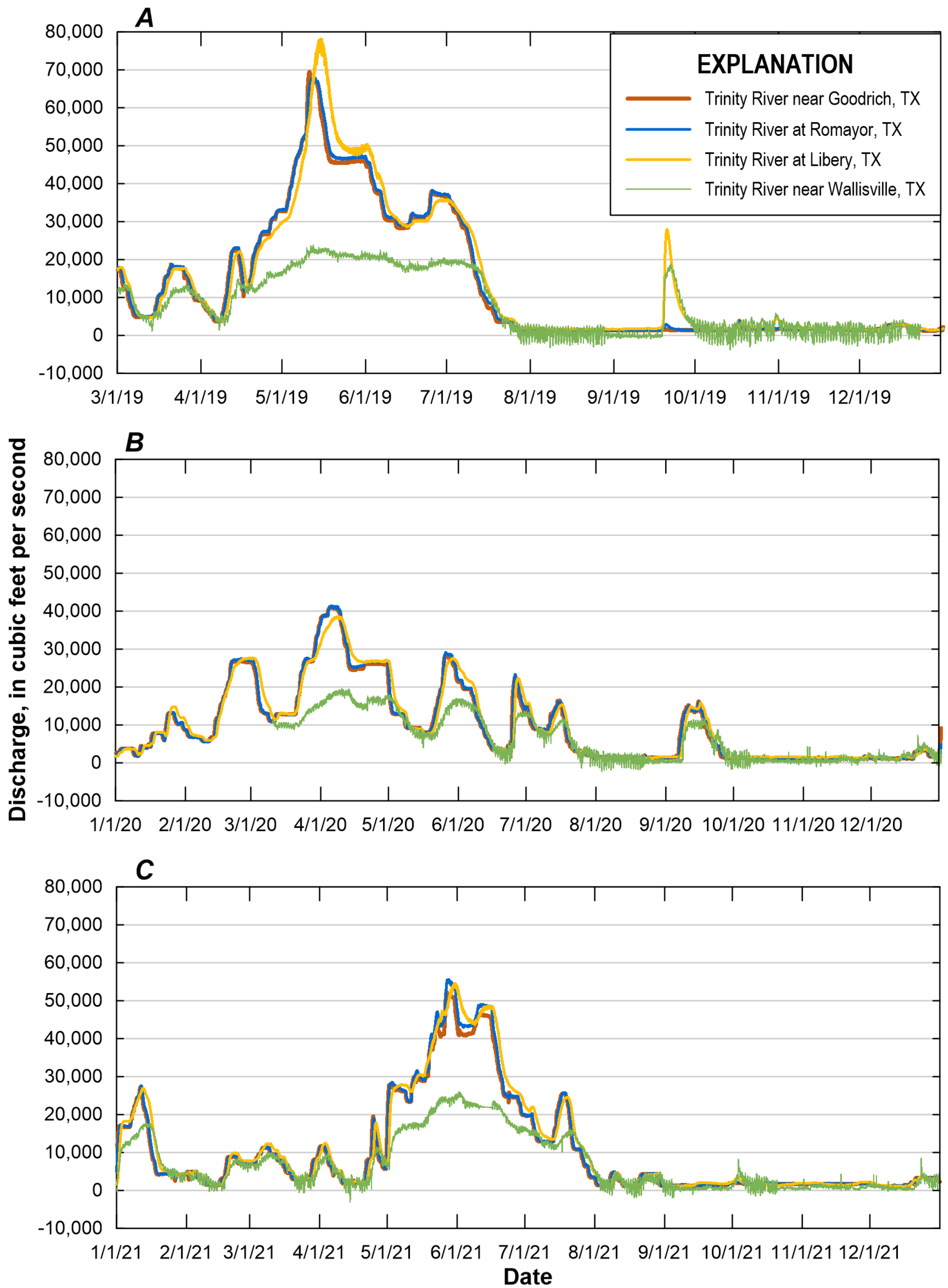

Figure 6. Instantaneous discharge at USGS streamgages in the lower Trinity River Basin during *A*, 2019, *B*, 2020, and *C*, 2021.

In 2016–18, samples were collected at the Liberty site in coordination with samples collected at the Wallisville site to examine the effects of streamflow patterns in the lower Trinity River Basin on water-quality traveling to Galveston Bay. Samples at the Liberty site are routinely collected by the USGS as part of a project in cooperation with the City of Houston and include the measurement of similar water-quality constituents as those measured at the Wallisville site. In 2019–21 the USGS collected an additional three samples at this station. The USGS also collected one sample at USGS station 08066250 Trinity River near Goodrich, TX and two samples at station 303935095055401 Livingston Reservoir Site BC nr Goodrich, TX as part of a cooperative agreement with the Houston Advanced Research Center and the TWDB. Water-quality data for these sample sets are also shown (Appendix 1, Table 1-4).

Objective 2: Colorado River — Matagorda Bay

This objective is a continuation of a study to examine freshwater inflows and nutrient and sediment concentrations delivered to Matagorda Bay by the Colorado River. In a previous study, USGS installed a streamgage in the lower Colorado River (08162501 Colorado River near Wadsworth, TX) equipped with an ADVM to better understand the variability and quantity of freshwater inflow and nutrient and suspended-sediment concentrations delivered to Matagorda Bay by the Colorado River. A streamflow rating for this site was developed as part of the previous study. Periodic water quality data were also collected as baseline data for the potential development of a surrogate model. In 2016–2019, USGS continued monitoring streamflow in the lower Colorado River and collecting water-quality data for the development of surrogate models to estimate suspended-sediment delivery to Matagorda Bay.

Objective 2a: Operation and maintenance of index-velocity streamgage

In 2016, A 1.5-megahertz SonTek SL 3G was installed at USGS station 08162501 Colorado River near Wadsworth, TX (hereinafter referred to as the "Wadsworth site") in accordance with USGS standards and practices and with additional assistance and in-kind services from the TWDB. Streamflow and stage data from this station begin on September 27, 2016 and can be accessed on NWIS. During March 2019–December 2021 the streamgaging station continued to be operated and maintained in accordance with USGS standard protocols (Levesque and Oberg, 2012). A summary of the 23 field measurements completed in March 2019–December 2021 is available on NWIS.

Objective 2b: Water-quality sample collection

A total of 13 water-quality samples were collected at the Wadsworth site during March 2019–December 2021. Streamflow at the Wadsworth site during this agreement period and corresponding water-quality samples collected are shown in Figure 7. Nutrient and suspended sediment data can be accessed on NWIS and the USGS Texas Coastal Science Webpage. Summary statistics for selected water-quality constituents are shown in Appendix 1 (Table 1-3).

A total of nine samples (five baseflow samples and three event samples) were also collected to determine the $\delta^{15}N$ and $\delta^{18}O$ of dissolved nitrate in water. Data from these samples are available on NWIS and the USGS Texas Coastal Science Webpage. Common fields of $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$ values derived from typical source signatures, as defined by Kendall and others (2007), are displayed in Figure 8.

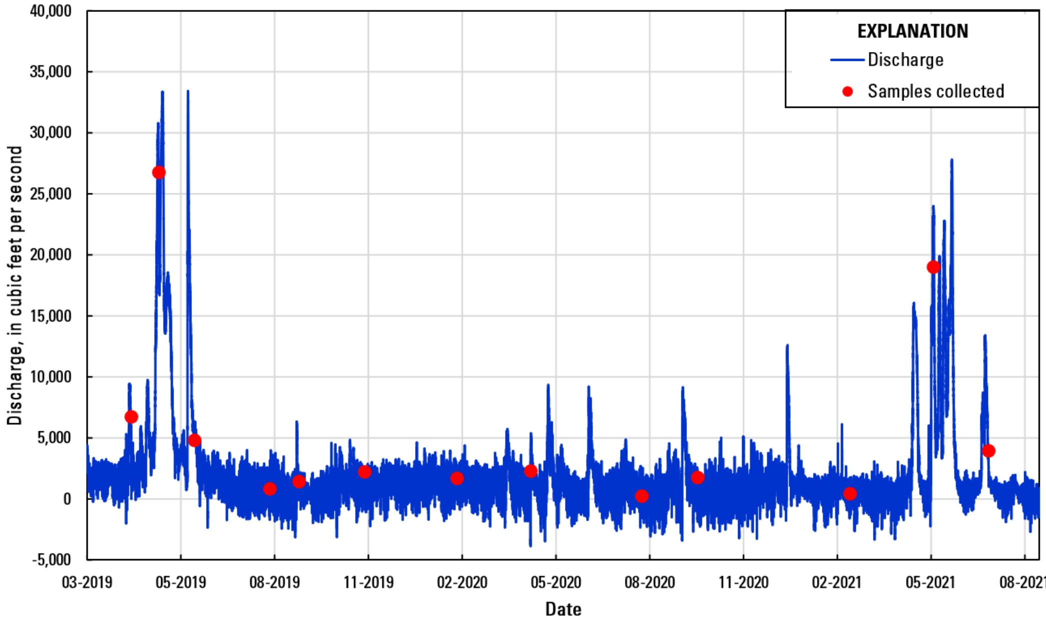

Figure 7. Instantaneous discharge at USGS station 08160501 Colorado River near Wadsworth, TX, March 2019–August 2021, and corresponding discrete water-quality samples.

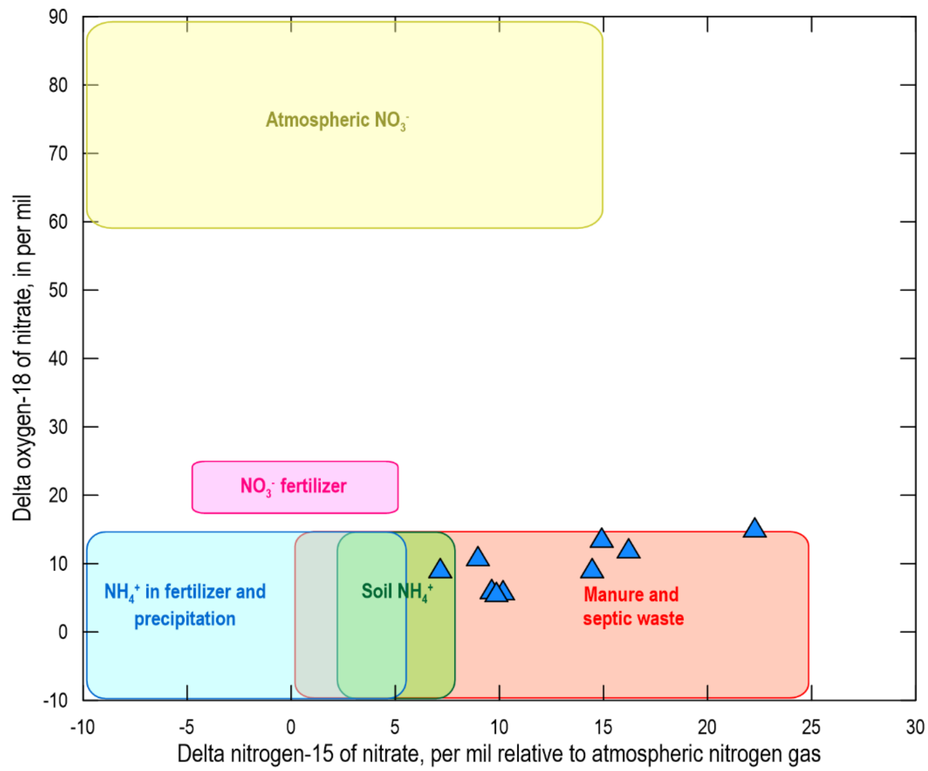

Figure 8. Nitrogen-15 and oxygen-18 isotope results and common source boxes, as defined by Kendall and others (2007) from samples collected at USGS monitoring station 08162501 Colorado River near Wadsworth, TX.

Objective 2c: Development of suspended-sediment regression equation

The USGS continued collecting data for developing a regression equation to estimate suspended-sediment at the Wadsworth site. The adequacy of the calibration dataset depends primarily on how well it represents the range of hydrologic and sedimentologic conditions. The dataset should describe how seasonal hydrology and particle size affect the surrogate relation. More than the count of measurements, these factors determine calibration dataset adequacy (Landers and others, 2016). Since the gage installation in 2016, the USGS has collected 19 suspended-sediment samples over a range of hydrologic conditions. Samples were collected at flows ranging from 250 ft^3/s to 78,300 ft^3/s (Figure 9); however, since the installation of the streamgage no events with a peak discharge ranging from 32,000 ft^3/s to 78,299 ft^3/s have occurred. To ensure the calibration data describes the range of hydrologic conditions observed at this site the USGS will continue collecting samples at targeted flows not yet represented in the dataset.

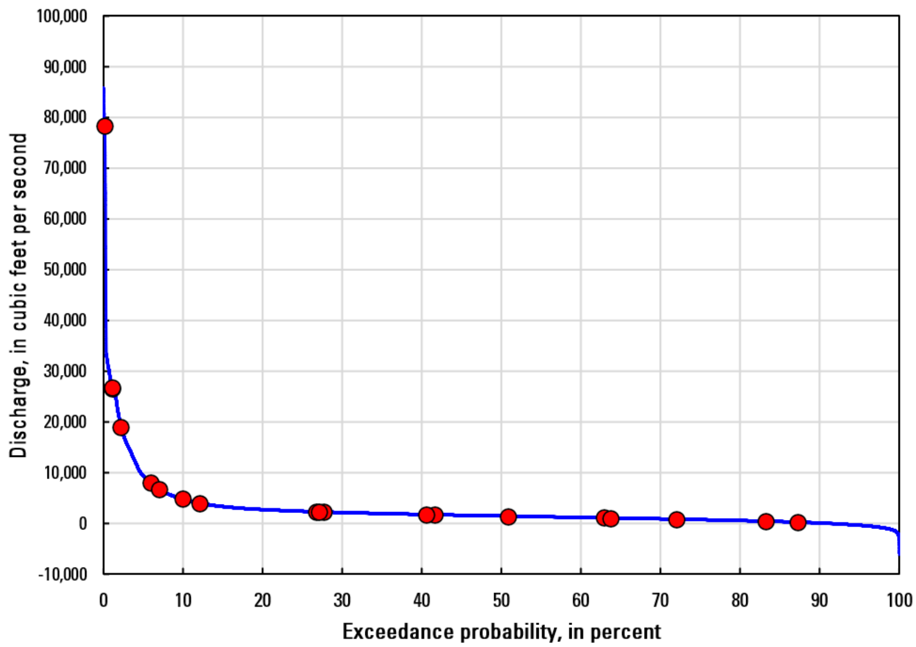

Figure 9. Flow duration curve at USGS 08162501 Colorado River near Wadsworth, TX indicating flows at which suspended-sediment samples were collected.

While reviewing the data for the preliminary development of a regression equation for sediment, the USGS found that a portion of the data collected at the Wadsworth site were affected by biofouling from barnacle growth on the acoustic transducers (Figure 10). Biofouling causes attenuation of the backscatter signal, which can affect the accuracy of computed suspended-sediment concentrations in various ways:

- If attenuation is present when collecting data for a model calibration dataset, the validity of regression equations may be impacted, and subsequent estimates of continuous suspended-sediment concentrations would be biased.
- The quality of in-situ measurements of backscatter may be affected, resulting in inaccurate continuous time-series suspended-sediment concentration estimates.

Figure 11 shows how backscatter data affected by biofouling at the Wadsworth site impacts the validity of regression equations for suspended-sediment concentrations.

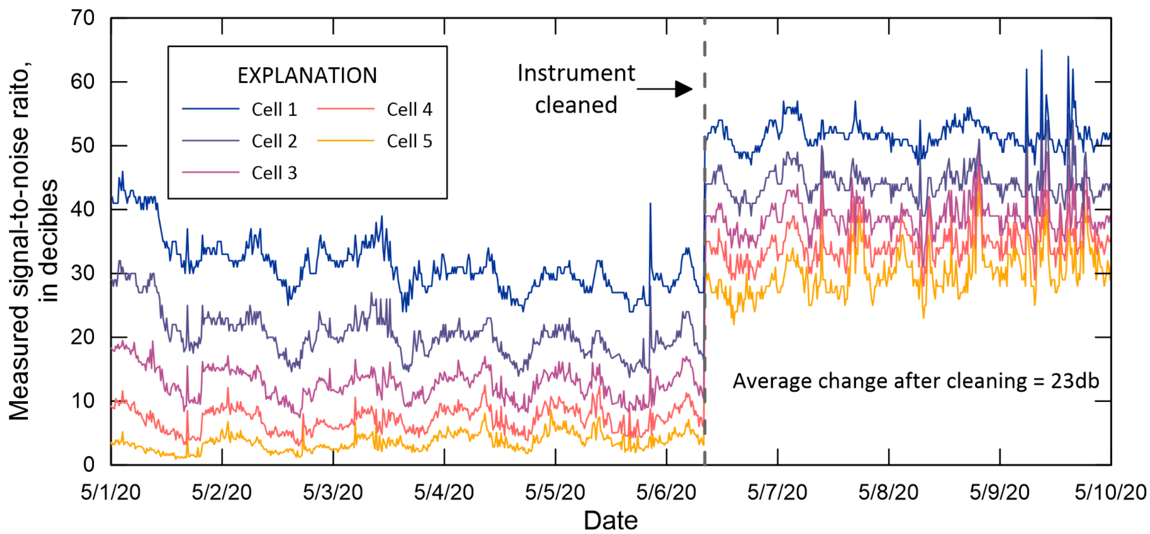

Figure 10. Signal-to-noise ratio before and after acoustic Doppler velocity meter at USGS station 08162501 Colorado River near Wadsworth, TX was cleaned to remove barnacles.

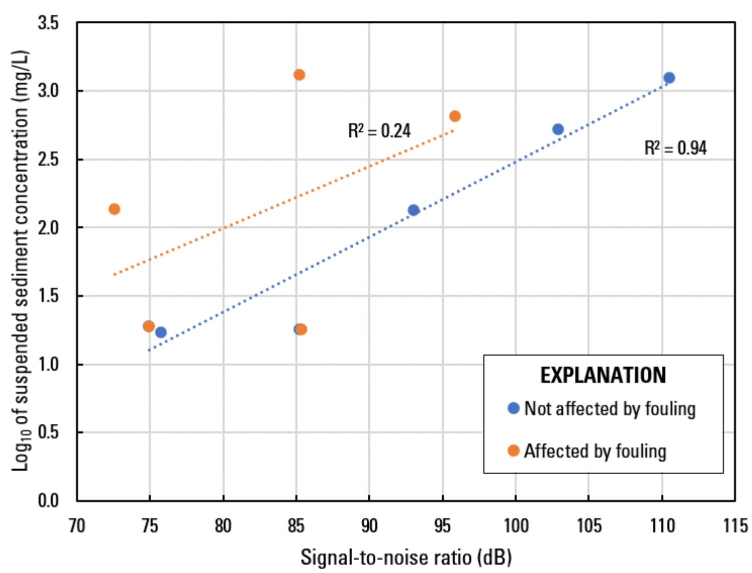

Figure 11. Relation between signal-to-noise ratio (in decibels) and suspended-sediment concentrations (in milligrams per liter) in a subset of data collected at USGS station 08162501 Colorado River near Wadsworth, TX affected by biofouling.

The USGS is currently evaluating potential methods for correcting acoustic backscatter data affected by biofouling through a separate project. Because backscatter data at USGS station Wadsworth site has been found to be affected by biofouling, developing a surrogate equation at this site will occur once an appropriate data correction method is determined. If data cannot be corrected, additional samples may need to be collected to replace data points affected by biofouling.

Objective 3: Guadalupe River — San Antonio Bay

In 2013, in cooperation with the TWDB and GBRA, the USGS installed an ADVM on the Guadalupe River at USGS station 08188810 Guadalupe River at State Highway 35 near Tivoli, TX. (hereinafter referred to as the "Tivoli site") The site is downstream from the confluence of the San Antonio River and Guadalupe River and is the most downstream viable location for streamflow measurements before discharging into the San Antonio Bay. Based on previous work funded by TWDB, discrete suspended sediment and nutrient samples were collected from this site. A regression equation based ADVM backscatter data was developed to estimate suspended-sediment concentrations continuously. In 2019–21 the USGS continued the collection of suspended-sediment samples to verify this regression equation and collected additional periodic water-quality data to better understand the various pathways of nutrient, sediment, and freshwater entering San Antonio Bay from the Guadalupe River.

Objective 3a: Operation and maintenance of index-velocity streamgage and suspended-sediment regression equation

The streamgage at the Tivoli site was installed in 2013 as part of the USGS streamgaging network. During March 2019–December 2021 the streamgage was operated and maintained in accordance with USGS standard protocols (Levesque and Oberg, 2012). A summary of the 21 field measurements completed in March 2019–December 2021 is available on NWIS. A total of eight samples were collected to maintain the suspended-sediment regression equation (Figure 12). Suspended-sediment concentrations from discrete samples were compared to the suspended-sediment concentrations computed by the regression equation (Figure 13). All concentrations for samples collected during 2019–21 were within the 90% prediction intervals of the model.

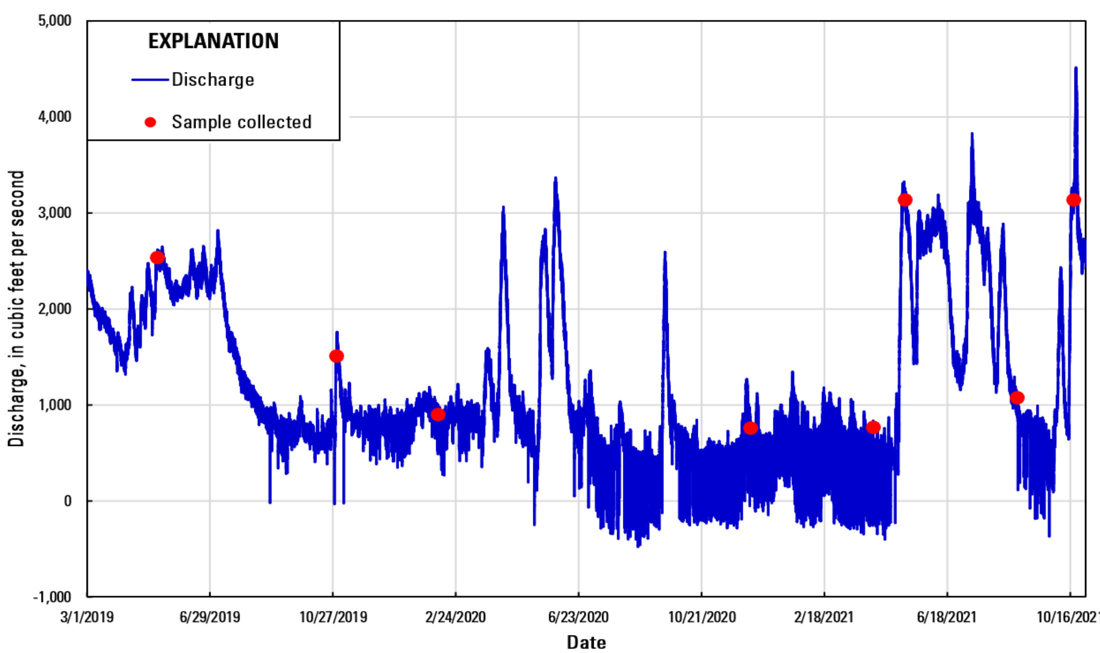

Figure 12. Streamflow and samples collected at USGS station 08188810 Guadalupe River at State Highway 35 near Tivoli, TX, March 2019–October 2021.

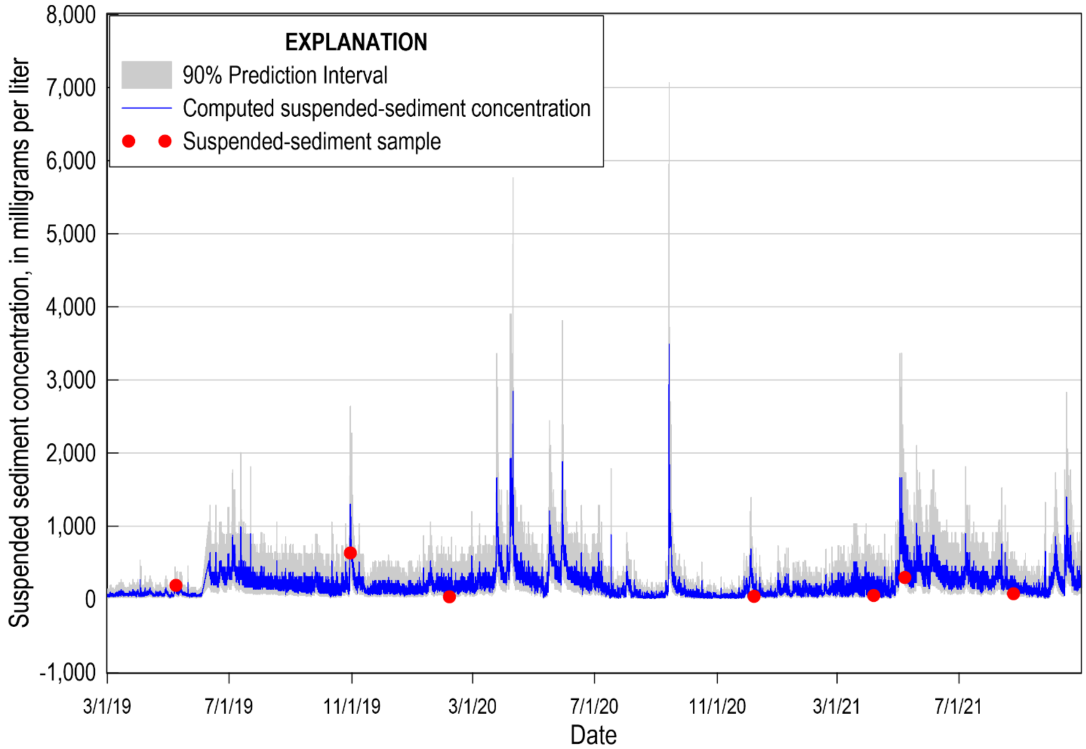

Figure 13. Regression computed suspended-sediment concentrations at USGS station 08188810 Guadalupe River at State Highway 35 near Tivoli, TX during 2019–2021 and measured suspended-sediment concentrations from discrete samples.

Objective 3b: Suspended-sediment sample collection in the San Antonio River and Guadalupe River

The USGS collected nutrient and suspended-sediment samples at USGS stations 08188500 San Antonio River at Goliad, TX (hereinafter referred to as the "Goliad site") and 08176500 Guadalupe River at Victoria, TX (hereinafter referred to as the "Victoria site") to help determine their contributions of sediment and nutrient loads to the Tivoli site. Both sites are upstream from the beginning of the sinuous/bayou reaches of the rivers (Figure 14). A total of nine samples were collected at each monitoring station. Suspended-sediment concentrations from these monitoring stations are provided in Table 4. Additional suspended-sediment data collected at these stations can be accessed on NWIS and the USGS Texas Coastal Science webpage. Summary statistics for selected water-quality constituents are shown in Appendix 1 (Table 1-3).

Figure 14. Map showing USGS monitoring stations in the lower Guadalupe River Basin.

Table 4. Suspended-sediment concentrations in samples collected at U.S. Geological monitoring stations in the Guadalupe River and San Antonio River.

[mg/L, milligrams per liter; NC, not collected; E, estimated from regression equation]

Date	Suspended sediment concentration (mg/L)		
	Guadalupe River at Victoria, TX	San Antonio River at Goliad, TX	Guadalupe River at SH 35 near Tivoli, TX
May 2019	625	514	187
Oct 2019	NC	1480	632
Feb 2020	56	34	46
May 2020	970	900	970
Aug 2020	53	38	21
Dec 2020	26	109	38
Apr 2021	39	58	52
May 2021	2,390	1,060	E1,037

As part of this objective, the USGS evaluated the relation between suspended-sediment concentrations from samples collected at the Goliad site, and turbidity data from a 6-parameter water-quality monitor installed at the site through an agreement with the San Antonio River Authority. The data used for this evaluation consist of only eight samples and was used to explore the potential of continuing the development of a regression equation in the future. The exploratory relation is shown in Figure 15. Because a strong relation is typically observed between turbidity and suspended-sediment concentrations (Rasmussen and others, 2009) the method used at the Goliad site could be applied to the Old River Lake site (Objective 1) to estimate suspended-sediment concentrations from turbidity data collected by a water-quality monitor installed at the site.

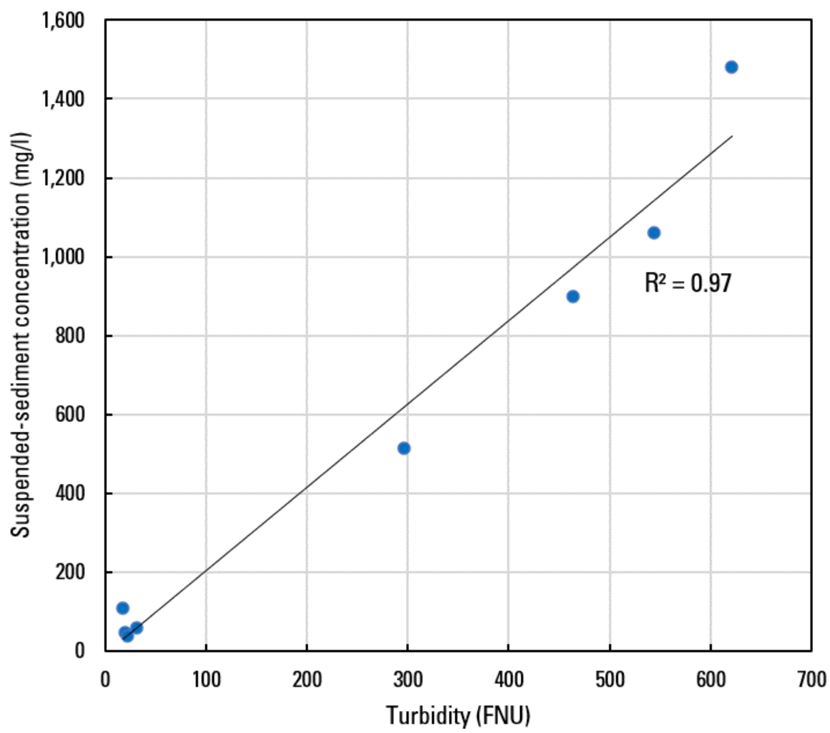

Figure 15. Preliminary relation between turbidity (in formazin nephelometric units) and suspended-sediment concentration (in milligrams per liter) at USGS station 08188500 San Antonio River at Goliad, TX.

Objective 3c: Reconnaissance synoptic survey

To better understand the nutrient and suspended-sediment load traveling through smaller bayous flowing into San Antonio Bay, the USGS completed a one-time reconnaissance synoptic survey during a high-flow event on May 7, 2021. Streamflow was measured and nutrient and suspended-sediment samples were collected at the stations shown in Figure 16. Results from this synoptic survey include concentrations and loads of suspended-sediment and nutrients (

Table 5).

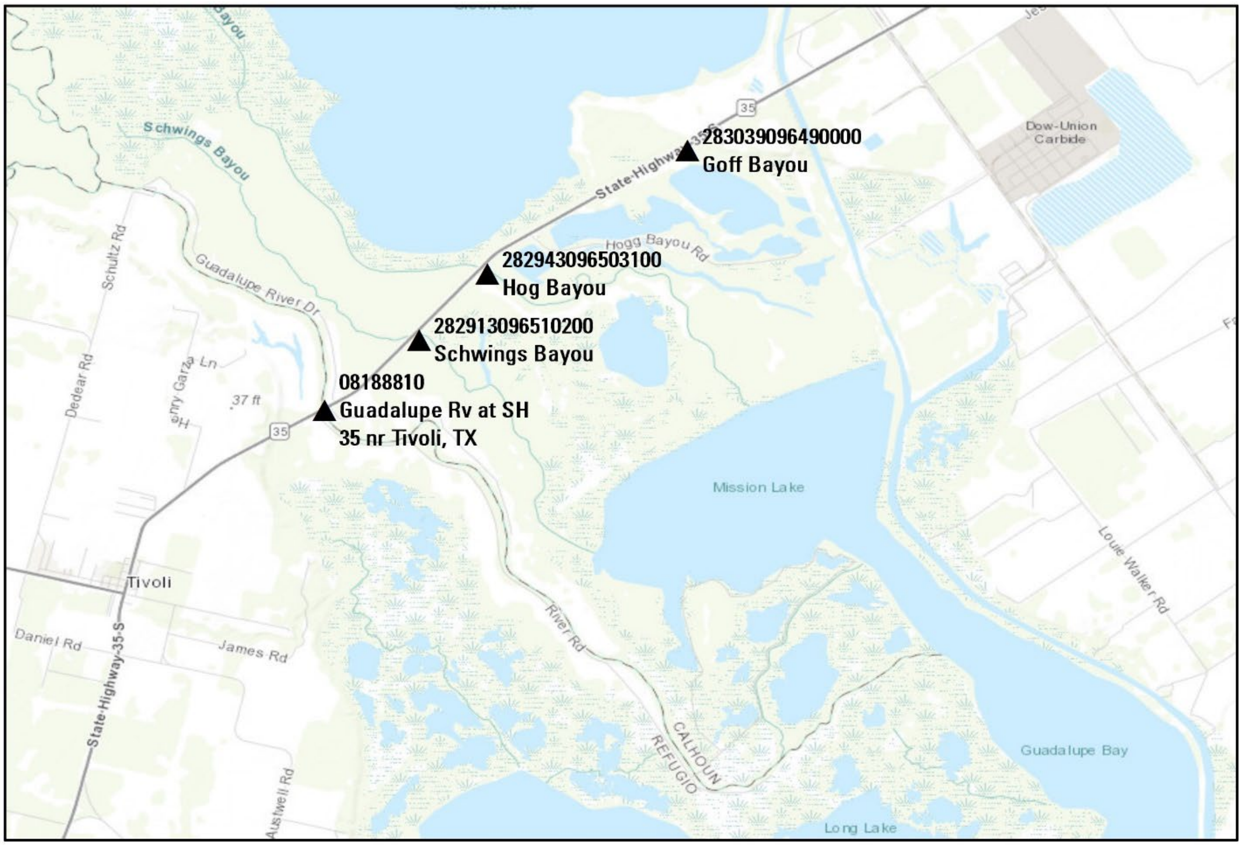

Figure 16. Streamflow and water-quality monitoring locations of reconnaissance synoptic survey conducted on May 7, 2021, in the lower Guadalupe River Basin.

Table 5. Suspended sediment and nutrients concentrations and loads for samples collected during synoptic survey on May 7, 2021.

[ft^3/s, cubic feet per second; mg/L, milligrams per liter; N, nitrogen; <, less than; P, phosphorus]

		08188810 Guadalupe River	282913096510200 Schwings Bayou	282943096503100 Hog Bayou	283039096490000 Goff Bayou
Discharge	Instantaneous (ft^3/s)	3,190	905	799	1,360
Ammonia, water, filtered	Concentration (mg/L as N)	<0.02	<0.02	<0.02	<0.02
	Instantaneous load (ton/day)	<0.17	<0.05	<0.04	<0.07
Ammonia plus organic nitrogen, water, unfiltered	Concentration (mg/L as N)	1.1	1.1	0.91	1.1
	Instantaneous load (ton/day)	9.5	2.7	2.0	4.0
Nitrate, water, filtered	Concentration (mg/L as N)	0.945	0.992	0.812	0.783
	Instantaneous load (ton/day)	8.14	2.42	1.75	2.88
Nitrite, water, filtered	Concentration (mg/L as N)	0.092	0.057	0.06	0.056
	Instantaneous load (tons per day)	0.792	0.139	0.129	0.206
Total nitrogen [nitrate + nitrite + ammonia + organic-N], water, filtered	Concentration (mg/L)	1.61	1.66	1.43	1.34
	Instantaneous load (tons per day)	13.9	4.1	3.1	4.9
Total nitrogen [nitrate + nitrite + ammonia + organic-N], water, unfiltered	Concentration (mg/L)	2.04	2.15	1.85	1.91
	Instantaneous load (ton/day)	17.6	5.3	4.0	7.0
Suspended sediment	Concentration (mg/L)	294	122	156	236
	Instantaneous load (ton/day)	2,532	298	337	867
Orthophosphate, water, filtered	Concentration (mg/L as P)	0.226	0.267	0.181	0.194
	Instantaneous load (ton/day)	1.947	0.652	0.390	0.712
Phosphorus, water, unfiltered	Concentration (mg/L as P)	0.541	0.508	0.424	0.448
	Instantaneous load (ton/day)	4.660	1.241	0.915	1.645

Objective 3d: Collection of nutrient samples at USGS station 08188810 Guadalupe River at SH 35 near Tivoli, TX

The USGS continued collecting nutrient samples at the Tivoli site concurrently with suspended-sediment samples collected for Objective 3a (Figure 12). Nutrient and suspended sediment data can be accessed on NWIS and the USGS Texas Coastal Science Webpage. The USGS also collected eight samples for δ15N and δ18O of dissolved nitrate in water at the Tivoli, Goliad, and Victoria sites. Common fields of $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$ values derived from typical source signatures, as defined by Kendall and others (2007), are displayed in Figure 17. Summary statistics for selected water-quality constituents are shown in Appendix 1 (Table 1-3).

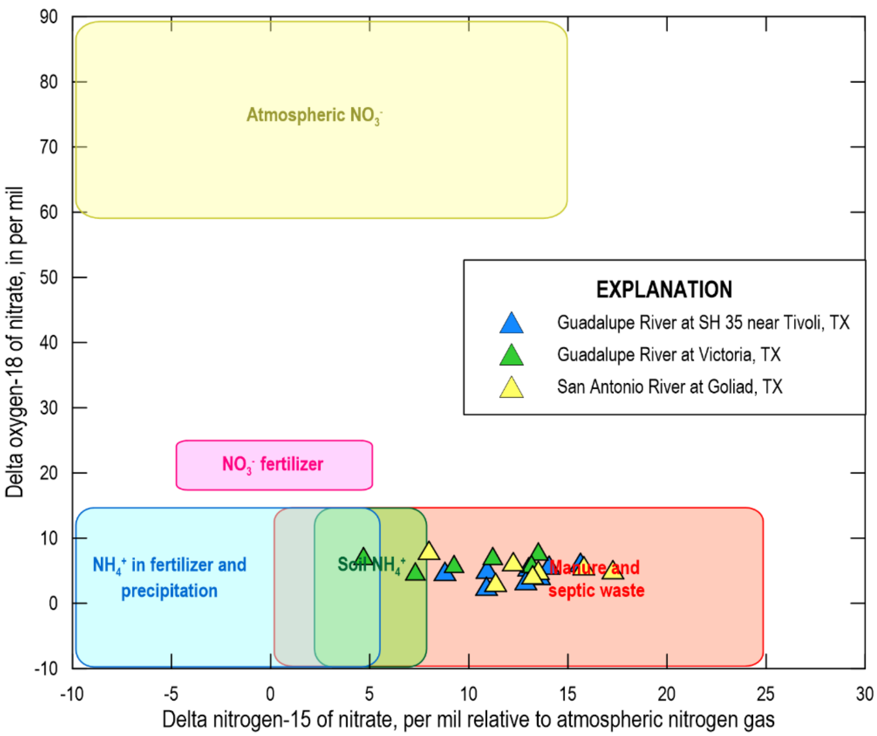

Figure 17. Nitrogen-15 and oxygen-18 isotope results and common source boxes, as defined by Kendall and others (2007) from samples collected at USGS monitoring stations in Guadalupe River and San Antonio River.

Objective 4: Nueces River — Nueces Bay

This objective continues a study completed in 2019 to evaluate stream discharge and sediment and nutrient concentrations across a range of hydrologic conditions in the lower reaches of the Nueces River. In the Nueces River Basin for the period of 2019–21, the suspended-sediment and nutrient monitoring efforts were focused on USGS stations 08211502 Nueces River near Odem, TX (hereinafter referred to as the "Odem site") and 0821150305 Rincon Bayou Channel near Odem, TX (hereinafter referred to as the "Rincon Bayou site") to evaluate the potential of developing regression equations to compute continuous suspended-sediment concentrations. This study extends efforts to improve knowledge of how peak inflows, relative to normal or low inflows, contribute to nutrient and sediment loading to Nueces Bay and Corpus Christi Bay.

Task 4a: Installation, operation, and maintenance of index-velocity streamgage

In a previous study, the USGS made a recommendation to install a permanent monitoring station at the Nueces River at the Highway 37 bridge to better account for the sediment and nutrient concentrations entering Nueces Bay. In 2019, the Coastal Bend Bay and Estuary Program funded the installation of an index-velocity streamgage at station the Odem site (Figure 18). This station captures all flow entering the Nueces Bay during high flow events because all flow from the Nueces River system is funneled under the IH-37 bridge (Figure 19).

Figure 18. Streamgage installed at USGS station 08211502 Nueces River near Odem, TX, August 2019.

Operation and maintenance of this streamgage is funded by the City of Corpus Christi. A summary of the nine streamflow measurements completed in 2019–21 is available on NWIS. The ADVM backscatter data obtained from this streamgage will be used by the USGS to evaluate the potential development of a regression equation for suspended-sediment concentrations (Objective 4c).

Figure 19. Locations of USGS monitoring stations in the lower Nueces River Basin.

Objectives 4b and 4C: Collection of nutrient and suspended-sediment samples from Rincon Bayou and Nueces River

The USGS collected nutrient and suspended-sediment samples at stations Odem and Rincon Bayou sites in 2019–21. Samples were collected predominantly during periods in which water was being pumped to Rincon Bayou to through the bypass pipeline (Figure 19), which occurred only in four occasions throughout the duration of this project. Because of these predominantly low-flow conditions only six samples were collected at the Odem site (two low-flow and four high-flow samples) and five samples were collected at the Rincon Bayou site (one low-flow and four high-flow samples). A plot indicating the gage height at which samples were collected at the Odem site (continuous streamflow data are not yet available) is shown in Figure 20. Nutrient and suspended sediment data can be accessed on NWIS and the USGS Texas Coastal Science Webpage.

Three of the six samples collected at each station in the Nueces River had nitrate concentrations greater that 0.06 mg/L and were analyzed for δ15N and δ18O of dissolved nitrate in water. Common fields of $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$ values derived from typical source signatures, as defined by Kendall and others (2007), are displayed in Figure 21. Summary statistics for selected water-quality constituents are shown in Appendix 1 (Table 1-3).

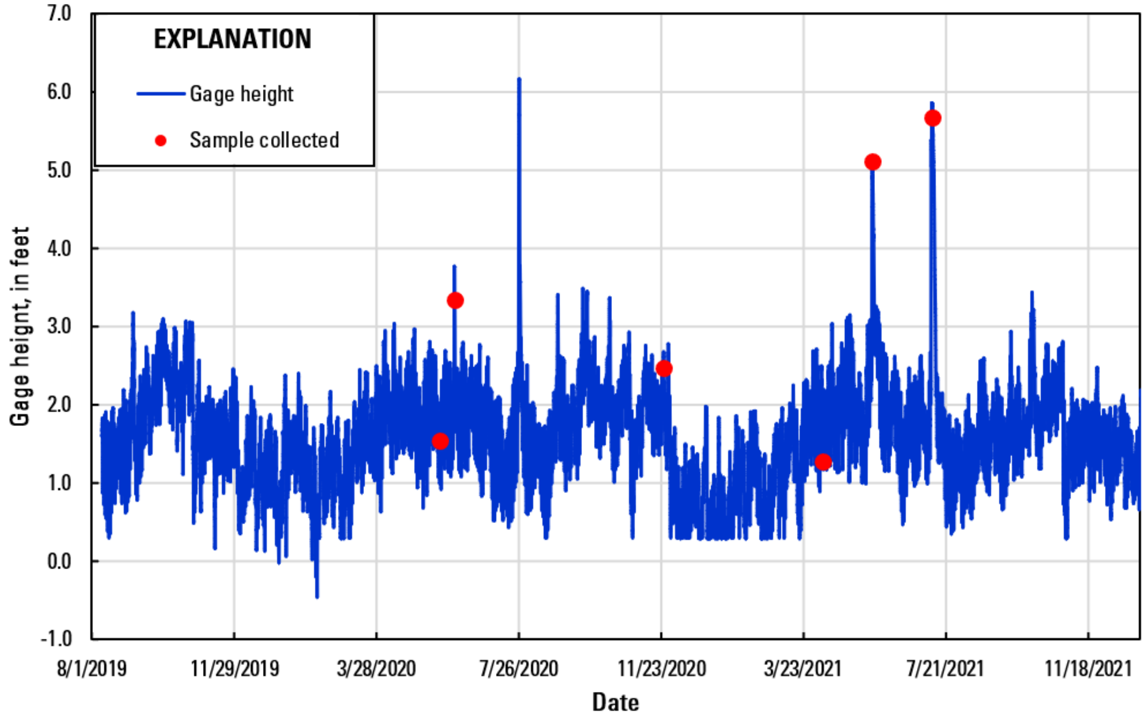

Figure 20. Gage height and samples collected at USGS streamgage 08211502 Nueces River near Odem, TX, August 2019–December 2021.

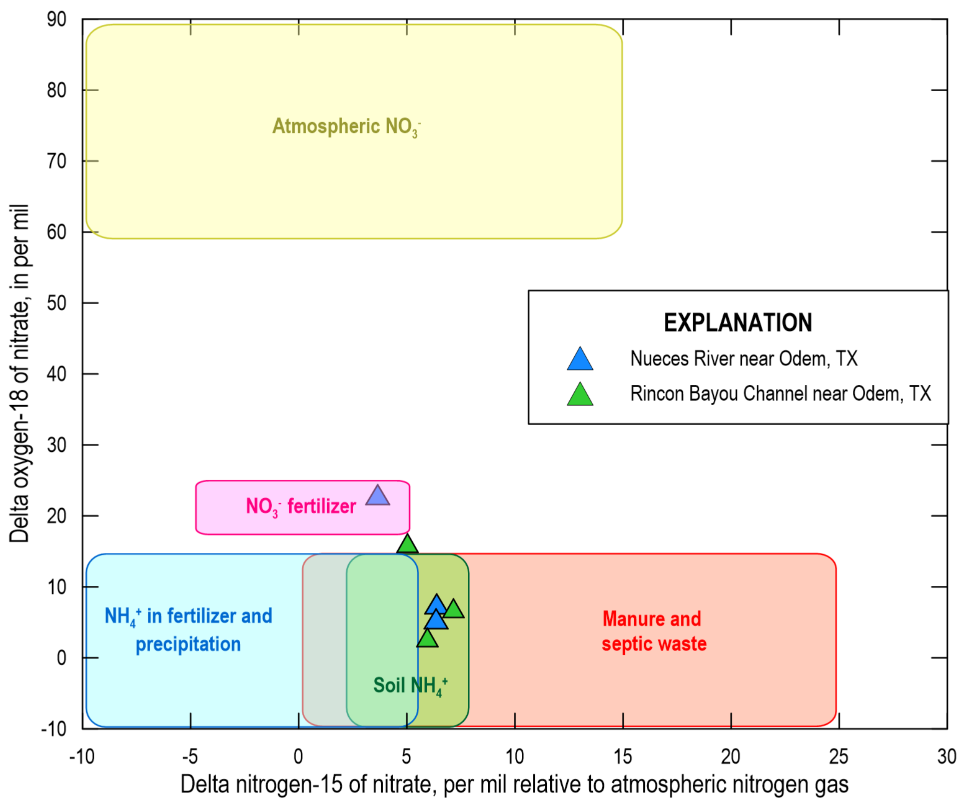

Figure 21. Nitrogen-15 and oxygen-18 isotope results and common source boxes, as defined by Kendall and others (2007), from samples collected at USGS monitoring stations in the Nueces River Basin.

ADVM data was collected at these sites at the time of sample collection from both a permanently mounted ADVM at the Odem site and a temporarily mounted ADVM at the Rincon Bayou site. Because of the small number of samples collected at these sites as a result from predominantly low-flow conditions, a preliminary evaluation of the potential to establish regression equations from backscatter data cannot yet be completed. A preliminary evaluation will require more data points that represent a wider range of hydrologic conditions and suspended-sediment concentrations. Developing an appropriate calibration dataset at this station is more challenging and will likely require a longer period of data collection than at other basins because of the unique hydrologic conditions in the lower Nueces River basin. No-flow and low-flow conditions are predominant at the Rincon Bayou site unless water is being pumped through the bypass pipeline, limiting the opportunities to collect data when a large portion of the nutrient and suspended-sediment loading delivered to Nueces Bay is being transported.

Future Considerations

The data collected as part of this project has further advanced our understanding of nutrient and sediment delivery to Texas bays and estuaries over a range of hydrologic conditions. Long-term discrete and continuous monitoring in these basins can continue providing data that can be used to assess changes in freshwater inflow and nutrient and sediment delivery over time and as a result of changing hydrologic conditions. To more accurately assess the variability of nutrient and sediment concentrations entering coastal ecosystems from these major rivers, future efforts should continue developing the optical turbidity and (or) acoustic backscatter surrogate methodology for each major river. Achievement of a validated surrogate model for generating real-time estimates of sediment and nutrient concentrations and loadings will vary based on progress previously accomplished for each basin. Additionally, by leveraging existing UGSS programs with additional cooperators to expand these efforts to other major basins, such as the San Jacinto River, additional information can be provided to scientists and stakeholders of the environmental flows process to validate or refine freshwater inflow standards.

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Appendix 1

Water Quality Data Tables

Table 1-1. Results from replicate samples collected in the Trinity River, Colorado River, Guadalupe River, and Nueces River Basins.

[nm, nanometer; %, percent; RPD, relative percent difference; <, less than]

Station name	Sample date-time	Ammonia, water, filtered, milligrams per liter as nitrogen	Ammonia plus organic nitrogen, water, unfiltered, milligrams per liter as nitrogen	Nitrate plus nitrite, water, filtered, milligrams per liter as nitrogen	Nitrite, water, filtered, milligrams per liter as nitrogen	Total nitrogen [nitrate + nitrite + ammonia + organic-N], water, filtered, analytically determined, milligrams per liter	Total nitrogen [nitrate + nitrite + ammonia + organic-N], water, unfiltered, analytically determined, milligrams per liter	Orthophosphate, water, filtered, milligrams per liter as phosphorus	Phosphorus, water, unfiltered, milligrams per liter as phosphorus	Organic carbon, water, filtered, milligrams per liter	Organic carbon, water, unfiltered, milligrams per liter	Absorbance, 254 nm, water, filtered, absorbance units per centimeter	Suspended sediment, sieve diameter, percent smaller than 0.0625 millimeters	Suspended sediment concentration, milligrams per liter
Trinity River at IH 10 nr Wallisville, TX	12/7/2020 12:15	0.03	0.46	0.103	0.004	0.54	0.69	0.033	0.080	6.47	8.0	0.204	94	30
	12/7/2020 12:20	0.03	0.49	0.103	0.004	0.50	0.69	0.033	0.080	6.40	6.4	0.204	99	31
	RPD	**0.0%**	**6.3%**	**0.0%**	**0.0%**	**7.7%**	**0.0%**	**0.0%**	**0.0%**	**1.1%**	**22.2%**	**0.0%**	**5.2%**	**3.3%**
Trinity River at Wallisville, TX	11/22/2019 10:30	<0.01	0.53	<0.040	<0.001	0.30	0.50	0.010	0.064	4.61	6.0	0.122	97	19
	11/22/2019 10:35	<0.01	0.52	<0.040	<0.001	0.31	0.49	0.010	0.059	4.63	6.1	0.124	97	20
	RPD	**0.0%**	**1.9%**	**0.0%**	**0.0%**	**3.3%**	**2.0%**	**0.0%**	**8.1%**	**0.4%**	**1.7%**	**1.6%**	**0.0%**	**5.1%**
Colorado River near Wadsworth, TX	4/11/2019 12:45	0.12	1.9	3.07	0.168	3.91	4.76	0.128	0.632	5.20	11.8	0.166	99	520
	4/11/2019 12:50	0.12	1.8	3.00	0.162	3.67	4.64	0.128	0.653	5.11	8.4	0.166	99	540
	RPD	**0.0%**	**5.4%**	**0.0%**	**0.0%**	**6.3%**	**2.6%**	**0.0%**	**3.3%**	**1.7%**	**33.7%**	**0.0%**	**0.0%**	**3.8%**
	8/13/2020 10:30	0.51	1.2	<0.040	0.003	0.85	1.18	0.222	0.350	4.97	6.7	0.130	79	25
	8/13/2020 10:35	0.54	1.1	<0.040	0.003	0.87	1.18	0.272	0.380	4.87	6.9	0.134	86	22
	RPD	**0.0%**	**8.7%**	**0.0%**	**0.0%**	**2.3%**	**0.0%**	**20.2%**	**8.2%**	**2.0%**	**2.9%**	**3.0%**	**8.5%**	**12.8%**
	10/6/2020 10:30	0.47	1.1	0.255	0.014	0.92	1.29	0.157	0.250	5.32	7.0	0.135	94	24
	10/6/2020 10:35	0.5	--	0.264	0.014	1.20	1.28	0.171	0.250	5.44	6.8	0.196	94	27
	RPD	**0.0%**	**--**	**0.0%**	**0.0%**	**26.4%**	**0.8%**	**8.5%**	**0.0%**	**2.2%**	**2.9%**	**36.9%**	**0.0%**	**11.8%**
Guadalupe River at SH 35 near Tivoli, TX	4/6/2021 11:00	0.03	0.46	2.62	0.015	3.07	3.20	0.355	0.467	2.48	3.5	0.067	99	52
	4/6/2021 11:05	0.03	0.47	2.71	0.016	3.17	3.17	0.365	0.466	2.50	3.3	0.066	99	46
	RPD	**0.0%**	**2.2%**	**0.0%**	**0.0%**	**3.2%**	**0.9%**	**2.8%**	**0.2%**	**0.8%**	**5.9%**	**1.5%**	**0.0%**	**12.2%**
	Mean RPD	**0.0%**	**4.9%**	**0.0%**	**0.0%**	**8.2%**	**1.0%**	**5.3%**	**3.3%**	**1.4%**	**11.5%**	**7.2%**	**2.3%**	**8.2%**

Table 1-2. Results for blank samples collected in the Trinity River and Colorado River Basins.

[N, nitrogen; <, less than; *, result above laboratory detection limit and below laboratory reporting limit]

Station name	Sample date-time	Ammonia, water, filtered, milligrams per liter as nitrogen	Ammonia plus organic nitrogen, water, unfiltered, milligrams per liter as nitrogen	Nitrate plus nitrite, water, filtered, milligrams per liter as nitrogen	Nitrite, water, filtered, milligrams per liter as nitrogen	Total nitrogen [nitrate + nitrite + ammonia + organic-N], water, unfiltered, analytically determined, milligrams per liter	Total nitrogen [nitrate + nitrite + ammonia + organic-N], water, unfiltered, milligrams per liter	Orthophosphate, water, filtered, milligrams per liter as phosphorus	Phosphorus, water, unfiltered, milligrams per liter as phosphorus	Total nitrogen [nitrate + nitrite + ammonia + organic-N], water, filtered, analytically determined, milligrams per liter	Organic carbon, water, filtered, milligrams per liter	Organic carbon, water, unfiltered, milligrams per liter	Absorbance, 254 nm, water, filtered, absorbance units per centimeter
Trinity River at IH 10 nr Wallisville, TX	9/22/2020 8:45	0.02	<0.07	<0.040	0.001	<0.05	<0.11	<0.004	<0.004	<0.05	<0.23	<0.7	<0.005
Colorado River near Wadsworth, TX	8/22/2019 12:00	<0.01	<0.07	<0.040	<0.001	<0.05	<0.11	<0.004	<0.004	<0.05	*0.33	<0.7	<0.005
Colorado River near Wadsworth, TX	7/12/2021 8:30	<0.02	<0.07	<0.040	<0.001	<0.05	<0.11	<0.004	<0.010	0.11	*0.33	<0.7	<0.005

Table 1-3. Summary statistics for selected water-quality constituents measured at USGS stations in the Trinity River, Colorado River, Guadalupe River, and Nueces River.
[N, nitrogen; <, less than]

Basin	Station name		Ammonia, water, filtered, milligrams per liter as nitrogen	Ammonia plus organic nitrogen, water, unfiltered, milligrams per liter as nitrogen	Nitrate plus nitrite, water, filtered, milligrams per liter as nitrogen	Nitrite, water, filtered, milligrams per liter as nitrogen	Total nitrogen [nitrate + nitrite + ammonia + organic-N], water, unfiltered, analytically determined, milligrams per liter	Total nitrogen [nitrate + nitrite + ammonia + organic-N], water, filtered, analytically determined, milligrams per liter	Orthophosphate, water, filtered, milligrams per liter as phosphorus	Phosphorus, water, unfiltered, milligrams per liter as phosphorus	Organic carbon, water, filtered, milligrams per liter	Organic carbon, water, unfiltered, milligrams per liter	Absorbance, 254 nm, water, filtered, absorbance units per centimeter	Suspended sediment, sieve diameter, percent smaller than 0.0625 millimeters	Suspended sediment concentration, milligrams per liter
Trinity River	Old River Lk nr Wallisville, TX	**Min**	<0.01	0.51	<0.040	0.002	0.68	0.40	0.024	0.080	5.27	7.10	0.140	92	30
		Max	<0.02	0.72	0.592	0.006	1.16	1.02	0.059	0.142	6.49	11.10	0.219	98	77
	Trinity River at Wallisville, TX	**Min**	<0.01	0.46	<0.040	<0.003	0.50	0.30	0.010	0.064	4.07	5.90	0.111	55	15
		Max	0.08	0.79	0.615	0.032	1.23	1.11	0.058	0.160	6.47	8.20	0.204	97	195
	Old River at Buckeye Island near Anahuac, TX	**Min**	<0.01	0.59	0.420	0.003	1.11	0.77	0.027	0.130	5.28	7.10	0.129	57	103
		Max	<0.02	1.10	0.611	0.009	1.16	1.05	0.053	0.149	6.08	8.30	0.208	81	222
Colorado River	Colorado River near Wadsworth, TX	**Min**	<0.01	0.63	<0.040	<0.003	0.65	0.64	0.085	0.150	3.05	4.30	0.065	60	18
		Max	0.72	1.90	3.070	0.168	4.76	3.91	0.323	0.870	8.06	12.80	0.344	100	1,320
Guadalupe River	Guadalupe River at SH 35 near Tivoli, TX	**Min**	<0.01	<0.07	1.040	0.014	1.92	1.61	0.201	0.276	2.31	3.00	0.056	93	21
		Max	0.06	0.93	5.030	0.092	5.48	4.94	0.514	0.672	6.28	10.80	0.222	100	970
	Guadalupe River at Victoria, TX	**Min**	<0.01	0.25	0.298	0.004	0.62	0.47	0.018	0.071	1.36	1.80	0.029	90	26
		Max	0.35	2.60	1.530	0.078	4.19	1.93	0.159	1.780	15.4	23.10	0.269	99	970
	San Antonio River at Goliad, TX	**Min**	<0.01	0.59	1.510	0.009	3.52	1.87	0.236	0.931	3.09	4.20	0.066	36	38
		Max	0.08	1.80	13.700	0.069	14.3	16.1	1.56	1.630	14.00	18.30	0.286	95	1,480
Nueces River	Nueces River near Odem, TX	**Min**	0.02	0.91	<0.040	<0.001	1.00	0.56	0.062	0.139	8.68	9.80	0.145	91	11
		Max	0.56	1.90	0.284	0.005	2.21	0.98	0.278	0.791	5.61	17.30	0.294	100	884
	Rincon Bayou Channel near Odem, TX	**Min**	0.02	0.55	<0.040	0.001	0.69	0.56	0.030	0.205	5.26	6.40	0.118	94	27
		Max	0.28	2.90	0.292	0.013	2.87	1.19	0.191	0.442	16.60	28.60	0.308	100	167

Sample data can be downloaded from NWIS, the Texas Coastal Science Webpage and the Water-quality Portal

Table 1-4. Results from water-quality and sediment sample sets collected at USGS monitoring stations in the lower Trinity River Basin.

[ft, feet; --, no data; P, results pending]

Station Name	Sample date	Discharge, instantaneous, cubic feet per second	Ammonia (NH3 + NH4+), water, filtered, milligrams per liter as nitrogen	Nitrite, water, filtered, milligrams per liter as nitrogen	Nitrate plus nitrite, water, filtered, milligrams per liter as nitrogen	Phosphorus, water, unfiltered, milligrams per liter as phosphorus	Orthophosphate, water, filtered, milligrams per liter as phosphorus	Organic carbon, water, unfiltered, milligrams per liter	Organic carbon, water, filtered, milligrams per liter	Suspended sediment concentration, milligrams per liter	Suspended sediment, sieve diameter, percent smaller than 0.0625 millimeters
Trinity River at Liberty, TX	11/25/2019	1,900	<0.01	0.002	0.062	0.073	0.022	5.6	4.30	30	96
Trinity River at Wallisville, TX	11/22/2019	2,118	<0.01	<0.001	<0.040	0.064	0.010	6.0	4.61	19	97
Trinity River at Liberty, TX	9/15/2020	13,200	0.01	<0.001	<0.040	0.139	0.064	6.0	4.01	93	76
Trinity River at IH 10 near Wallisville, TX	9/22/2020	2,813	0.08	0.002	<0.040	0.106	0.058	6.8	4.07	15	95
Trinity River at Liberty, TX	2/24/2021	8,230	0.02	0.005	0.643	0.149	0.048	6.7	4.89	42	78
Trinity River at IH 10 near Wallisville, TX	3/2/2021	6,692	<0.02	0.005	0.525	0.114	0.037	7.0	4.92	51	95
Livingston Res Site BC near Goodrich, TX	5/7/2021 (10 ft)	--	0.03	0.014	0.614	0.084	0.021	6.0	5.23	10	84
Livingston Res Site BC near Goodrich, TX	5/7/2021 (30 ft)	--	0.09	0.036	0.687	0.094	0.049	5.5	5.51	9	90
Trinity River near Goodrich, TX	5/7/2021	25,400	<0.02	0.018	0.501	0.076	0.014	6.3	5.12	49	39
Trinity River at IH 10 near Wallisville, TX	5/10/2021	15,931	<0.02	0.010	0.464	0.122	0.027	7.7	5.23	195	58
Trinity River at Liberty, TX	7/15/2021	19,200	<0.02	<0.001	0.132	0.152	0.081	7.7	6.20	P	P
Trinity River at IH 10 near Wallisville, TX	7/29/2021	8,218	<0.02	<0.001	<0.040	0.164	0.051	7.9	5.81	143	95