2022 LAVACA BASIN SUMMARY REPORT

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LAVACA-NAVIDAD RIVER AUTHORITY

THE TEXAS CLEAN RIVERS PROGRAM

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

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FOREWORD

The Clean Rivers Program (CRP) is a water quality monitoring, assessment, and public outreach program administered by the Texas Commission on Environmental Quality (TCEQ) and funded by state collected fees. The Lavaca–Navidad River Authority (LNRA) coordinates the CRP for the Lavaca Basin.

Under the CRP, LNRA staff collect field parameters as well as water samples for laboratory analysis, and make flow measurements throughout the watershed. These data are used to assess a water body and determine if it meets the appropriate quality standards for its designated use. This reoccurring monitoring and assessment can provide valuable insight about land use, possible sources of pollution, and trends over time.

The LNRA actively administers the CRP which enables the LNRA to:

- Pay personnel to administer and complete CRP tasks in the Lavaca Basin
- Perform monthly monitoring, quarterly monitoring, and special studies in the watershed.
- Purchase equipment
- Accomplish additional water quality analyses
- Support volunteer organizations in the Basin, such as Texas Stream Team, with the purchase of monitoring equipment and supplies
- Support Major Rivers, an educational program for fourth grade students in the schools located within the Lavaca Basin
- Encourage public participation in watershed management through CRP meetings, to bring together stakeholders, local municipalities, industries, and state agencies

Under the authorization of the Clean Rivers Act (1991), the LNRA completes reports detailing highlights in the Basin, special studies, updates to ongoing projects, and assessments of trends. These reports are used to inform the communities LNRA serves about water quality and resource management. Public participation is encouraged and information regarding how to get involved is included in this Basin Summary Report.

The LNRA contracted with Water Monitoring Solutions, Inc. to evaluate the historical data, perform trend analysis, and author this Basin Summary Report.

Cover photo: Photo of the confluence of the Lavaca River and Navidad River

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LIST OF ACRONYMS AND ABBREVIATIONS

ALU	Aquatic Life Use
AU	Assessment Unit (a hydrologically distinct reach of a segment)
cfs	Cubic feet per second (measurement of stream flow)
CRP	Clean Rivers Program
DO	Dissolved Oxygen
FM	Farm-to-Market Road
FY	Fiscal Year
HUC	Hydrologic Unit Codes
LNRA	Lavaca-Navidad River Authority
M	Meter
MGD	Million Gallons per Day
mg/L	Milligrams per Liter
MPN/100 mL	Most Probable Number per 100 milliliters (bacteria measurement units)
PCR	Primary Contact Recreation
RUAA	Recreational Use Attainability Analysis
S.U.	standard unit (pH)
SH	State Highway
SWQMIS	Surface Water Quality Monitoring Information System
TCEQ	Texas Commission on Environmental Quality
TKN	Total Kjeldahl Nitrogen
TPWD	Texas Parks and Wildlife Department
TSSWCB	Texas State Soil and Water Conservation Board
TSWQS	Texas Surface Water Quality Standards
UAA	Use Attainability Analysis
USGS	United States Geological Survey
WPP	Watershed Protection Plan
WWTP	Wastewater Treatment Plant
2020 IR	2020 TCEQ Integrated Report
2022 IR	2022 TCEQ Integrated Report
µg/L	Micrograms per Liter
§303(d) List	Impaired water bodies in Section §303(d) of the Federal Clean Water Act

EXECUTIVE SUMMARY

The Lavaca Basin, which is comprised of the Lavaca and Navidad River Watersheds, are located between the Colorado River watershed to the east and the Guadalupe River watershed to the west. Roughly equal portions of the Lavaca Basin are drained by the Lavaca and Navidad Rivers, which together encompass 188 stream miles and a total drainage area of 2,309 square miles.

The Lavaca Basin drains into upper Lavaca Bay, a secondary embayment of the Matagorda Bay system. The watershed contains all or portions of Colorado, DeWitt, Fayette, Jackson, Lavaca, Wharton, and Victoria Counties. Major population centers located within the Basin include Edna, Ganado, Hallettsville, Moulton, Shiner, Schulenburg, and Yoakum.

Protecting and preserving water quality in the Lavaca Basin is of upmost importance. Water in the Navidad River flows into Lake Texana which serves as a drinking water source to the City of Corpus Christi service area that includes Nueces, Refugio, Aransas, Bee, San Patricio, Kleberg and Jim Wells counties and the City of Port Comfort in Calhoun County. Preservation of water quality ultimately lowers water treatment costs and ensures a reliable source of drinking water for the future.

While the Lavaca River is one of the few remaining unrestricted rivers in Texas, the Lavaca and Navidad rivers provide critical freshwater inflow into Lavaca Bay, a secondary embayment of the Matagorda Bay system. These marshes, bays, and estuaries provide critical habitat for the reproduction of aquatic species including fish, shrimp and other invertebrates, such as blue crab. These organisms not only support recreational and commercial fisheries along the Texas Gulf Coast, they also provide critical habitat and food supplies for local and migratory waterfowl including the endangered whooping crane.

With only three waterbodies included in the 2020 Texas §303(d) List, the Lavaca River Basin maintains some of the highest water quality in the state. The 2020 Texas Integrated Report evaluated waterbodies based upon samples collected from December 1, 2011 through November 30, 2018. During this time period, data were collected during periods of extreme and near historic droughts followed by periods of near historic flooding along with the landfall of Hurricane Harvey, the first Category 4 hurricane in over fifty years.

TCEQ evaluated these sample results to determine if the waterbodies met their associated designated uses which included Aquatic Life, General, Recreation, and Domestic Water Supply uses. Of the 148 assessments performed, seven were found to not meet the associated designated use. Those not meeting their uses included three impairments for bacteria and two for low dissolved oxygen while one concern each was identified for low dissolved oxygen grab and for total phosphorus. All of the other evaluations revealed that the waterbodies fully supported their designated uses.

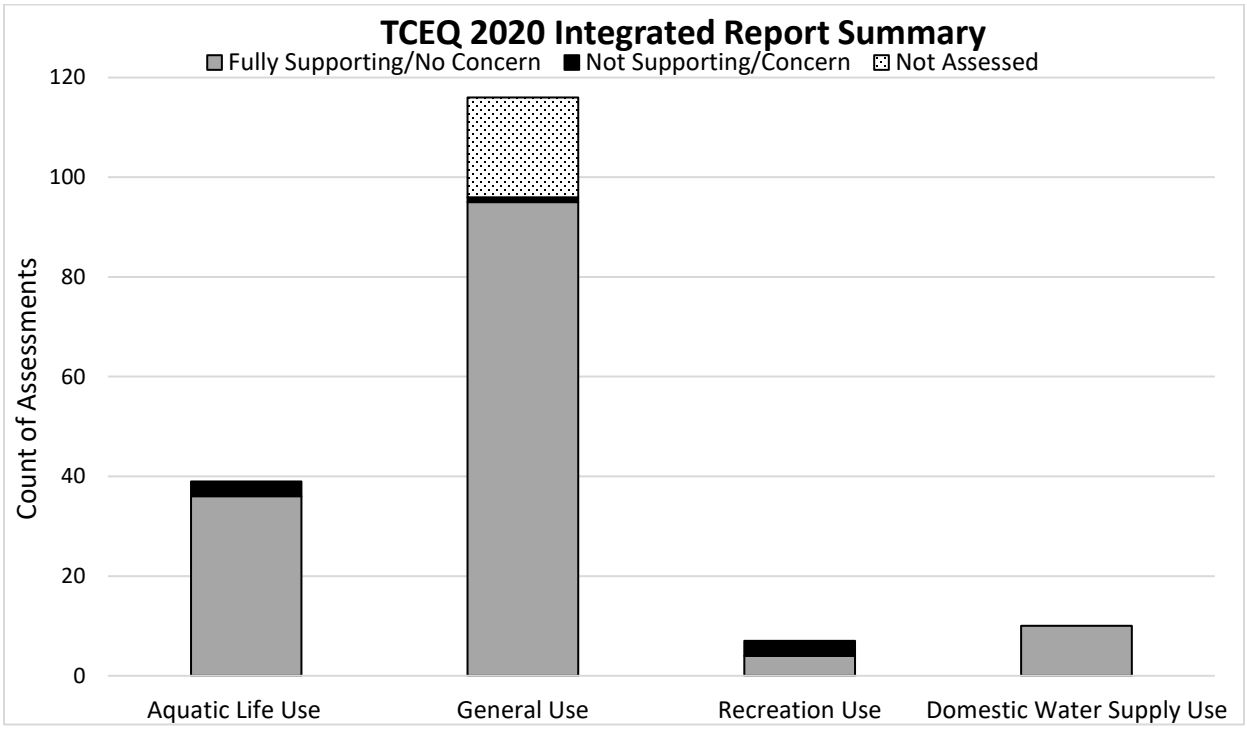

Figure 1: Summary of the 2020 Texas Integrated Report in the Lavaca-Navidad River Basin

All of the impairments and concerns occurred in Segment 1602 – Lavaca River above Tidal. Two assessment units of Segment 1602 and Unclassified Segment 1602B – Rocky Creek were impaired for bacteria. Assessment Units 1602_02 and 1602_03 had bacteria geometric means in excess of the 126 MPN/100 mL criterion with 202.7 MPN/100 mL and 175.5 MPN/100 mL, respectively. The Draft 2022 IR showed similar values. While the bacteria results had a moderate correlation with stream flow, the sources of bacteria were likely the result of both direct animal deposition and from runoff during storm events. Since the riparian corridor is mostly wooded, wildlife was one probable bacteria source. Due to cattle trails leading to the stream and the observance of livestock in the waterway, livestock were another likely source.

Unclassified Segment 1602B – Rocky Creek was added to the §303(d) List for bacteria in 2014. The 2020 IR reported a geometric mean of 279.8 MPN/100 mL while the geometric mean was 339.8 MPN/100 mL in the Draft 2022 IR. Based upon the regular sightings of cattle in the stream by field staff during sampling, livestock were a likely source of bacteria through direct deposition. Wildlife, including feral hogs, were another probable source of the impairment.

A Recreational Use Attainability Analysis was performed in 2017 to evaluate the use of Rocky Creek for primary contact recreation through data collection, observation, and interviews with land owners and the general public. The results of the study showed that primary contact recreation in the river was rare and that most contact with the waterbody was incidental through fishing and hunting activities.

The Lavaca River Watershed Protection Plan (WPP) commenced in 2016 and was developed to address water quality issues throughout the entire length of the Lavaca River and its tributary streams. The stakeholders of the Lavaca River Basin developed a strategy to restore water quality in the river. Stakeholders dedicated considerable time and effort in discussing the watershed, influences on water quality and potential methods to address water quality concerns, and selecting appropriate strategies to improve water quality.

The WPP determined that no single source of bacteria was the primary cause of the impairment. A variety of bacteria sources were identified by stakeholders including livestock, wildlife, domestic pets, improperly functioning on-site septic systems, sanitary sewer overflows, illicit dumping, and urban stormwater. Stakeholders identified management measures to reduce and feasibly manage instream bacteria levels. Stakeholders are responsible for the implementation of these voluntary management strategies and the Watershed Coordinator will continue to lead the efforts to implement the plan.

Both assessment units of Unclassified Segment 1602C – Lavaca River Above Campbell Branch were included on the §303(d) List for 24-Hour Dissolved Oxygen Average. The impairment was carried forward from previous assessments since no diel data were collected during the assessment period. In FY 2021, the LNRA began performing diels six times per year to address the impairment and to provide data for the assessment.

Trend analyses were conducted using data collected from 2001 through 2020 for flow, temperature, transparency (secchi depth), DO, specific conductance, pH, alkalinity, total suspended solids, ammonia, total Kjeldahl nitrogen, nitrate, total phosphorus, total organic carbon, hardness, chloride, sulfate, *E. coli*, total dissolved solids, and chlorophyll-*a*. There were 285 data sets that met the criteria for trend analysis. Of those data sets, 57 were mathematically normally distributed while statistically significant trends were identified for eighteen. However, only four of these trends met the analysis criteria of being both normally distributed and statistically significant. Statistically significant decreasing trends were identified for pH and flow in Segment 1602 – Lavaca River Above Tidal and for total Kjeldahl nitrogen and hardness in Unclassified Segment 1602B - Rocky Creek. Many of the trends that had been identified in the 2012 and 2017 Basin Summary Reports were caused by the pervasive drought and did not persist into this evaluation.

For Segment 1602 – Lavaca River Above Tidal, a statistically significant decreasing trend for pH at station 12527 was identified. Although there were no chlorophyll-*a* data available to review, it is perceived by field observation that algal productivity may have been affecting pH levels. Total phosphorus and nitrate exhibit higher concentrations at lower flows which is frequently observed downstream of wastewater treatment plants. The City of Moulton treatment plant, located upstream of this station, may be a source of excess nutrients. The physical conditions of the river upstream of the monitoring station along with elevated levels of nutrients at lower flows are ideal for promoting algal productivity. It also should be noted that about ninety percent of samples were collected before noon. Due to the lack of photosynthesis after dark,

algal respiration decreases pH throughout the night, thus samples collected in the morning hours tend to have low pH levels than those obtained midday.

A statistically significant decreasing trend for stream flow was also found at station 12527. The decreasing trend appeared to be the result of the drought periods of 2005 through 2006 and 2011 through 2014. Stream flow was often reported near zero during periods of drought.

Decreasing trends for Total Kjeldahl Nitrogen and hardness were identified in Unclassified Segment 1602B – Rocky Creek. Both decreasing trends may be a result of the pervasive drought followed by having more stream flow to dilute the parameter. The trend for total Kjeldahl nitrogen may also be due to improvements at the City of Shiner WWTP or a combination of both.

Hardness levels appear to decrease during prolonged droughts and then increase during the recovery periods. The decreasing trend is likely due to decreased runoff during the drought periods.

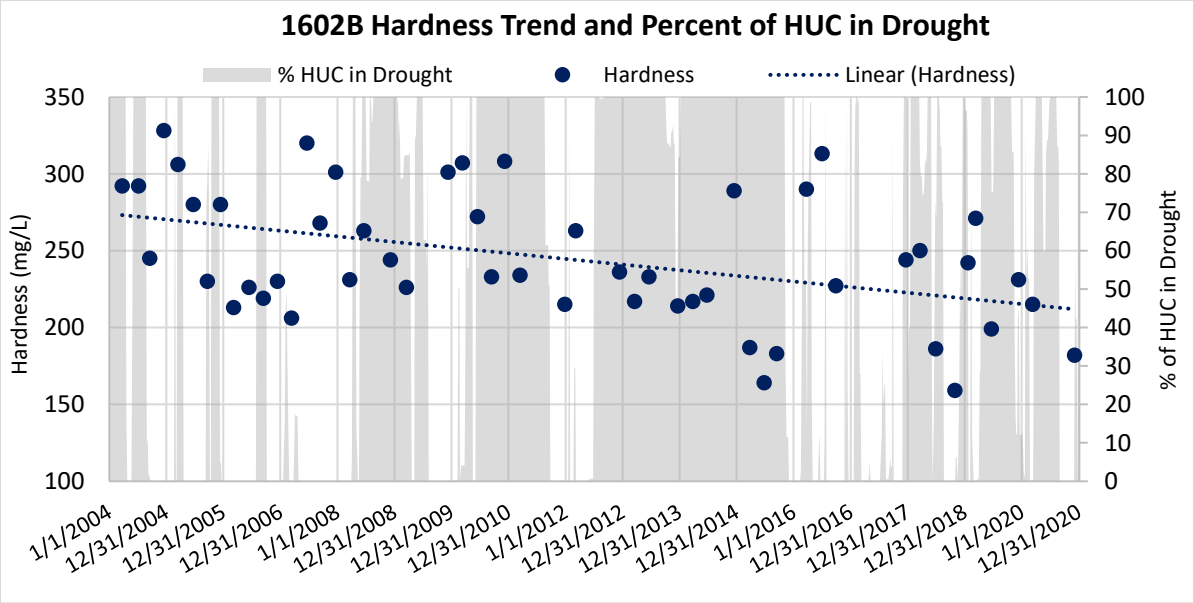

Figure 2: 1602B Decreasing Hardness Trend and Percent *of HUC in Drought*

Water used for irrigation may be a contributing source of hardness. The evaporation of irrigation water can leave behind minerals on the soil's surface. High runoff events then wash these minerals into the stream, thereby increasing their concentrations. In recent years, drought periods have been shorter than in the previous fifteen years. As a result, less irrigation has been needed, and in turn, the build-up of minerals on irrigated lands would not be as great as during extended drought periods.

Samples for total phosphorus and nitrate collected during the 2020 assessment period in Segment 1604A – West Mustang Creek were reported over the screening levels. The mean of the exceedances was 0.76 mg/L for total phosphorus and 6.33 mg/L for nitrate. Data collected

during the Draft 2022 IR assessment period showed one total phosphorus result at 0.75 mg/L and three nitrate exceedances with a mean of 7.48 mg/L.

Sediment and nutrient loading into Lake Texana are of great interest for the LNRA since high concentrations of nutrients can perturb water quality, drinking water sources, and aquatic life, while an increase in sediment loads can reduce water clarity and light penetration within the water column. During runoff events, nutrients bound to soil particles are transported into waterbodies through the process of soil erosion.

The 2020 Trophic Classification of Texas Reservoirs ranked Lake Texana as mesotrophic for having one of the lowest concentrations of chlorophyll-*a* in the state. With a mean chlorophyll-*a* concentration of 4.0 µg/L, Lake Texana is in the top ten percent out of 138 reservoirs for the lowest amount of chlorophyll-*a*. However, the reservoir falls into the bottom ten percent statewide for highest concentration of total phosphorus and lowest transparency.

On average, nitrate exceeded its screening level of 0.37 mg/L in almost one-third of all samples collected in Lake Texana over the past twenty years while total phosphorus surpassed its 0.20 mg/L screening level in over half of all samples. The highest percentage of exceedances occurred in the upper two assessment units which are the Navidad Arm and the Mustang Arm. The highest percentage of nutrient exceedances occurred in the Mustang Arm (AU 1604_02) with 32 percent of all nitrate and 85 percent of the total phosphorus results reported above their respective screening levels. The mean nitrate concentration was 0.43 mg/L while total phosphorus had an average of 0.30 mg/L. The maximum sample result obtained during this period was 2.98 mg/L of nitrate and 1.04 mg/L of total phosphorus. The nutrient results also had a moderate inverse correlation with lake elevation, meaning that as the lake elevation decreased, the nutrient concentrations increased. Nitrate had a correlation coefficient of -0.48 while total phosphorus correlated to lake elevation at -0.46.

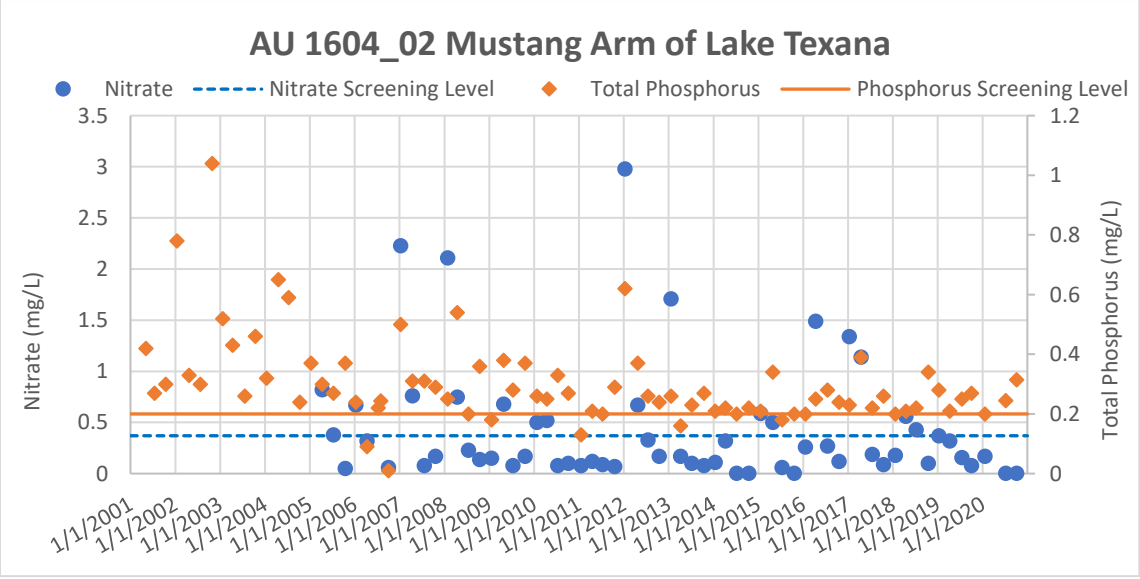

Figure 3: Nitrate and Total Phosphorus results in AU 1604_02 Mustang Arm from 2001 - 2020

Despite the high levels of nutrients throughout the entire reservoir, chlorophyll-*a* concentrations rarely exceeded the screening level. Out of 384 samples collected over the past twenty years, only four elevated chlorophyll-*a* values were reported. Those high values were obtained in the upper two arms of the reservoir.

Transparency, a measure of water clarity, is very limited in Lake Texana with a mean secchi depth of 0.26 meters (less than one foot). This poor water clarity in the reservoir limits the amount of light penetrating the water column, thereby limiting algal productivity. This has most likely prevented excessive algal blooms and its associated water quality issues including low dissolved oxygen and high pH.

During the process of photosynthesis, carbonic acid is reduced, thereby increasing the pH of the water column. Since grab samples are often collected near midday, pH readings reported to CRP tend to be higher than when collected soon after daybreak.

Although pH was generally trending higher in Lake Texana, it was no longer increasing at a statistically significant rate as observed in the 2017 Basin Highlights Report. However, it should be noted that all exceedances of the high criterion occurred in 2019 and 2020. In fact, high pH was measured in all assessment units in September 2019 while all but the Navidad Arm exceeded the high pH criterion in June 2020. Although no chlorophyll-*a* samples were collected on those dates, field notes stated that there were algal blooms present at the time of sampling. In September 2019, DO ranged from 129.4 percent saturation to 178.9 percent in all five assessment units. These super-saturated DO values corroborate the field notes that excessive algal production was the likely cause for the high pH exceedances throughout the reservoir. These results further indicate that high pH, caused by excessive algal productivity, could become a larger issue in Lake Texana in the future.

Since Lake Texana serves as a domestic drinking water supply, the reduction of nutrient inputs into the reservoir is of great value to the LNRA and its municipal raw water customers. Excessive nutrients lead to algal blooms which can cause taste and odor issues in treated drinking water, as well as the potential for the formation of trihalomethanes, depending upon the treatment process.

After a thorough review of all data collected over the past twenty years in the Lavaca Basin, it is recommended that the LNRA continue the current Clean Rivers monitoring program to address water quality concerns, impairments, and data needs throughout the Basin; continue to support the development and participation in the Watershed Protection Plan; and support stakeholder outreach and landowner education programs to reduce bacteria and nutrient inputs into the watershed from failing on-site septic systems and agricultural activities. It is further recommended that LNRA consider performing a Recreational Use Attainability Analysis in the Lavaca River to assess its use for primary contact recreation. Further, the LNRA should consider collecting monthly nutrient samples over a period of one to two years in Mustang and East Mustang creeks to thoroughly evaluate their contributions into Lake Texana.

INTRODUCTION

The Texas Commission on Environmental Quality (TCEQ) administers the Clean Rivers Program (CRP) and ensures its managing objectives are met throughout the state. TCEQ partners with river authorities, municipal water districts, councils of government, and other regional entities to pursue a coordinated approach to water quality issues and resource management to address monitoring needs in the watershed. A component of the CRP is interaction and input from stakeholders, local residents, and active members of the community affected by water quality issues.

The Lavaca-Navidad River Authority (LNRA) serves as the coordinator for managing and monitoring water quality in the Lavaca Basin. To accomplish the tasks set forth by the CRP, the LNRA coordinates with other entities including the TCEQ, U. S. Geological Survey (USGS), Texas State Soil and Water Conservation Board (TSSWCB), and the Texas Parks and Wildlife Department (TPWD).

Watershed Characterization

The Lavaca Basin is located between the Colorado Basin to the east and the Guadalupe Basin to the west. Roughly equal portions of the watershed are drained by the Lavaca and Navidad Rivers, which together encompass 188 stream miles and a drainage area of 2,309 square miles. The watershed contains portions of Colorado, DeWitt, Fayette, Jackson, Lavaca, Wharton, and Victoria Counties. Major population centers located within the basin include Edna, Ganado, Hallettsville, Moulton, Shiner, Schulenburg, and Yoakum.

Protecting and preserving water quality in the Lavaca Basin is of upmost importance. The Navidad River provides unique bottomland hardwood habitats rarely found elsewhere in the state. Water in the Navidad River flows into Lake Texana which serves as a drinking water source to the surrounding communities. Preservation of water quality ensures lower water treatment costs and will extend the reliable source of drinking water for the future.

The Lavaca River is one of the few remaining unrestricted rivers in Texas. The Lavaca and Navidad rivers provide critical freshwater inflow into Lavaca Bay, a secondary embayment of the Matagorda Bay system. These marshes, bays, and estuaries provide critical habitat for the reproduction of aquatic species including fish, shrimp, and other invertebrates, such as blue crab. These organisms not only support recreational and commercial fisheries along the Texas Gulf Coast, they also provide critical habitat and food supplies for local and migratory waterfowl including the endangered whooping crane.

As a result of the characteristically flat coastal plain topography and the low permeability of its soils, flooding can routinely occur within the watershed during rainfall depending upon antecedent conditions. The Lavaca and Navidad Rivers are typical of Texas rivers in general; their annual hydrographs can be characterized by extended low flow periods punctuated by flooding events.

Both the east and west headwaters of the Navidad River rise from southern Fayette County at an elevation of 440 feet. These forks join near Oakland at an elevation of 201 feet and flow southward to Lake Texana. Constructed by the U.S. Bureau of Reclamation for municipal, industrial, fish and wildlife, and recreational benefits, Lake Texana has a firm yield of 74,500 acre-feet of water per year with an additional 12,000 acre-feet of interruptible water available each year.

The Lavaca River originates above Moulton in Lavaca County at an elevation of 470 feet and flows southeast approximately 116.4 river miles into Lavaca Bay. The confluence of the Lavaca and Navidad Rivers is about two miles east of Vanderbilt in Jackson County. The Lavaca Basin is part of the West Gulf Coast Section of the Coastal Plain Physiographic Province and includes the Blackland Prairie, Claypan, and Coastal Prairie land resource areas.

In the upper part of the watershed, the Blackland Prairie is a level to rolling, well-dissected grassland with rapid drainage. The Claypan area is a gently rolling moderately-dissected post oak savannah with moderate surface drainage. In the lower watershed, the Coastal Prairie is a nearly level, practically undissected plain with slow surface drainage. The upper Lavaca Basin is underlain by gray clay of the Fleming Formation of the Tertiary Age which dips gently toward the Gulf of Mexico. Overlying the Fleming Formation are gravel, sand, silt, and clay of the Willis, Lissie, and Beaumont Formations each of which are dated to the Pleistocene Age.

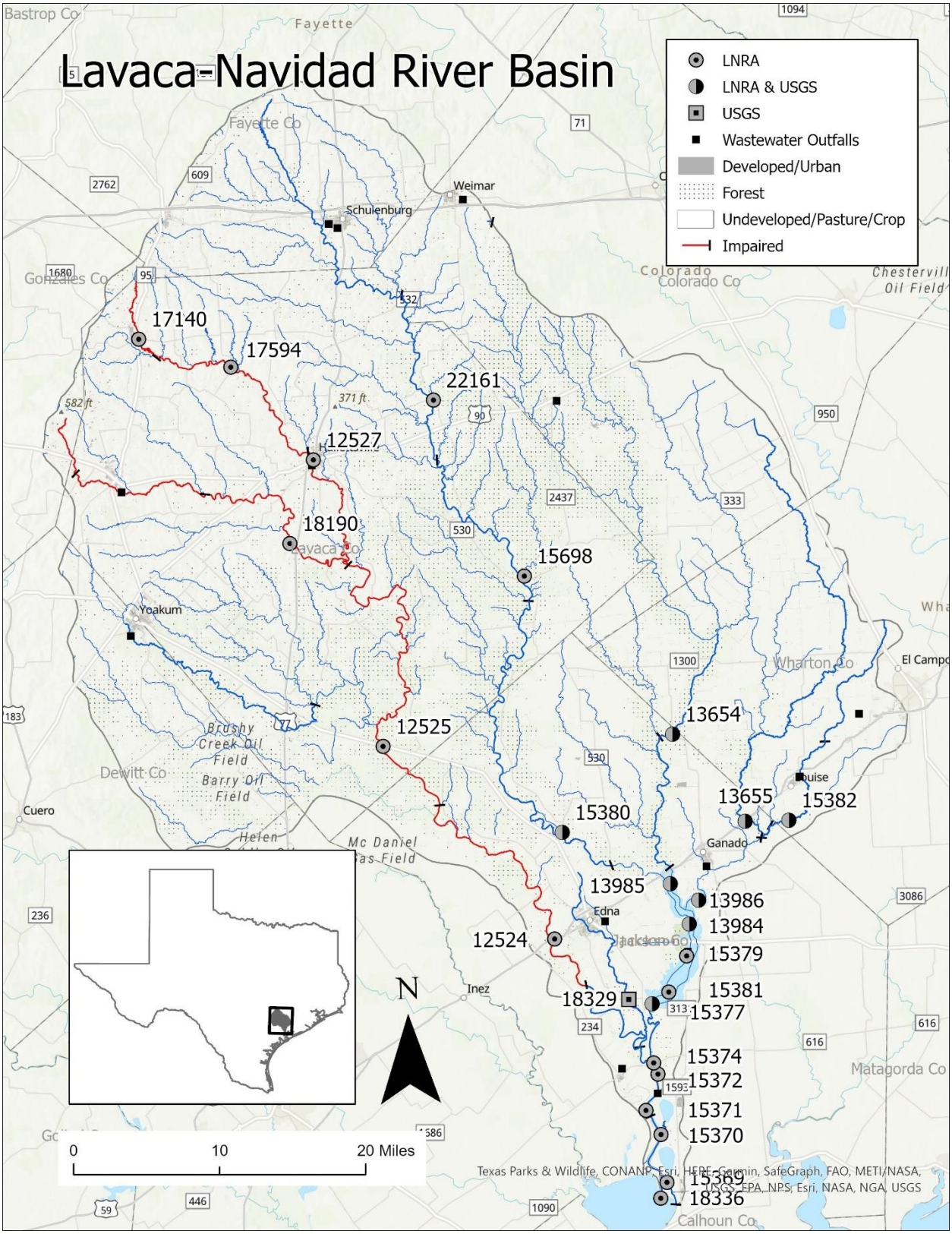

Figure 4: Map of the Lavaca-Navidad River Basin

2020 Texas Integrated Report Summary

The 2020 Texas Integrated Report (2020 IR) assessed data collected between **December 1, 2011 and November 30, 2018**. Note that the assessment for *E. coli* in Unclassified Waterbody 1602B required additional data to meet the number of records for a full assessment, thus evaluated results reported back to March 15, 2011. The methods used for the Integrated Report are described in the TCEQ document titled 2020 Guidance for Assessing and Reporting Surface Water Quality Data in Texas.

The Integrated Reports are based on designated uses and assessment units. **Designated uses** for waterbodies include Aquatic Life Use, Recreation Use, General Use, and Domestic Water Supply Use. Support for each of these designated uses is based on attainment of water quality criteria for various parameters. These criteria may be either standards or screening levels. Standards are defined in the Texas Surface Water Quality Standards (TSWQS) and are "narrative and numerical criteria deemed necessary to protect" the designated uses of waterbodies. Screening levels are criteria that have been developed for parameters which do not have water quality standards.

Each river basin in the state is broken into **segments** which are major waterbodies such as reservoirs, rivers, and tributaries. These segments can be either classified or unclassified. **Classified segments** are waterbodies that are defined in Appendix A of the TSWQS. **Unclassified segments** are those waterbodies that are not defined in Appendix A. These waterbodies are identified by the segment number of the waterbody into which they flow followed by a letter suffix. **Assessment units** (AU) are hydrologically distinct sub-sections of classified and unclassified waterbodies. They represent discrete areas of the segment such as the arms of a reservoir or portions of a stream between tributary confluences. If there are multiple monitoring stations within an assessment unit, data from these stations are grouped together for assessment purposes. Some segments may only have a single assessment unit while others may consist of several assessment units.

When assessment units are discussed in this report, they are designated by the letters "**AU**" followed by the segment number and assessment unit number. For example, Lake Texana is segment number 1604. The lowest assessment unit, the 1,824.8 acres near the dam, is numbered 01. When discussing the water quality of this assessment unit, the discussion will include "AU 1604_05" to identify the segment and assessment unit. The headwater of Lake Texana in the Navidad Arm is in assessment unit 01; discussions about the upmost portion of the reservoir are identified as "AU 1604_01".

Data collected through CRP has many uses, including the development of the surface water quality standards, determining if waterbodies meet those standards, and the development of wastewater permit limits. This report references the 2020 Texas Integrated Report which compares all available quality assured data to the TSWQS — or to screening levels when no

standards have been established. The Integrated Report defines the status of each waterbody as one of the following:

1. Meets or Supports — *Sufficient data are available to assess. The waterbody meets all applicable surface water quality standards and fully supports its designated uses. These waterbodies are labeled in tables as "FS" for fully supporting the criteria. When the waterbody meets its screening level for a parameter, the label of "NC" is assigned meaning there is "No Concern" for that constituent.*

2. Concern — *a) A concern for not meeting water quality criterion based upon adequate data, b) Sufficient data are not available to perform a full assessment and the limited data indicate surface water quality standards are not being met, or c) Surface water quality standards have not yet been established. If water quality data indicate a concern, resources are allocated to collect more data and verify the concern. These waterbodies are labeled in tables as "CN" or "CS". The "CN" label indicates that there is a concern for not meeting the water quality criterion for the parameter while "CS" indicates a concern for not meeting TCEQ screening levels.*

3. Impaired — *Sufficient data are available and show that the waterbody does not meet surface water quality standards. If monitoring data indicate a waterbody does not support one or more of its designated uses, then it is said to be impaired. Details of the impairment are published in the Texas Integrated Report and §303(d) List. Impaired waterbodies are shown as "NS" for not supporting its designated uses.*

LEVELS OF SUPPORT	
Designated Use Criteria	**Screening Level**
FS Fully Supporting	NC No Concern
CN Use Concern	CS Screening Level Concern
NS Non-support	

Figure 5: Levels of Support

These standards define an anti-degradation policy of the Clean Water Act to protect existing uses and water quality of less impacted waterbodies. Some water quality standards are applied generally across the State while other criteria are site-specific. Site-specific criteria are often revised when new data become available. Initially, site-specific standards were set for individual waterbodies in the State using limited data to establish uses and criteria. Many of the subsequent changes in water quality standards have involved revisions to the initial standards based upon additional data and evaluations. As new data were collected, a subsequent evaluation found that a revised criterion was appropriate.

The 2020 IR identified a total of seven concerns or impairments in the basin as shown in Figure

6. One concern and two impairments were identified for depressed Dissolved Oxygen by previous integrated reports and were carried forward into this assessment period due to lack of current monitoring. One concern for Total Phosphorus and three impairments for elevated *E. coli* levels were also identified by TCEQ based on data collected between 2011 and 2018. The water quality impairments and concerns shown in the 2020 IR are discussed for each segment. This report also details information released in the Draft 2022 Texas Integrated Report (2022 IR) which evaluates the results of samples collected from **December 1, 2013 through November 30, 2020**. The Draft 2022 IR was released for public comment on January 28, 2022.

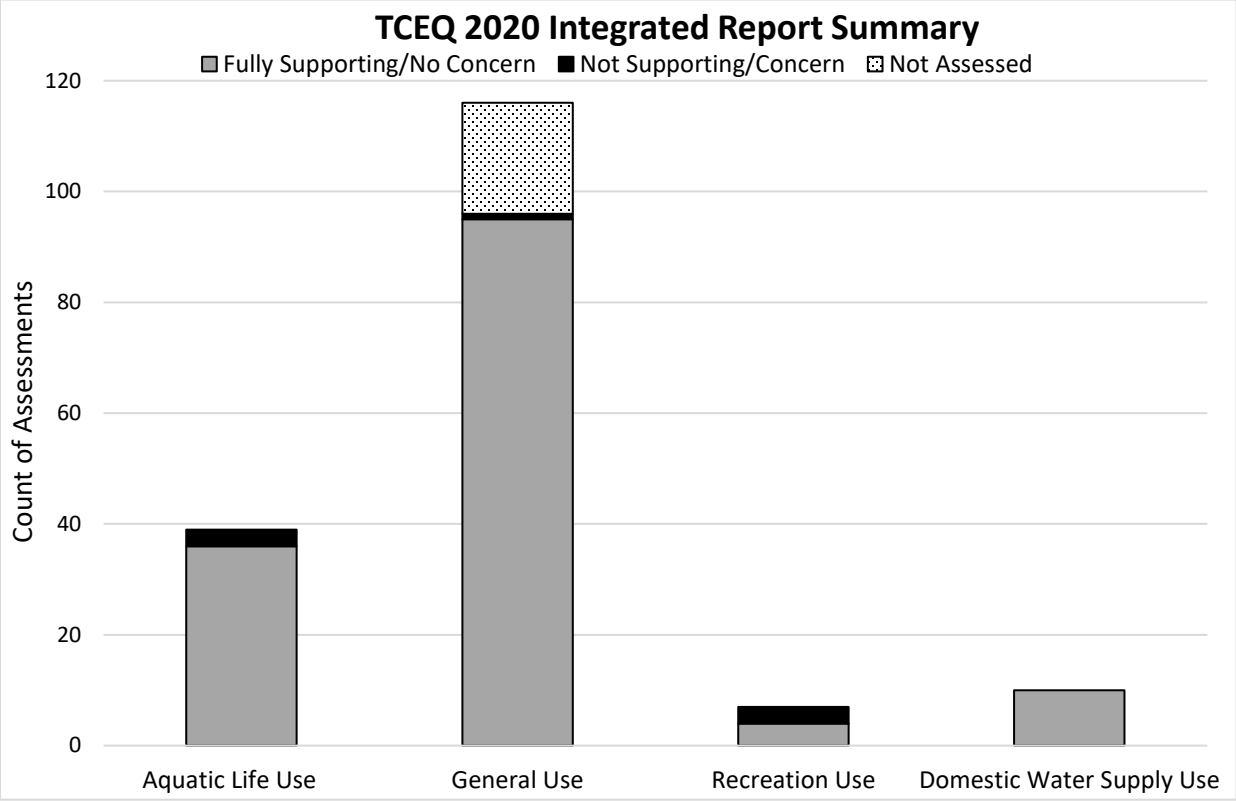

Figure 6: Summary of the 2020 Texas Integrated Report in the Lavaca-Navidad River Basin

Climate

The Lavaca Basin lies within the warm temperate zone and is classified as humid and subtropical with hot summers. Due to the proximity of the watershed to the Gulf of Mexico and its prevailing southeasterly wind, a marine climate exists throughout spring, summer, fall, and much of the winter season. Summers are hot and humid with little variation in day-to-day weather conditions, except for occasional thunderstorms. The central coastal region is subject to tropical storms and hurricanes. Winters are short and mild, moderated by polar air masses which frequently push southward and bring weather to the watershed that alternates from cool, overcast, and drizzly to mild, sunny, and dry conditions. The mean annual precipitation in

the Basin varies from 34 inches along the northern portions of the watershed to approximately 41 inches in the coastal areas.

Average annual net surface water evaporation rates range from approximately 20 inches along the eastern river basin boundary to approximately 28 inches along the western border. Relative humidity is often higher during winter and spring seasons, since hot air has a greater capacity for holding moisture. Mean monthly relative humidity has been measured at noon as 63 percent in January and April to 54 percent in July and October.

Graphs in the following water quality summary chapters may contain drought data. An example of this data is shown in Figure 7. Drought data can be useful in interpreting water quality data because parameters such as total dissolved solids and salts can increase during periods of drought due to evaporation concentrating these parameters. The concentration of these constituents is especially pronounced in reservoirs. Increases in nutrient level concentrations can be seen in effluent dominated streams due to the lack of inflows from precipitation. Nutrient levels in streams that are not effluent dominated can increase during drought recovery periods due to run-off washing nitrogen and phosphorus from fertilizers and animal waste into the stream.

Like much of Texas, the Lavaca Basin experienced a pervasive drought that began around 1999 and extended through 2014. The drought was punctuated with large rainfall events, but in 2011 and 2012, the drought reached comparable levels with the drought of record from the 1950's. Near-historic flooding in 2015 and 2016 ended the extended drought.

The drought data shown in the graphs of this report are based on information reported by the United States Drought Monitor website. Drought information is organized by Hydrologic Unit Codes (HUC). HUCs are subdivisions of watersheds; the more digits in the HUC, the smaller the watershed size. The codes are classified by the number of digits from HUC 2 to HUC 8 at the Drought Monitor website. The Lavaca Basin lies within the Texas Gulf Region 12; a HUC 2 code. The HUC 6 level further subdivides river basins, and the Lavaca region is coded HUC 121001. The HUC 8 level further divides these basins into smaller drainage areas such as 12100101 for the Lavaca River basin and 12100102 for the Navidad.

Data from 2002 through 2021 were obtained for Hydrologic Unit Code (HUC) 121001 which includes the entire basin. The Drought Monitor reports the percent of the area in the six stages of drought intensity: None, D0 – abnormally dry; D1 – moderate drought; D2 – severe drought; D3 – extreme drought; and D4 – exceptional drought. Note that, with the exception of Figure 7, there is no distinction made between the drought intensity categories in the data analysis graphs in the remainder of the report.

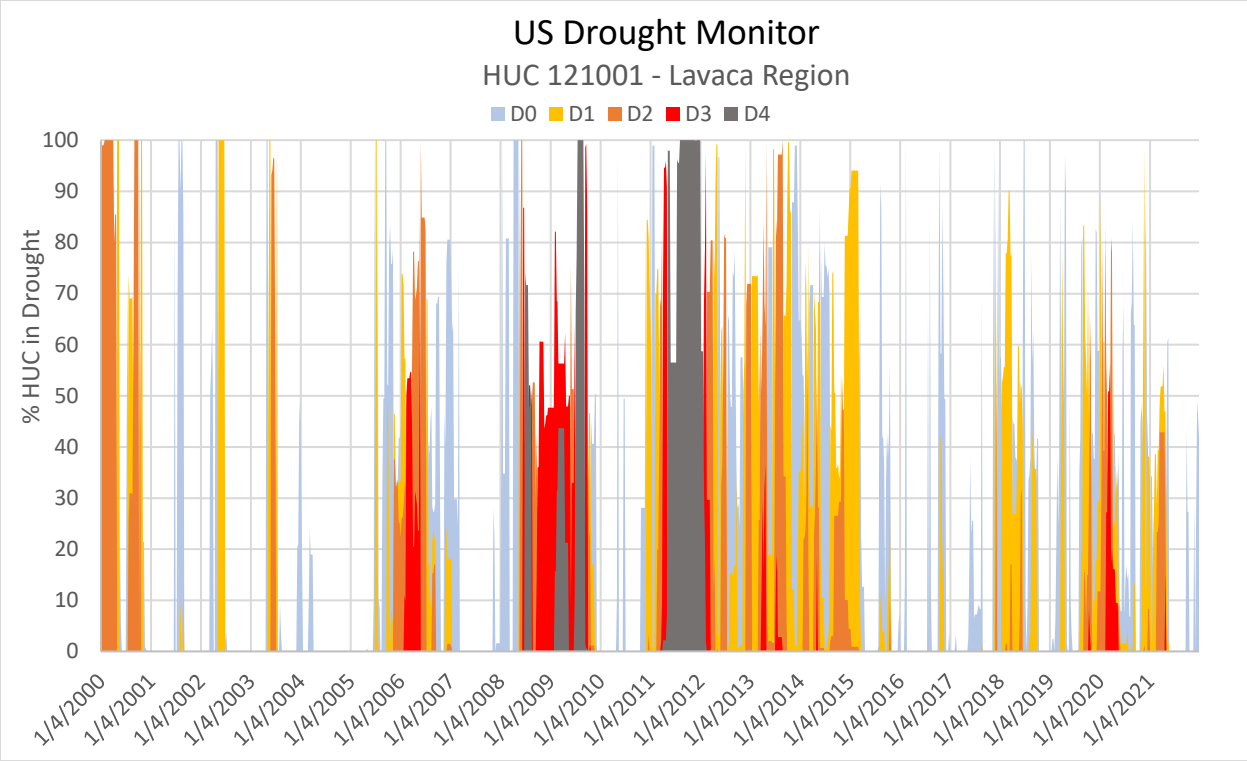

Figure 7: US Drought Monitor, Percent of HUC 121001 - Lavaca Region, in Various Stages of Drought from 2000 – 2021

On August 25, 2017, Hurricane Harvey made landfall on the Texas Coastal Bend; the first category 4 storm to impact the region in 56 years. The last hurricane to make landfall of comparable size was Hurricane Carla, a category 5 hurricane which made landfall in Calhoun County near Port Lavaca in 1961.

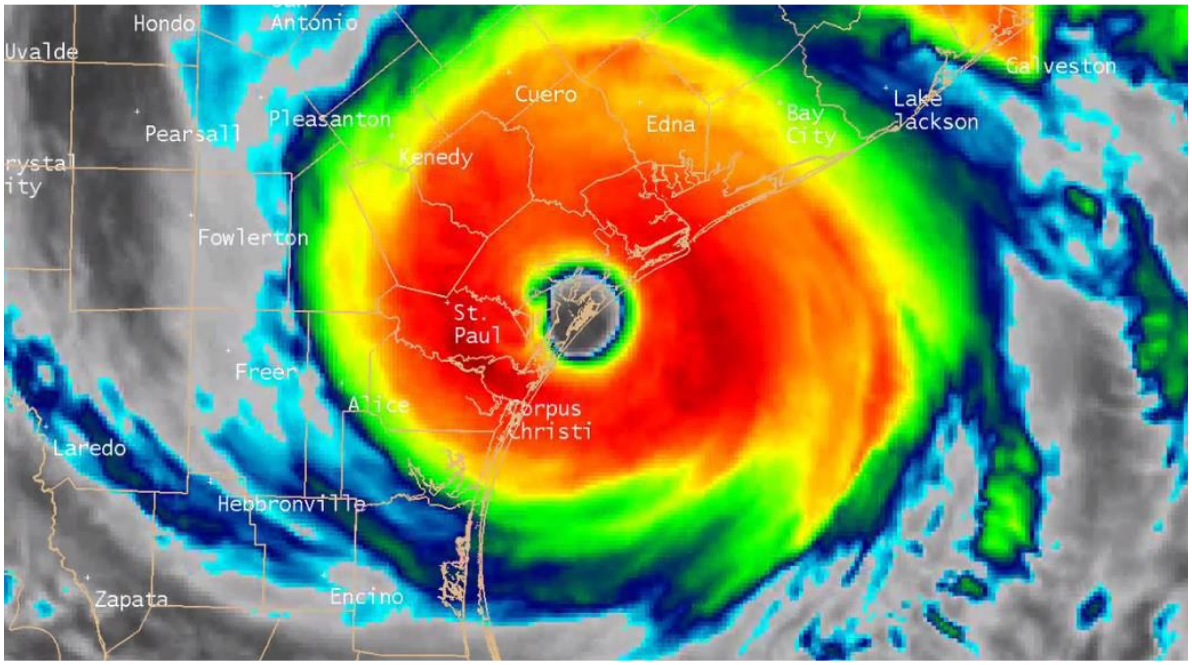

Figure 8: Photo of Hurricane Harvey making landfall in the Texas Coastal Bend

Due to flooding from Harvey, LNRA released 70,344 cubic feet per second (cfs) of water, with a total volumetric discharge of 478,122 acre-feet. Considering that Lake Texana has a storage capacity of 161,085 acre-feet, approximately three times the reservoir's capacity was released. While Hurricane Harvey devastated many areas with high winds and torrential rainfall, the Lavaca Basin was mostly spared.

The event did have a positive impact on Lake Texana water quality. Water clarity in Lake Texana is normally considered turbid due to the clay substrate that embodies the impoundment; average secchi readings range from 0.15 - 0.25 meters. Three to four months after Hurricane Harvey, secchi readings ranged from 0.65 - 0.71 meters.

Figure 9: Water released from the Palmetto Bend Dam spillway into the Navidad River, Segment 1603, after Hurricane Harvey

Special Studies

The LNRA contracts with the USGS to monitor Lake Texana and its tributaries (including Mustang and Sandy Creeks and the Navidad River) for pesticides, herbicides, and metals. The USGS has historically provided monitoring at nine stations concentrated in and near Lake Texana and its tributaries. Field parameters and flow (at stream stations) are measured at the time of sampling. The locations of USGS sampling are identified in the report and can be found at the FY 2022 Coordinated Monitoring Schedule.

In addition, the LNRA supports the Lavaca River Watershed Protection Plan (WPP). The WPP was developed through direct stakeholder involvement and is designed to improve the water quality of the Lavaca River and its tributaries through public outreach and voluntary measures including best management practices to reduce nutrient and bacteria inputs. More details on the WPP are discussed in the Watershed Summaries under Segment 1602 – Lavaca River Above Tidal.

Community Involvement

Public outreach efforts by LNRA include seeking guidance for water quality issues and activities from the Lavaca Basin Steering Committee, education and assistance in water conservation and drought contingency planning, news releases, public meetings, attendance at water quality issues meetings, providing water education materials (*Major Rivers*) to elementary schools throughout and near the Basin, presentations to groups, and support of the Texas Stream Team volunteer water quality monitoring program.

LNRA staff members are available to answer questions or give assistance with water quality information to students, stakeholders, members of the public and to respond to calls from concerned citizens. LNRA staff investigate concerns provided by citizens and contact the appropriate regulatory agency to address the issue. This cooperation between citizens, LNRA, and regulatory agencies has resulted in an effective response to potential water quality problems within the Basin. In addition, Michael Price is LNRA's Public Outreach Coordinator. Mr. Price teaches nature crafts and programs at the Community Education Center located at Texana Park and is also available to travel to schools and libraries to present various environmental education programs. LNRA provides the cost of these programs. You may contact Michael Price by phone, 361-308-0153 or via e-mail at mprice@lnra.org.

The Lavaca Basin Steering Committee: LNRA works with its CRP Steering Committee to seek public input, disseminate water quality information, and set monitoring priorities in the Lavaca Basin. Membership in the Steering Committee is open to staff from state and local governments, private landowners, representatives of industry and agriculture, and other

stakeholders from inside or outside the Basin. Anyone interested in participating as a member of the Steering Committee may contact the offices of LNRA and speak to the Director of Environmental Services, Chad Kinsfather or to the Deputy General Manager of Administration, Karen Gregory at 361-782-5229.

The Lavaca Basin Steering Committee provides guidance on the use of resources that come from the CRP. The Steering Committee allows LNRA to gain insight from local stakeholders and expertise from such members as TPWD, TCEQ, USGS, NRCS, Texas Stream Team, Texas Department of Agriculture, TSSWCB, and the County Agricultural Extension Service. Input from the Committee allows LNRA to prioritize water quality issues and to determine the most effective water quality monitoring program.

CRP Steering Committee meetings are held annually in the summer. Meeting notices are mailed at least forty-five days in advance to Committee members, and notices of the meetings are posted on the LNRA website. Contact information and a map to the meeting location are found on the LNRA Clean Rivers page by selecting "Water" from the LNRA home page. Agendas and minutes of the meetings are also posted on-line. In addition, LNRA places notices of the meetings in all local newspapers (Edna, Hallettsville, Moulton, Schulenburg, Shiner, Yoakum) inviting the public to attend.

To become involved, contact:

Lavaca-Navidad River Authority
361-782-5229
PO Box 429
Edna, Texas 77957
Environmental Department:
Chad Kinsfather ckinsfather@LNRA.org

Texas Stream Team (formerly named Texas Watch): LNRA provides support to the Texas Stream Team volunteer water quality monitoring program by providing equipment, supplies and reagents, quality assurance, and environmental data to the volunteers. The Texas Stream Team Program is a statewide network of concerned volunteers, partners, and institutions collaborating to promote a healthy and safe environment through environmental education, data collection, and community action.

Anyone wishing to become involved with Texas Stream Team may contact the Texas Stream Team at 1-877-506-1401, Chad Kinsfather ckinsfather@lnra.org with LNRA, or by visiting the Texas Stream Team website.

Extensive water quality information for the Lavaca Basin is available via the LNRA website. Visit the LNRA home page for links to the TCEQ, to information about the Clean Rivers Program, stream flow gages, lake and weather information, and much more.

News and Information

LNRA Water Quality Database: Extensive water quality information for the Lavaca Basin is available via the TCEQ SWQMIS Data Viewer. The TCEQ Surface Water Quality Monitoring Information System (SWQMIS) Data Viewer includes all TCEQ-approved water quality data for the Lavaca Basin, both historical and recent. The data may be accessed by basin, segment, or by TCEQ site number. Current TCEQ-approved data can also be accessed via the LNRA website under: Water, Water Quality, Water Quality Links, SWQMIS Data Viewer.

Water quality data can be displayed as ASCII delimited text file that can be imported into a spreadsheet or database. Once a station is selected, data can be retrieved either by sampling date or by parameter—both of which are displayed in pull down menus. This is an excellent tool for students or anyone needing to access historical or current water quality information for the Lavaca Basin.

As a service to residents in the watershed, the LNRA maintains an Early Warning System on the LNRA website. Sixty-four (64) continuous monitoring stations around the watershed are maintained for the following purposes:

Stream Level Alarms: Stream levels are monitored at 20 stations throughout the Basin. Water levels for bank full (immediately before flood level), zero flow, alarm, warning, major flood, road closures, and record highs can be located on the LNRA website.

Current Weather Conditions: The LNRA posts hourly data for precipitation, wind speed and direction, humidity, temperature, barometric pressure, and lake elevation recorded at the meteorological station at the LNRA headquarters.

Rain and Stream Levels: Water level sensors are continuously monitored at several stations. Multiple sensors are included on the Lavaca River, Navidad River, Sandy Creek, East Mustang Creek, West Mustang Creek, Tres Palacios Bay, Carancahua Bay and Lavaca Bay.

24-Hour Precipitation Map: A map of the Lavaca Basin contains the locations of 40 rainfall gauges throughout the watershed. Daily rainfall is displayed to the one hundredth (0.01”) of an inch at each location.

Anyone wishing to be notified of certain conditions such as lake elevations, water releases, stream levels, or alarm levels. Please visit the Early Warning System information on the LNRA website.

Data Preparation and Trend Analysis

Data Preparation

All data used for trend analyses were obtained from the TCEQ Surface Water Quality Monitoring Information System. The period of record used for this Basin Summary Report is from May 2001 to December 2020. The data were processed to obtain data sets that were suitable for trend analyses. Although the Integrated Report groups monitoring stations in assessment units, trend analyses in this Basin Summary Report are based on individual stations. This is because there may be localized conditions which may affect water quality between stations that could be missed if trends were analyzed on the assessment unit scale.

Non-detect data are generally problematic when determining usefulness in data analysis. A data point that is reported as "less than" a reporting limit is an unknown value that may be anything from zero to the concentration at the reporting limit. Therefore, it is not acceptable to censor the value to zero as this falsely biases the data set down. It is not acceptable to delete the data point as that removes the record of sampling. Reporting limits can change over time; they normally decrease as technology improves. Simply removing the less than symbol may introduce false decreasing trends for data sets that have a lot of non-detect data. For the purposes of this report, all non-detect data were censored to one-half of the lowest reporting limit in the data set for each parameter. While this method may introduce false trends if the non-detect data are concentrated near the beginning or end of the data set, it prevents influencing trends if the non-detect data are spread throughout the data set. Additionally, false trends are visually obvious when viewing graphed data as the censored data appear as a fixed minimum concentration in the data set. Data that are reported as "greater than" a given value are less problematic. Typically, there are far fewer of these data points in a data set and represent parameters such as Days Since Precipitation Event and *E. coli*. There are no standards or screening levels for Days Since Precipitation Event and this parameter is useful for determining reasons for elevated concentrations of parameters that occur soon after precipitation. *E. coli* has a maximum test result of 2400 MPN/100 mL for undiluted samples, which is much greater than the standard of 126 MPN/100 mL. For these reasons, if a data point was reported with a greater than symbol, the symbol was simply removed.

Flow severity data were also edited. Data for this parameter are reported as a single digit number that represents a broad range of flows. Due to the addition of flow categories over time, the existing values do not represent a linear increase in flow ranges: 1=no flow, 2=low flow, 3=normal flow, 4=flood, 5=high flow, 6=dry. These values were recategorized as follows to be meaningful for trend analysis: 1=dry, 2=no flow, 3=low flow, 4=normal flow, 5=high flow, 6=flood. Data at stations for which depth profiles were collected were summarized as appropriate. The lower boundary of the mixed surface layer is the depth where the temperature difference is greater than 0.5 degrees Celsius from the surface sample. Data for

each parameter within the mixed surface layer were averaged together with the exception of pH which was taken as the median.

Further processing was conducted to meet TCEQ guidelines for trend analyses. Any data sets with less than ten years of data or with irregular sampling/large data gaps were removed. Any stations and parameters for which there were less than twenty data points were removed and for which more than fifty percent of the data set were censored non-detect data were removed. The remaining data were then passed to the trend analysis step.

Trend Analysis

Trend analyses were conducted for log transformed Flow, Water Temperature, Secchi Depth, Dissolved Oxygen, Specific Conductance, pH, Alkalinity, Total Suspended Solids, Ammonia, Total Kjeldahl Nitrogen, Nitrate, Total Phosphorus, Total Organic Carbon, Hardness, Chloride, Sulfate, log transformed *E. coli*, Total Dissolved Solids, and Chlorophyll-*a*.

Most water quality data are inherently non-normal, while most statistics are based on the assumption of normality. This can make the results of statistical analyses performed on water quality data less reliable. To increase the reliability of trend analyses in this report, only trends identified for data sets that fell within predefined boundaries of adequate normality were considered significant. Normality can be determined by the skewness and kurtosis of the data set.

Skewness refers to the length of one tail compared to the other on a distribution plot. In a normally distributed data set, the skewness is zero. This indicates that the length of the tails on either side of the peak are equal. If skewness is less than zero, the data is skewed to the left indicating that the left tail is longer compared to the right tail. If skewness is greater than zero, the data is skewed to the right indicating that the right tail is longer than the left tail. To extend these findings to a population, a test statistic must be calculated. Skewness divided by the standard error of skewness is a common test statistic. If the test statistic for the sample set is greater than two or less than negative 2, then it can be inferred that the population is likely to be skewed in the same direction as the sample set.

Kurtosis is a measure of peakness of a data set. The standard kurtosis calculation for a normally distributed data set results in a value of three. Excess kurtosis simply subtracts a value of three from the standard calculation, resulting in a value of zero. This is a matter of convention and ease of comprehension. For this report, excess kurtosis is used. If excess kurtosis is positive, the peak is taller and narrower with longer tails indicating that there are more values around the mean than a normal distribution. If excess kurtosis is negative, the peak is shorter and flatter with shorter tails indicating that there are more values at the extremes than a normal distribution. Similar to skewness, a test statistic is calculated by dividing excess kurtosis by the standard error of excess kurtosis. If the test statistic is greater than three or less than negative

three, then it can be inferred that the population is peaked in a manner similar to the sample set.

Significance of a trend is based on the R^2, p-value, and t-statistic. The R^2 value is used as a measure of how well the predicted line, or the regression line, fits the observed data. R^2 values range from zero to one with one being a perfect fit. R^2 values greater than or equal to 0.1 were considered to be a good fit; meaning that 10 percent of the difference between the observed and predicted values is explained by the independent variable. Although this may not seem like a good fit, as stated previously, most water quality data are not normally distributed while most statistics are based on normality. An R2 value of 0.1 was selected because it is more inclusive.

The null hypothesis for temporal trend analysis is that there is no correlation between time and measured values; in other words, there is no significant trend. The p-value is the probability of a null hypothesis being true or a measure of confidence that a data set can be used to make predictions and that the observed values are not random. For trend analyses in this report, a significance level of 0.1 was used to determine statistical significance. If the p-value is less than 0.1, the trend is significant and the observed values are not random.

The t-statistic is the probability that a correlation (or slope) is due to chance. If the regression line falls entirely within two standard errors away from the slope, then the t-statistic value is close to zero and the correlation is due to chance and therefore not significant. If the regression line crosses over the lines two standards error away from the slope, then the t-statistic is greater than the absolute value of two and the correlation is not due to chance and is significant. If the data set passed the R^2, p-value, and t-statistic tests, then the trend was considered significant.

There were 285 data sets that met the criteria for trend analysis. Of those data sets, 57 were mathematically normally distributed while statistically significant trends were identified for eighteen. However, only four of these trends met the analysis criteria of being both normally distributed and statistically significant. Statistically significant decreasing trends were identified for pH and flow in Segment 1602 – Lavaca River Above Tidal and for total Kjeldahl nitrogen and hardness in Segment 1602B - Rocky Creek. These trends are discussed in more detail in the Watershed Summaries for each waterbody.

Table 1: Statistically Significant Trends in the Lavaca Basin

AU ID	Station	Parameter	Samples	Skewness	Kurtosis	R^2	p-value	t-statistic	Trend
Segment 1602B Rocky Creek									
1602B_01	18190	Total Kjeldahl Nitrogen	25	0.266	0.303	0.174	0.038	2.201	Decreasing
1602B_01	18190	Hardness	51	0.337	1.057	0.194	0.001	3.434	Decreasing
Segment 1602 Lavaca River Above Tidal									
1602_02	12527	pH	72	1.388	1.393	0.141	0.001	3.394	Decreasing
1602_02	12527	Flow	84	1.644	0.17	0.146	0.000	3.74	Decreasing

Water Quality Parameters

LNRA collects and analyzes water quality samples in the Lavaca Basin and submits the resulting data three times annually to TCEQ for inclusion in the state water quality database. After acceptance and approval by TCEQ, the data is made available via the LNRA website for public access. Water quality monitoring includes collection of field parameters at 24 sites and conventional lab analysis at 19 stations.

Field Parameters

Temperature – Water temperature affects the oxygen content of the water, with warmer water unable to hold as much oxygen. When water temperature is too cold, cold-blooded organisms may either die or become weaker and more susceptible to other stresses, such as disease or parasites. Colder water can be caused by reservoir releases. Warmer water can be caused by removing trees from the riparian zone, soil erosion, or use of water to cool manufacturing equipment.

Dissolved Oxygen (DO) – Organisms that live in the water need oxygen. In stream segments where DO is low, organisms may not have sufficient oxygen to survive. Modifications to the riparian zone, human activity that causes water temperatures to increase, increases in organic matter, bacteria and over abundant algae may cause DO levels to decrease.

Specific Conductance – Conductivity is a measure of the water body's ability to conduct electricity and indicates the approximate levels of dissolved salts, such as chloride, sulfate and sodium in the stream. Elevated concentrations of dissolved salts can impact the water as a drinking water source and as suitable aquatic habitat.

pH – pH is a measure of the acidity or basicity of a solution. Most aquatic life is adapted to live within a relatively narrow pH range, but tolerant species can adjust to varying pH ranges. However, pH levels below 4 (acidity of orange juice) or above 12 (basicity of ammonia) are lethal to most fish species. Industrial and wastewater discharge, runoff from quarry operations, and accidental spills are examples of factors that can change the pH composition of a water body.

Flow – Flow is an important parameter affecting water quality. Low flow conditions common in the warm summer months create critical conditions for aquatic organisms. At low flows, the stream has a lower assimilative capacity for waste inputs from point and nonpoint sources.

Transparency – Transparency is a measure of the depth to which light is transmitted through the water column and thus the depth at which algae and aquatic plants can grow. Secchi disk transparency is an important secondary parameter for assessing eutrophication, the natural aging process in reservoirs and lakes, and for identifying trends in water clarity.

Salinity – Salinity is computed from specific conductance and temperature. It is recorded at tidally influenced stations only. Salinity plays a role in determining estuarine sites and the composition of saline water diluted by river water.

Flow Severity – Flow severity is a parameter recorded at freshwater (non-tidally influenced) sites. It is an observational measurement that depends on the sampler's knowledge of the water body. This parameter is often used when assessing a water body as a supporting detail of conditions present during sampling.

Flow Method – The method used to measure flow is also recorded to provide information as to how the flow was determined. Flow is often reported using a USGS gage or measured in wadeable streams using a Doppler or electronic flow meter.

Conventional Laboratory Parameters

Water quality monitoring also includes laboratory analyses for conventional parameters. Laboratory analysis include:

Total Dissolved Solids – High total dissolved solids may affect the aesthetic quality of the water, interfere with washing clothes and corrode plumbing fixtures. High total dissolved solids in the environment can also affect the permeability of ions in aquatic organisms. Mineral springs, carbonate deposits, salt deposits and sea water intrusion are sources for natural occurring high concentration dissolved solids levels. Other sources can be attributed to oil exploration, drinking water treatment chemicals, storm water and agricultural runoff, and point/non-point wastewater discharges.

Total Suspended Solids – All particles suspended in water which will not pass through a filter – commonly results from erosion of soils, run-off, and sediment.

Total Hardness – Hardness is a composite measure of certain ions in the water, primarily calcium and magnesium. The hardness of the water is critical due to its effect on the toxicity of certain metals. Higher hardness concentrations in the receiving stream can result in reduced toxicity of heavy metals.

Chloride – Chloride is an essential element for maintaining normal physiological functions in all organisms. Elevated chloride concentrations can disrupt osmotic pressure, water balance, and acid/base balances in aquatic organisms which can adversely affect survival, growth, and/or reproduction. Natural weathering and leaching of sedimentary rocks, soils, and salt deposits can release chloride into the environment. Other sources can be attributed to oil exploration and storage, sewage and industrial discharges, run off from landfills, and saltwater intrusion.

Sulfate – Effects of high sulfate levels in the environment have not been fully documented. However, sulfate contamination may contribute to the decline of native plants by altering chemical conditions in the sediment. Due to abundance of elemental and organic sulfur and

sulfide mineral, soluble sulfate occurs in most natural waters. Other sources are the burning of sulfur containing fossil fuels, steel mills, and fertilizers.

E. coli **and Enterococcus (Bacteria)** – Although not all bacteria are harmful to human beings, the presence of *Escherichia coli* is an indication of recent fecal matter contamination and that other pathogens dangerous to human beings may be present. Occurring naturally in the digestive system of all warm-blooded animals, these bacteria are commonly found in surface water. Poorly maintained or ineffective septic systems, overflow of domestic sewage, wildlife, waterfowl, and other non-point sources, such as runoff from animal feedlots can elevate bacteria levels.

Chlorophyll-*a* – High levels of chlorophyll-*a* can indicate algal blooms, decrease water clarity, and cause swings in dissolved oxygen concentrations due to photosynthesis and respiration processes. An increase in nutrients can increase growth and reproduction in algal species.

Turbidity – Turbidity is a measure of the water clarity or light transmitting properties. Increases in turbidity are caused by suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms.

Nutrients (Ammonia, Nitrate, Phosphorus) – Nutrients increase plant and algal growth. When plants and algae die, the bacteria that decompose them use oxygen. This reduces the dissolved oxygen in the water.

Elevated levels of nitrogen in the environment can adversely affect fish and invertebrate reproductive capacity and reduce the growth of young. Ammonia is excreted by animals and is produced during the decomposition of plants and animals.

High levels of nitrates and nitrites can produce nitrite toxicity, or “brown blood disease.” It can contribute to Blue Baby Syndrome in humans, a disease which reduces the ability of blood to transport oxygen throughout the body.

Nutrients are found in effluent released from wastewater treatment plants, fertilizers, and agricultural runoff. Soil erosion and runoff from farms, lawns, and gardens can add nutrients to the water.

WATERSHED SUMMARIES

Factors with the potential to influence water quality in the Lavaca Basin include oil and gas exploration, concentrated animal feeding operations, agricultural activities, wildlife (including feral hogs), and municipal wastewater treatment facilities. Based on the analysis of water quality (and considering factors like drought in the region) it appears water quality is improving with the upgrades to industrial pre-treatment and wastewater treatment plants.

The Lavaca River is divided into non-tidal and tidal segments, while the Navidad River is divided into three segments including the non-tidal section, Lake Texana, and the tidal portion of the river. The watershed summaries are presented in hydrologic order beginning with the upper reaches of the waterbodies and ending with the most downstream segments of each river. Segment 1602, the non-tidal reaches of the Lavaca River and its tributaries, is presented first followed by Segment 1601, or the tidal portion of the Lavaca River. Similarly, the non-tidal reach of the Navidad River and its tributaries (Segment 1605) are discussed first, then Segment 1604 – Lake Texana and its tributaries, and finishing with the tidal portion of the Navidad River below Lake Texana (Segment 1603).

Figure 10: Segment 1604 - Lake Texana and Segment 1603 - Navidad River Tidal below the Palmetto Bend Dam

Segment 1602 - Lavaca River above Tidal

The Lavaca River watershed is largely rural with a land use dominated by agriculture including rangeland, pasture and hayfields, and row crop production. Urban development is limited to the small towns of Moulton, Hallettsville, Shiner, Yoakum, and Edna. As of 2010, the population of the watershed was approximately 30,000 people with a density of 33 people per square mile. The population is projected to have a modest growth of around ten percent over the next fifty years.

The Lavaca River is divided into two segments. Segment 1602 is the section of the river that is not tidally-influenced while the lower portion (Segment 1601) is tidally-influenced. Segment 1602 is a 67.3-mile-long portion of the Lavaca River running from the confluence of Campbell Branch, west of Hallettsville in Lavaca County, to a point 5.3 miles downstream of US 59 in Jackson County. This portion of the river is classified as perennial and flows from the Southern Blackland Prairie through the Southern Post Oak Savanna to Floodplains and Low Terraces of the Western Gulf Coastal Plain. Wastewater effluents from the cities of Yoakum, Shiner, Moulton and Hallettsville enter either directly into the Lavaca River or through its tributaries.

Almost the entire corridor of the watershed is surrounded by riparian woodlands. Land use in the upper portion of the segment is primarily rangeland and pastureland. To the south of SH 111, land use begins to transition to a mixture of rangeland, pastureland, and cropland.

The USGS maintains a gage number 08164000 in the Lavaca River near Edna. The median flow rate over the past twenty years was 42.7 cfs with a peak flow of 66,300 cfs on August 29, 2017 during Hurricane Harvey.

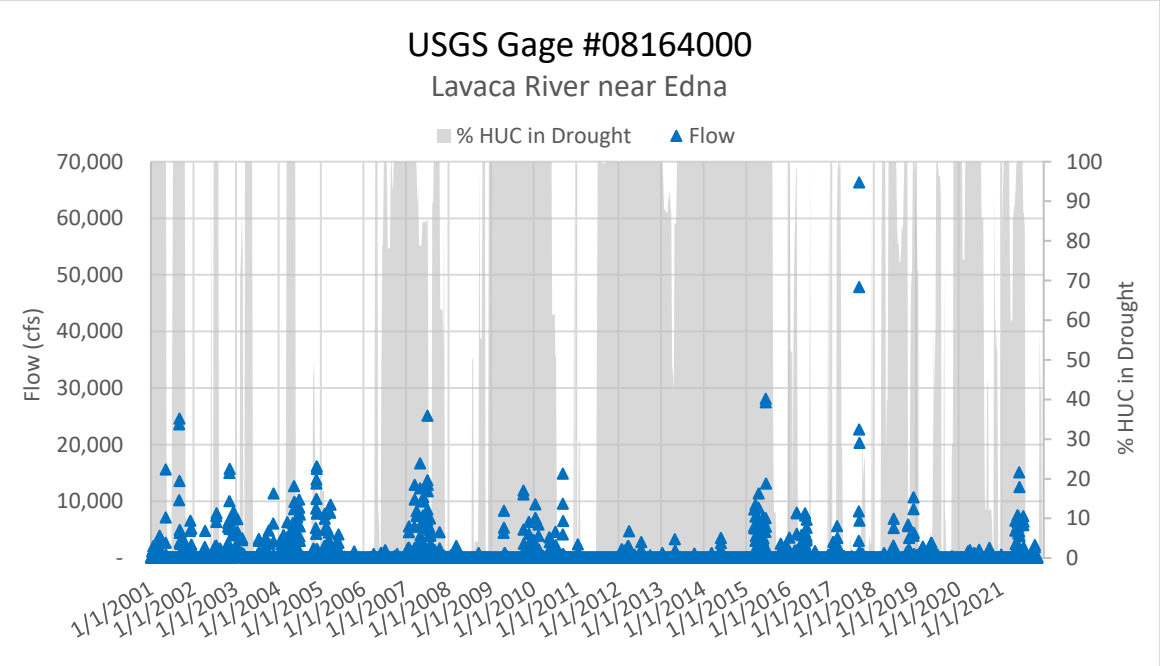

Figure 11: Stream flow and Percent of HUC in Drought in the Lavaca River near Edna, 2001 - 2021

There are three unclassified tributaries to this segment:

- Segment 1602A Big Brushy Creek
- Segment 1602B Rocky Creek
- Segment 1602C Lavaca River above Campbell Branch

Monitoring in Segment 1602 is performed by LNRA at five locations in the Lavaca River along with a station in Rocky Creek *(Table 2)*. The Lavaca River is sampled monthly for field parameters and flow at stations 12524 and 12525, and diel monitoring is performed six times per year at stations 17140 and 17594. Samples for conventional laboratory parameters and bacterial analysis are collected quarterly at all locations except station 17140.

Table 2: FY 2022 Coordinated Monitoring Schedule in Segment 1602

Segment 1602 - Lavaca River above Tidal								
Station	**Description**	**Segment**	**Entity**	**Field**	**Lab**	**Bacteria**	**Flow**	**24 HR DO**
12525	LAVACA RIVER AT SH 111	1602	LNRA	12	4	4	12	
12524	LAVACA RIVER AT US 59	1602	LNRA	12	4	4	12	
12527	LAVACA RIVER AT US ALT 90/US HWY 77	1602	LNRA	4	4	4	4	
18190	ROCKY CREEK UPSTREAM OF CR 387	1602B	LNRA	4	4	4	4	
17140	LAVACA RIVER AT FM 532	1602C	LNRA	6			6	6
17594	LAVACA RIVER UPSTREAM OF FM 1295	1602C	LNRA	4	4	4	10	6

Figure 12: Station 12527 - Lavaca River at US ALT 90/US 77 near Hallettsville

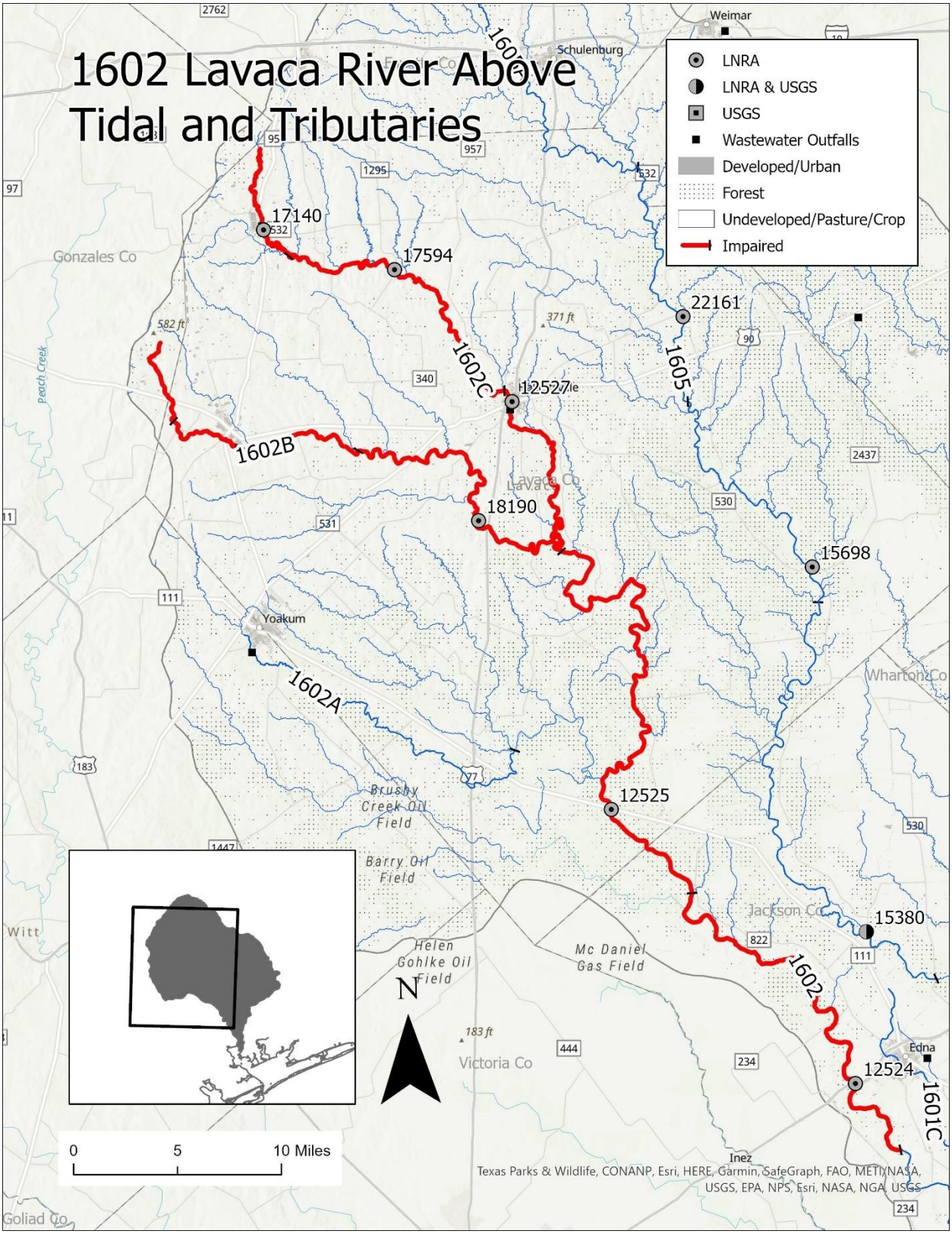

Figure 13: Map of Segment 1602, Lavaca River above Tidal

Unclassified Segment 1602A - Big Brushy Creek

Segment 1602A is the 22.5-mile-long perennial portion of Big Brushy Creek running from the confluence with an unnamed tributary just downstream of the Loop 51/US B77 bridge crossing south of the City of Yoakum downstream to the confluence with Clarks Creek in Lavaca County. The headwaters of this stream drain the Southern Blackland Prairie before flowing through the Southern Post Oak Savanna.

There are no current monitoring stations, and no data have been collected in this reach since 2003. Therefore, there were no data available to evaluate in the 2020 IR nor to perform trend analysis.

Unclassified Segment 1602B - Rocky Creek

Unclassified Segment 1602B is the 35.7-mile-long perennial portion of Rocky Creek running from 1.8 miles upstream of County Road 364 northwest of the City of Shiner downstream to the confluence with the Lavaca River. Most of this stream drains the Southern Blackland Prairie with a small portion of the downstream end flowing through the Southern Post Oak Savanna.

The stream is divided into three assessment units:

- AU 1602B_03 upper 4.9-mile reach from 1.8 miles upstream of County Road 364 northwest of the City of Shiner downstream to 0.6 miles above FM 533 west of the City of Shiner.
- AU 1602B_02 middle 11.9-mile section from 0.6 miles above FM 533 west of the City of Shiner downstream to the confluence with Ponton Creek.
- AU 1602B_01 lower 18.9-miles from the confluence with Ponton Creek downstream to the confluence with the Lavaca River.

Monitoring is being conducted quarterly at station 18190 by LNRA for field parameters, flow, conventional laboratory, and *E. coli*.

The 2020 IR lists Rocky Creek as impaired for elevated levels of *E. coli* and shows a concern for elevated Total Phosphorus. The impairment and concern continued into the Draft 2022 IR.

Table 3: 2020 Texas Integrated Report Summary for Unclassified Segment 1602B

Designated Use	Parameter	Criterion	Status
Aquatic Life Use	DO Grab Minimum	3 mg/L	FS
Aquatic Life Use	DO Grab Screening Level	5 mg/L	NC
Recreation Use	*E. coli*	126 MPN/100 mL	**NS (5a)**
General Use	Ammonia	0.33 mg/L	NC
General Use	Nitrate	1.95 mg/L	NC
General Use	Total Phosphorus	0.69 mg/L	**CS**

The geometric mean for *E. coli* samples collected during the 2020 IR was 279.8 MPN/100 mL, exceeding the 126 MPN/100 mL criterion. The geometric mean increased to 339.8 MPN/100 mL during the assessment period for the Draft 2022 IR. Elevated *E. coli* results were regularly reported at this station regardless of drought or flow conditions. No correlation between *E. coli* and stream flow was found indicating that the sources of bacteria regularly enter the stream.

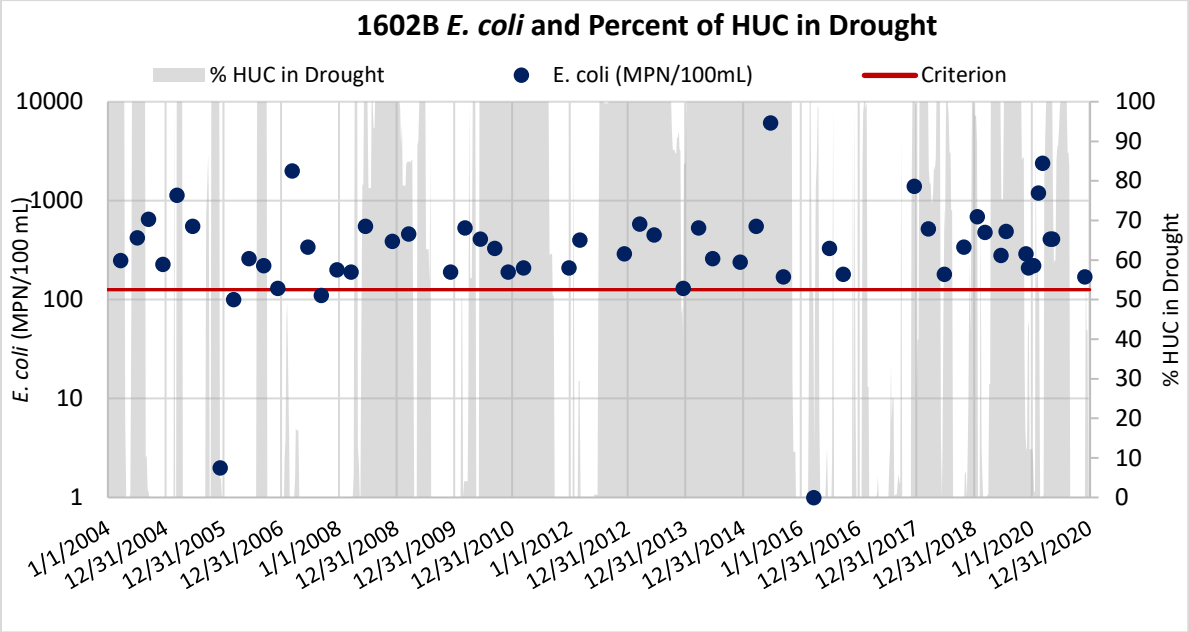

Figure 14: 1602B E. coli and Percent *of HUC in Drought*

Possible sources of *E. coli* include wildlife and livestock that visit the stream for watering in addition to failing septic systems. The lightly wooded riparian areas upstream of station 18190 may shelter wildlife. Livestock are regularly observed in the stream during monitoring visits. Landowner education and livestock best management practices may help reduce bacteria concentrations in the stream.

A Recreational Use Attainability Analysis (RUAA) is performed to determine the appropriate recreational use category of a water body. Primary contact recreation is the presumed designated use for all unclassified waters bodies. Primary contact recreation is defined as activities involving a significant risk of ingestion of water, including wading by children, swimming, water skiing, diving, and surfing. Noncontact recreation is defined as aquatic recreational pursuits not involving a significant risk of water ingestion including fishing, commercial and recreational boating, and limited body contact incidental to shoreline activity such as hunting. Field surveys are performed to measure stream morphology while observations of human activity are documented. Those observations include identifiers of human activity such as graffiti, trash, fishing tackle, and vehicle tracks. In addition, landowner and local resident interviews are conducted to identify contact recreational activities.
In May and July 2017, the Texas Institute for Applied Environmental Research performed RUAA surveys at seventeen sites in Rocky Creek (1602B). Stream flow was considered low to normal during both surveys. Based upon the RUAA summary of findings, primary and secondary contact

recreation were not observed by field staff but were reported to seldom occur by residents during interviews. Several pools greater than one meter deep were encountered during the field surveys which could allow for contact recreation. However, contact recreation was found to be limited since most of the study area is private property. Stream access at public road crossings was moderately difficult to difficult with steep densely vegetated banks and poison ivy. Log jams and barbed wire fences are obstacles to stream access. Venomous snakes were regularly observed by field staff which may also act as a deterrent for contact recreational activities. At the time of this writing, the TCEQ has not made a recommendation about changing the status of the stream from primary contact recreation.

By plotting the total phosphorus results against stream flow, the graph revealed that elevated concentrations of total phosphorus occurred during low flow conditions *(Figure 15)*. This type of observation is commonly identified at stations located below continuous contributors of nutrients such as WWTP outfalls and on-site septic systems. These results suggest that effluent discharged from the City of Shiner WWTP, as well as on-site septic systems, were potential sources of total phosphorus in the stream.

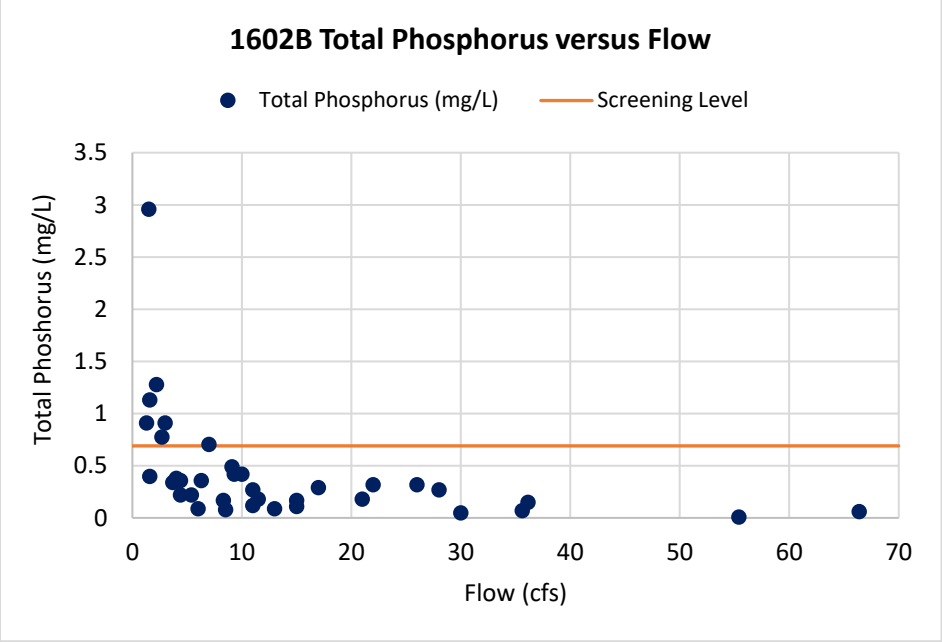

Figure 15: 1602B Total Phosphorus versus Flow

Data for station 18190 met the criteria for trend analysis. Statistically significant decreasing trends for flow, Total Kjeldahl Nitrogen (TKN), and hardness were identified. The decreasing trend for flow was disqualified due to not having values reported between 2011 and 2017.

The TKN trend was interesting since the parameter was also strongly inversely correlated to flow with a correlation coefficient of -0.76. As with total phosphorus, higher concentrations of organic nitrogen identified at lower flows is commonly observed downstream of WWTP outfalls or other point source discharges. However, this observation runs counter to the findings of

trend analysis. The decreasing trend may be due to the extended drought and then having more stream flow to dilute the parameter beginning in 2015; it may be due to improvements at the City of Shiner WWTP; or it may be due to a combination of both. It should also be noted that the trend was somewhat borderline for the criteria outlined for this report with a T-score of 2.2 and p-value of 0.038.

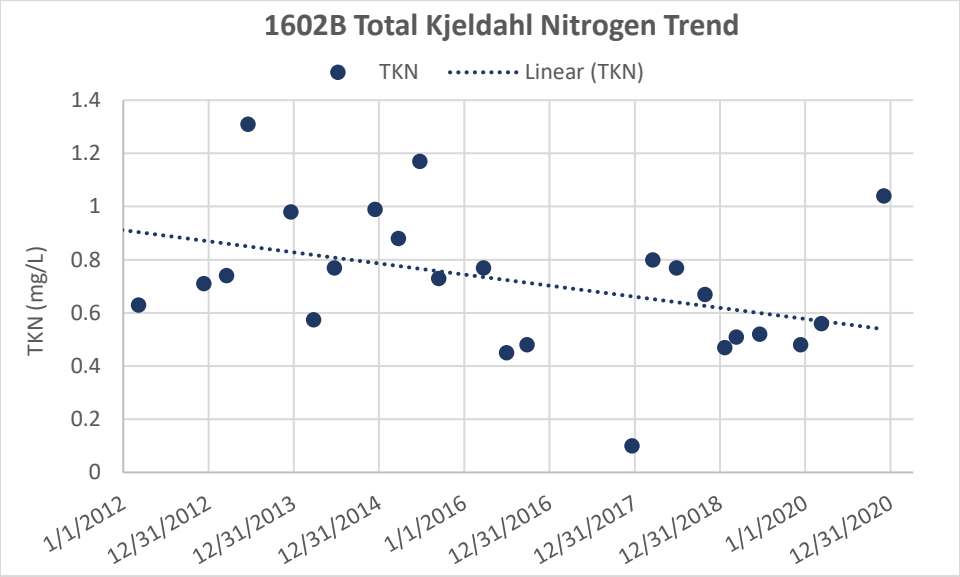

Figure 16: 1602B Decreasing Total Kjeldahl Nitrogen Trend

A decreasing trend for Hardness was also identified in the *2017 Lavaca - Navidad Basin Summary Report*. As shown in Figure 17, hardness levels appear to decrease during prolonged droughts and then increase during the recovery periods. The decreasing trend is likely due to decreased runoff during the drought periods.

Rain events wash calcium and magnesium compounds from the surrounding land into the stream by leaching these constituents from rocks and soils during precipitation events. Irrigation of surrounding land could also introduce hardness to the stream. Evaporation of irrigation water can leave behind minerals on the soil's surface. Precipitation then washes these minerals into the stream, thereby increasing their concentrations. In recent years, drought periods have been shorter which would require less irrigation. In turn, the build-up of minerals on irrigated land would be lower than in the past fifteen years. Hardness was moderately correlated to flow, with a correlation coefficient of 0.50, indicating that higher concentrations of hardness occur during elevated flows. This correlation supports both the geology and irrigation assumptions.

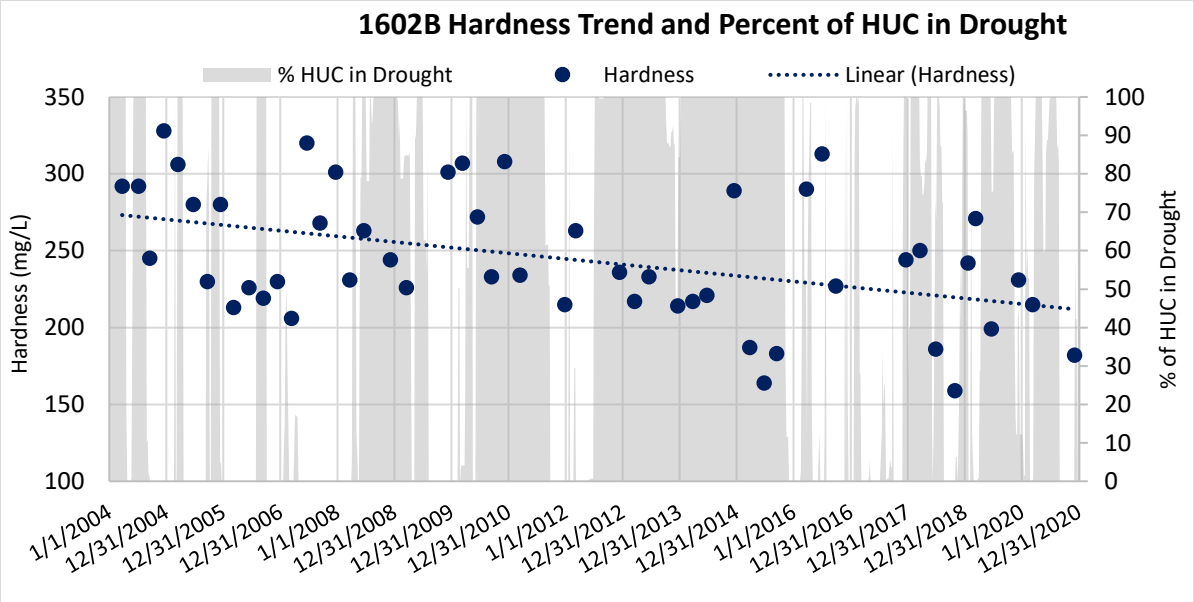

Figure 17: 1602B Decreasing Hardness Trend and Percent *of HUC in Drought*

Unclassified Segment 1602C - Lavaca River Above Campbell Branch

Unclassified Segment 1602C is the upper 26.1-mile portion of the Lavaca River from approximately 4 miles upstream of SH 95 in Lavaca County downstream to the confluence with Campbell Branch in Hallettsville. This portion of the river is classified as intermittent with perennial pools and flows through the Southern Blackland Prairie.

This reach had been identified as AU 1602_01, but is now assessed as two assessment units:

- AU 1602C_02 upper 8.6-mile portion from the headwaters approximately 4 miles upstream of TX Highway 95 in the City of Moulton downstream to the confluence of the West Prong Lavaca River.
- AU 1602C_01 lower 17.6-miles from the confluence of the West Prong Lavaca River downstream to the confluence with Campbell Branch in Hallettsville.

Table 4: 2020 Texas Integrated Report Summary for Unclassified Segment 1602C

Designated Use	Parameter	Status
Aquatic Life Use	DO 24-Hour Average	**NS (5b)**
Aquatic Life Use	DO 24-Hour Average	**NS (5b)**

A Use Attainability Analysis (UAA) was completed for the upper portions of the Lavaca River in 2005 and 2006. The results of the UAA included the recommendation that the upper portion of the river be reclassified as intermittent with perennial pools due to natural causes, and for the DO criteria to be modified during the time period of March 15th through October 15th when a site-specific DO criterion of 2.0 mg/L as a 24-Hour average and 1.0 mg/L as a minimum would

apply. For the rest of the year, the reach should maintain a high aquatic life use of 5.0 mg/L for the 24-Hour DO Average and 3.0 mg/L for the 24-Hour DO Minimum.

In 2014, the EPA approved removal of the upper 29 miles of the Lavaca from the perennial lower portion of Segment 1602 and acknowledged the intermittent nature of the upper portion of the river, but they disapproved the site-specific seasonal change in DO standards. The EPA gave guidance for intermittent streams with perennial pools: "The seasonal site-specific criteria will not protect a high aquatic life community from March 15 through October 15 because the spawning period occurs in early spring and higher levels of dissolved oxygen are needed for reproduction and survival of early life stages." Since the decision, the upper portion of the Lavaca River is approved for a seasonal change in DO criteria for the period of March 15 through October 15 to greater than or equal to 3.0 mg/L 24-Hour DO Average and greater than or equal to 2.0 mg/L for 24-hour DO Minimum.

The 2020 IR listed impairments in both assessment units for low 24-Hour Dissolved Oxygen Average. The impairments were carried forward from previous assessments as there were no data collected during the 2020 IR or the Draft 2022 IR assessment periods. Diel monitoring was last conducted in this watershed in 2002 and 2003 at station 17954. Out of ten samples, three had an average Dissolved Oxygen result of less than 5 mg/L. Quarterly sampling resumed at station 17954 in FY 2020. The LNRA collects field parameters, flow, conventional laboratory, and *E. coli*. LNRA began diel monitoring to address the DO impairments in 2021. In FY 2022, sampling is being performed six times per year at station 17954 in AU 1602C_01 and at station 17140 in AU 1602C_02.

The available data for this reach did not meet the criteria for trend analysis so no analyses were performed.

Segment 1602 - Lavaca River Above Tidal

Segment 1602 is a 67.3-mile-long reach that extends from the confluence of Campbell Branch, west of Hallettsville in Lavaca County, downstream to a point 5.3 miles downstream of US 59 in Jackson County. This portion of the river is classified as perennial and flows from the Southern Blackland Prairie through the Southern Post Oak Savanna to Floodplains and Low Terraces of the Western Gulf Coastal Plain.

This portion of the Lavaca River is divided into two assessment units:

- AU 1602_02 upper 44.4-miles from the confluence with Campbell Branch in Hallettsville downstream to the confluence with Beard Branch. Sampling is conducted at stations 12525 at SH 111 and 12527 at US Alt 90/US 77.
- AU 1602_03 lower 22.9-miles from the confluence with Beard Branch downstream to a point 5.3 miles downstream of US 59 in Jackson County. Monitoring is performed at station 12524 at US 59.

Quarterly sampling is being conducted by the LNRA at all three stations for field parameters, flow, laboratory conventionals, and *E. coli*. The LNRA also monitors field parameters and flow at stations 12524 and 12525 on a monthly basis.

Segment 1602 meets all of its designated uses except for its Recreation Use. Both assessment units are impaired in the 2020 IR for elevated levels of *E. coli*. These impairments continued into the Draft 2022 IR.

Table 5: 2020 Texas Integrated Report Summary for Segment 1602

Designated Use	Parameter	Criterion	1602_02	1602_03
Aquatic Life Use	DO Grab Minimum	3 mg/L	FS	FS
Aquatic Life Use	DO Grab Screening Level	5 mg/L	NC	NC
Recreation Use	*E. coli*	126 MPN/100 mL	**NS (5a)**	**NS (5a)**
General Use	Chloride	200 mg/L	FS	FS
General Use	Sulfate	100 mg/L	FS	FS
General Use	Total Dissolved Solids	700 mg/L	FS	FS
General Use	pH	6.5 - 9 S.U.	FS	FS
General Use	Ammonia	0.33 mg/L	NC	NC
General Use	Nitrate	1.95 mg/L	NC	NC
General Use	Total Phosphorus	0.69 mg/L	NC	NC
Water Supply Use	Nitrate	10 mg/L	FS	FS

There are two stations in AU 1602_02: station 12527 at the upper section of the reach, and station 12525, at the lower end. Bacteria results from both stations were combined in the assessment. The geometric mean of 45 samples was 202.7 MPN/100 mL, exceeding the 126 MPN/100 mL criterion. For the Draft 2022 IR, the geometric mean was slightly lower at 197.95

MPN/100 mL based upon 65 samples. There was a moderate correlation between *E. coli* and flow at station 12525 with a coefficient of 0.50. There was not a correlation found for station 12527.

Station 12524 is located at the downstream end of AU 1602_03. Elevated *E. coli* values were regularly reported, especially during drought periods. The station had a geometric mean of 175.5 MPN/100 mL in the 2020 IR and 188.8 MPN/100 mL in the Draft 2022 IR. This station also had a moderate correlation with flow with a coefficient of 0.53.

The results from both assessment units indicate that there were likely consistent sources of bacteria entering the stream. Station 12527 is located in Hallettsville above the WWTP. Although the site is downstream of the City of Moulton WWTP, it was an unlikely source of bacteria due to the distance between the outfall and station 12527. There would likely be extensive bacterial die-off from ultra-violet light exposure over the long stretches of unshaded stream. However, livestock visiting the stream for watering may be a significant contributor of bacteria. Livestock trails leading to the stream less than 400 meters upstream of station 12527 are visible in Google Earth images.

Livestock trails are also evident along the stream near stations 12525 and 12524. In addition, there is wooded riparian areas upstream of both stations. As a result, livestock and wildlife are likely contributors of bacteria through both direct deposition and from runoff during storm events. Landowner education and livestock best management practices may help reduce bacteria levels in this watershed. A Recreational Use Attainability Analysis should be considered to address the bacteria impairments.

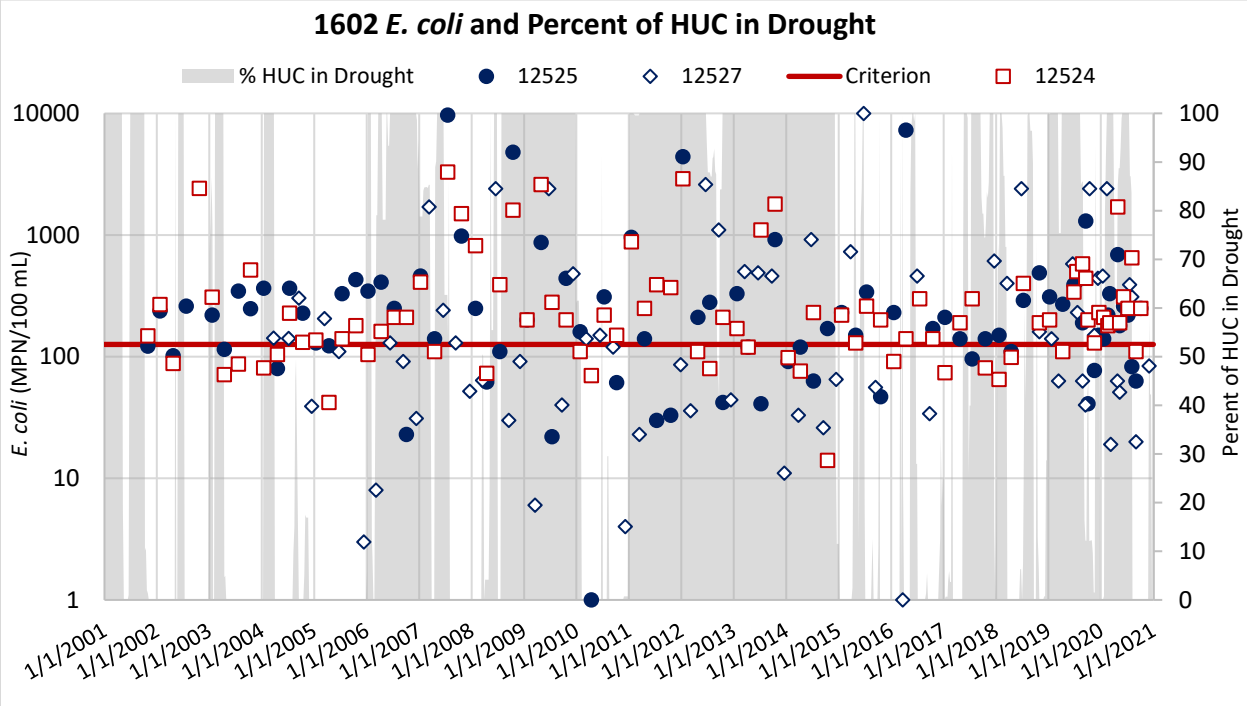

Figure 18: 1602 E. coli and Percent of HUC in Drought

In 2016, the Lavaca River Watershed Protection Plan (WPP) commenced to address water quality issues throughout the entire length of the Lavaca River and its tributary streams. The stakeholders of the Lavaca River basin developed a strategy to restore water quality in the river. Stakeholders dedicated considerable time and effort in discussing the watershed, influences on water quality and potential methods to address water quality concerns, and selecting appropriate strategies to improve water quality.

The WPP determined that no single source of bacteria was the primary cause of the impairment. A variety of sources were identified by stakeholders including livestock, wildlife, domestic pets, improperly functioning on-site septic systems, sanitary sewer overflows, illicit dumping, and urban stormwater. Stakeholders identified management measures to reduce and feasibly manage instream bacteria levels. Stakeholders are responsible for the implementation of these voluntary management strategies and the Watershed Coordinator will continue to lead the efforts to implement the plan. The WPP was discussed in more detail in the 2018 Lavaca Basin Highlights Report.

Trend analyses were performed on stations 12524, 12525, and 12527. Significant decreasing trends for Flow and pH were identified at station 12527. The t-statistic and p-value for pH were 3.394 and 0.001, respectively. For stream flow, the t-statistic was 3.74 and p-value, 0.000.

The decreasing trend for pH at station 12527 is shown in Figure 19. Although there were no chlorophyll-*a* data available to review, algal productivity may be affecting pH levels. Total phosphorus and nitrate exhibit higher concentrations at lower flows which is frequently observed downstream of WWTPs. The City of Moulton WWTP, located upstream of this station, may be a source of excess nutrients. The river channel, for approximately one mile upstream of the station, is wide, shallow, and unshaded with narrow braided meanders for much of the reach. These physical conditions, along with elevated levels of nutrients at lower flows, are ideal for algal productivity. It also should be noted that about ninety percent of samples were collected before noon. Due to the lack of photosynthesis after dark, algal respiration decreases pH throughout the night, thus samples collected in the morning hours tend to have lower pH levels than those obtained during daylight hours. Chlorophyll-*a* sample analyses are needed to confirm this assertion.

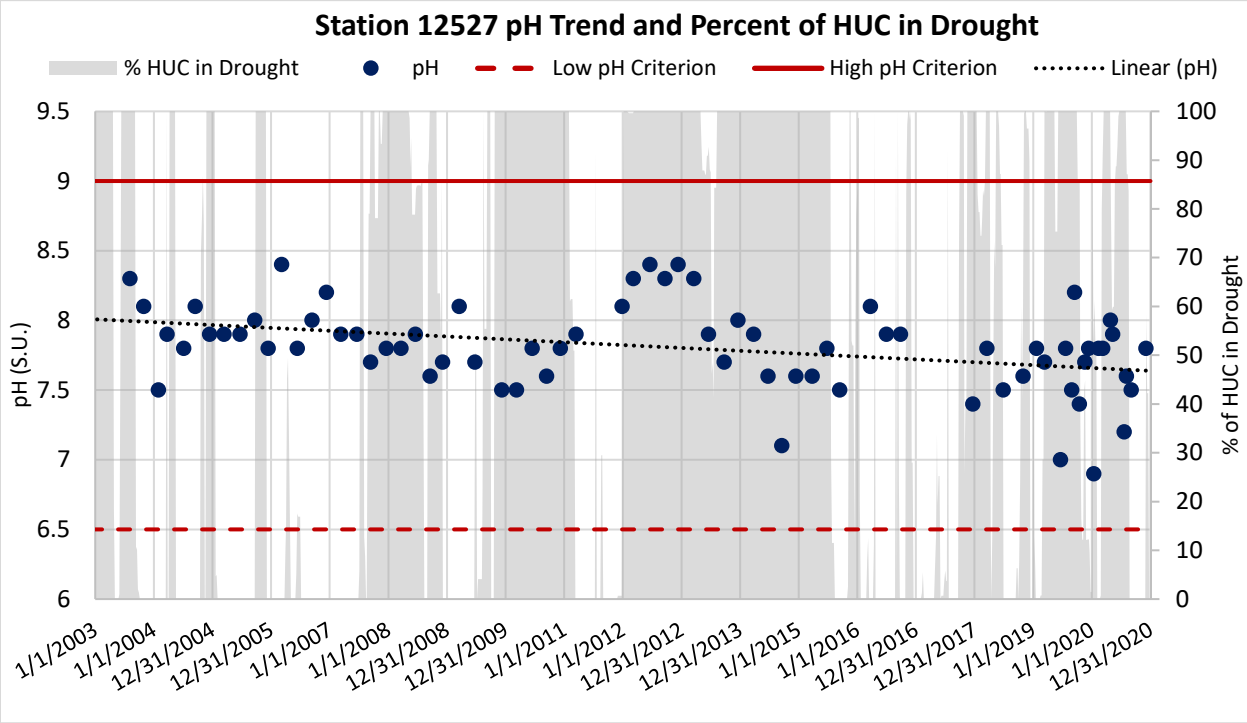

Figure 19: Decreasing Trend for pH and Percent of HUC in Drought at station 12527

A statistically significant decreasing trend for stream flow at station 12527 is shown in Figure 20. The trend had a T-stat of 3.74 and p-value of 0.000. The decreasing trend appeared to be the result of higher flows in 2003 and 2004 followed by the drought periods of 2005 and 2006 and of 2011 through 2014. As seen in the graph, stream flow was often reported near zero during periods of drought in the HUC.

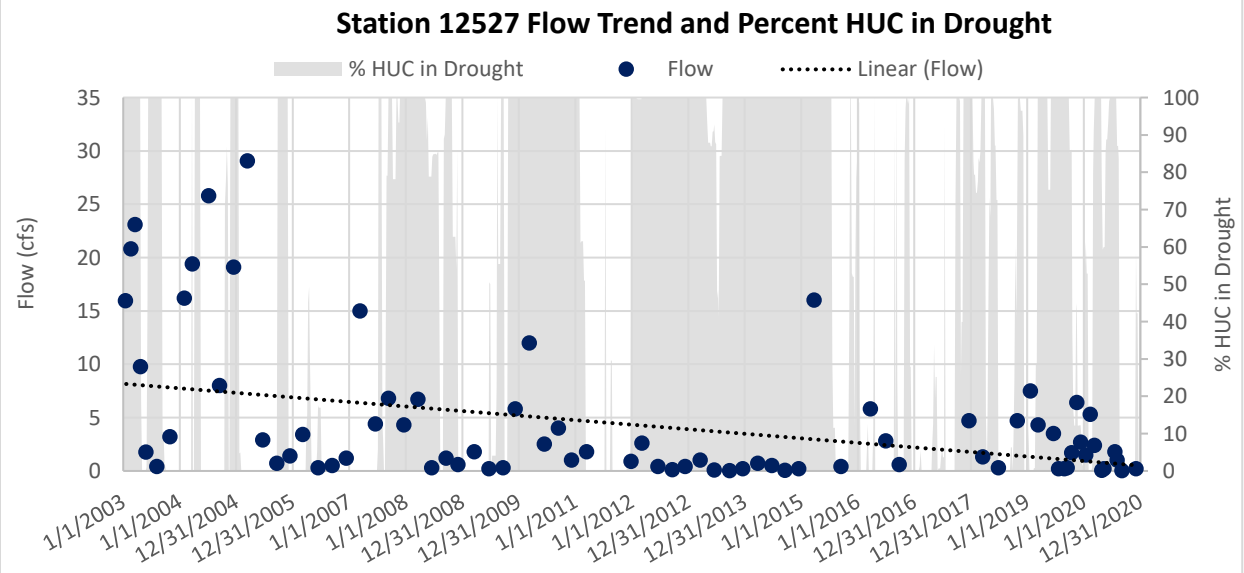

Figure 20: Decreasing Trend for Flow and Percent of HUC in Drought at station 12527

Figure 21: Station 12524 - Lavaca River at US 59 near Edna

Segment 1601 – Lavaca River Tidal

Segment 1601 is the tidal portion of the Lavaca River that extends from the mouth of Lavaca Bay upstream to a point 8.6 kilometers below US 59 in Jackson County. The Menefee Lakes, Redfish Lake, Swan Lake, Catfish Bayou (1601A), Redfish Bayou (1601B), and Dry Creek (1601C) provide freshwater flows to the river. The Navidad River (Segment 1603) joins the Lavaca River near Lavaca Bay.

Segment 1601 is designated as a tidal stream and provides important nursery grounds for marine organisms. Wastewater treatment plants include Vanderbilt and the City of Edna. As with the upper portion of the river (Segment 1602), the watershed is primarily rural and land use is dominated by agricultural activities including rangeland, improved pastures, rice and row crops, while the riparian areas around the river are mostly woodland and marshes.

Monitoring for field parameters is conducted monthly by the LNRA at three stations in the Lavaca River and at stations in Catfish and Redfish bayous. Quarterly laboratory samples are collected by LNRA at station 18336. LNRA contracts the USGS to collect organics in water (pesticides and herbicides) samples twice per year and metals in water annually on Dry Creek.

Table 6: FY 2022 Coordinated Monitoring Schedule in Segment 1601

Segment 1601 - Lavaca River Tidal									
Station	**Description**	**Segment**	**Entity**	**Field**	**Lab**	**Bacteria**	**Flow**	**Metals**	**Organics**
18336	LAVACA RIVER MID CHANNEL BELOW CATFISH BAYOU	1601	LNRA	12	4				
15371	LAVACA RIVER TIDAL 740 M UPSTREAM OF MENEFEE BAYOU	1601	LNRA	12					
15372	LAVACA RIVER TIDAL AT FRELS BOAT RAMP	1601	LNRA	12					
15369	CATFISH BAYOU EAST BANK	1601A	LNRA	12					
15370	REDFISH BAYOU MID CHANNEL	1601B	LNRA	12					
18329	DRY CREEK DOWNSTREAM OF FM 1822	1601C	USGS	2			2	1	2

There were no impairments for Segment 1601 and its tributary streams shown in the 2020 IR or the Draft 2022 IR indicating that the watershed fully supports its designated uses.

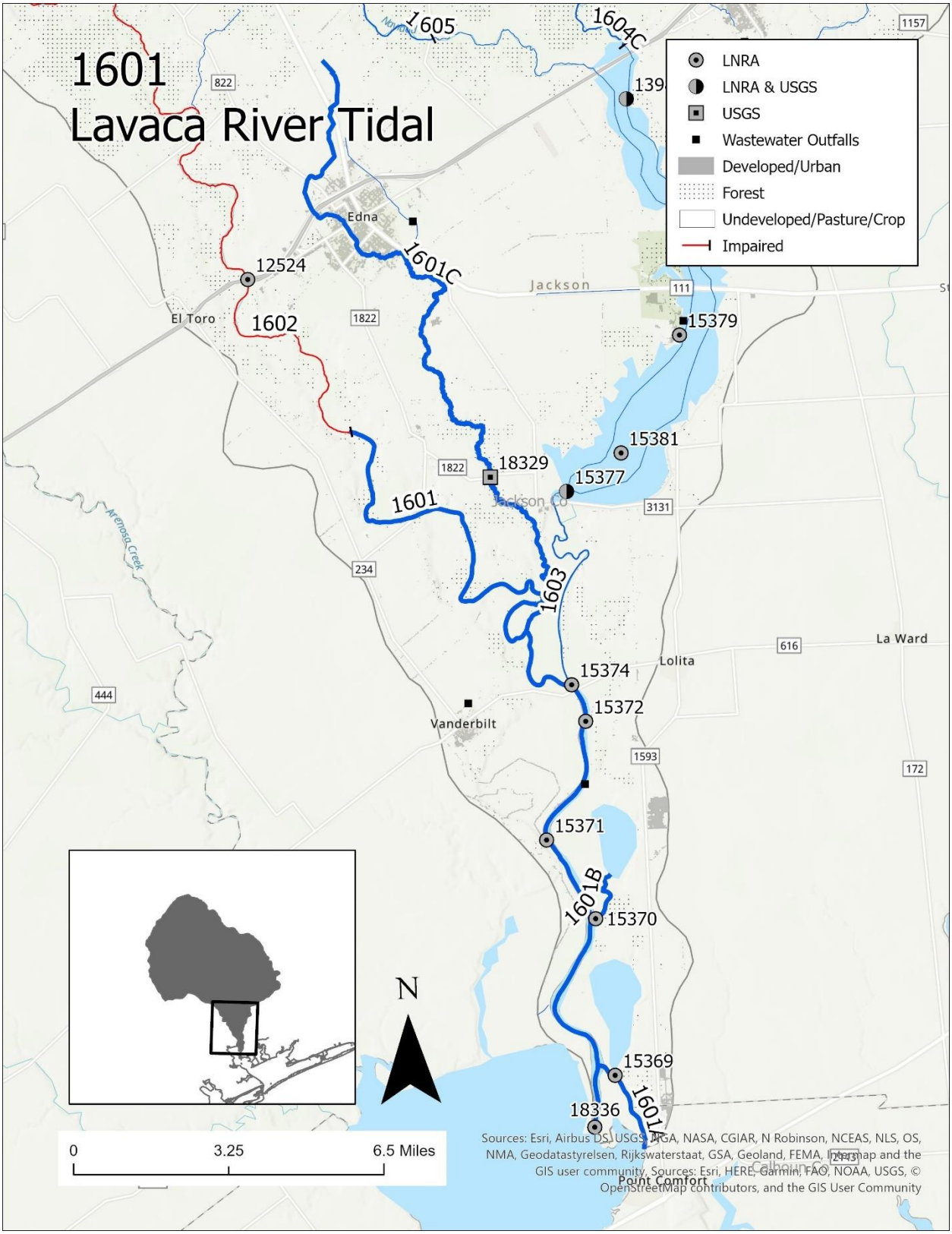

Figure 22: Map of Stations in Segment 1601 - Lavaca River Tidal

Unclassified Segment 1601C - Dry Creek

Segment 1601C is an 18.5-mile-long stream running from a point three miles north of the City of Edna downstream to the confluence with the tidal portion of the Lavaca River. This portion of the stream is classified as intermittent with perennial pools and flows through the Northern Humid Gulf Coastal Prairies of the Western Gulf Coastal Plain. Segment 1601C is a receiving water for the City of Edna WWTP.

There were no impairments for Dry Creek in the 2020 IR; however, there was a concern for DO grab screening level carried forward from previous assessments. USGS sampling data are not submitted to TCEQ for the assessment of this stream and no sampling is currently being conducted in Dry Creek by LNRA; thus, the concern will continue into future assessments.

Table 7: 2020 Texas Integrated Report Summary for Unclassified Segment 1601C

Designated Use	Parameter	Criterion	Status
Aquatic Life Use	DO Grab Screening Level	3 mg/L	**CS (Carry Forward)**

A review of historical data indicated that the DO Grab screening level concern may be due to drought. The two values from 2009 that were reported below the 3 mg/L screening level were obtained when much of the HUC was shown to either be in severe or exceptional drought.

Trend analysis was not performed since the available data did not meet the criteria.

It is recommended that sampling for field parameters be conducted to address the DO concern.

Segment 1601 - Lavaca River Tidal

Segment 1601 is the 23-mile-long tidal portion of the Lavaca River running from a point 5.3 miles downstream of US 59 in Jackson County downstream to the confluence with Lavaca Bay in Calhoun/Jackson County. This portion of the river flows through the Northern Humid Gulf Coastal Prairies and Mid-Coastal Barrier Islands and Coastal Marshes of the Western Gulf Coastal Plain.

Segment 1601 is comprised of three assessment units:

- AU 1601_01 upper 12.5-miles from a point 5.3 miles downstream of US 59 in Jackson County to the confluence with the Navidad River.
- AU 1601_02 middle 4.1-miles from the confluence with the Navidad River to a point 3.5 miles downstream of FM 616.
- AU 1601_03 lower 6.5-miles from a point 3.5 miles downstream of FM 616 to the confluence of Lavaca Bay.

There were no impairments or concerns shown in the 2020 IR or the Draft 2022 IR for Segment 1601 indicating that the river fully supports its designated uses.

Table 8: 2020 Texas Integrated Report Summary for Segment 1601

Designated Use	Parameter	Criterion	1601_02	1601_03
Aquatic Life Use	DO Grab Minimum	3 mg/L	FS	FS
Aquatic Life Use	DO Grab Screening Level	4 mg/L	NC	NC
General Use	pH	6.5 - 9 S.U.	FS	FS
General Use	Ammonia	0.46 mg/L		NC
General Use	Nitrate	1.1 mg/L		NC
General Use	Total Phosphorus	0.66 mg/L		NC

Two stations are monitored in AU 1601_02: station 15371, located near Menefee Bayou; and station 15372, near Frels Boat Ramp. Almost all DO samples collected in this assessment unit have met the DO grab screening level and DO grab minimum criteria. Out of 226 DO samples collected at station 15371, only two were reported below the 4 mg/L DO screening level. Only five out of 225 samples at station 15372 were below the screening level while three fell below the DO grab minimum of 3 mg/L. No relationship with salinity or drought conditions were identified for these low values.

Similarly, of the 225 samples for pH collected at stations 15371 and 15372, only seven results were reported above the high pH criterion of 9 S.U. As with DO, there was no correlation between pH and salinity or drought conditions.

For AU 1601_03, samples are collected at station 18336 which is located near the mouth of Lavaca Bay. Out of the 190 DO and pH values reviewed, only one DO measurement was

reported below the 4 mg/L screening level. This observation was recorded while the region was under exceptional drought conditions. One pH result was reported above the high pH standard of 9 S.U. As found in AU 1601_02, there were no correlations between these parameters and salinity.

Data for stations 15371 and 15372, in assessment unit 1601_02, met the criteria for trend analysis. However, no significant trends were identified.

The *2017 Lavaca-Navidad Basin Summary Report* identified a significant decreasing trend for pH along with increasing trends for hardness and chloride in AU 1601_03. None of these trends persisted into the current report. The trends for hardness and chloride identified in the previous summary report may have been an artifact the data collected during the extended drought.

Unclassified Segment 1601B - Redfish Bayou

Unclassified Segment 1601B is a 1.3-mile bayou running from the confluence with Redfish Lake south of Edna downstream to the confluence with the Lavaca River north of Point Comfort. This reach is classified as tidal and flows through the Mid-Coastal Barrier Islands and Coastal Marshes of the Western Gulf Coastal Plain.

There were no concerns or impairments shown in the 2020 IR or Draft 2022 IR.

Table 9: 2020 Texas Integrated Report Summary for Unclassified Segment 1601B

Designated Use	Parameter	Criteria	Status
Aquatic Life Use	DO Grab Minimum	3 mg/L	FS
Aquatic Life Use	DO Grab Screening Level	4 mg/L	NC

There were 225 DO measurements in the bayou; none of the results were reported below the screening level of 4 mg/L.

Data from station 15370 met the criteria for trend analysis, but no statistically significant trends were identified.

Unclassified Segment 1601A - Catfish Bayou

Unclassified Segment 1601A is a 2.2-mile reach of the bayou extending from the confluence with the Lavaca River south of Edna to the confluence of Lavaca Bay north of Point Comfort. This reach is classified as tidal and flows through the Mid-Coastal Barrier Islands and Coastal Marshes of the Western Gulf Coastal Plain.

There were no concerns or impairments shown in the 2020 IR or Draft 2022 IR.

Table 10: 2020 Texas Integrated Report Summary for Unclassified Segment 1601A

Designated Use	Parameter	Criteria	Status
Aquatic Life Use	DO Grab Minimum	3 mg/L	FS
Aquatic Life Use	DO Grab Screening Level	4 mg/L	NC

Historical data show that the bayou meets its Aquatic Life Use. Only one out of 227 DO samples was reported below the screening level of 4 mg/L.

The 2017 Basin Summary Report identified an increasing trend for total dissolved solids. The trend did not continue into this report and was most likely due to the extended drought. Since total dissolved solids are no longer analyzed, specific conductance was used as a surrogate. Figure 23 shows a shift in specific conductance results beginning in 2015 when the extended drought came to an end and tends to track higher during drought periods in 2018 and 2020.

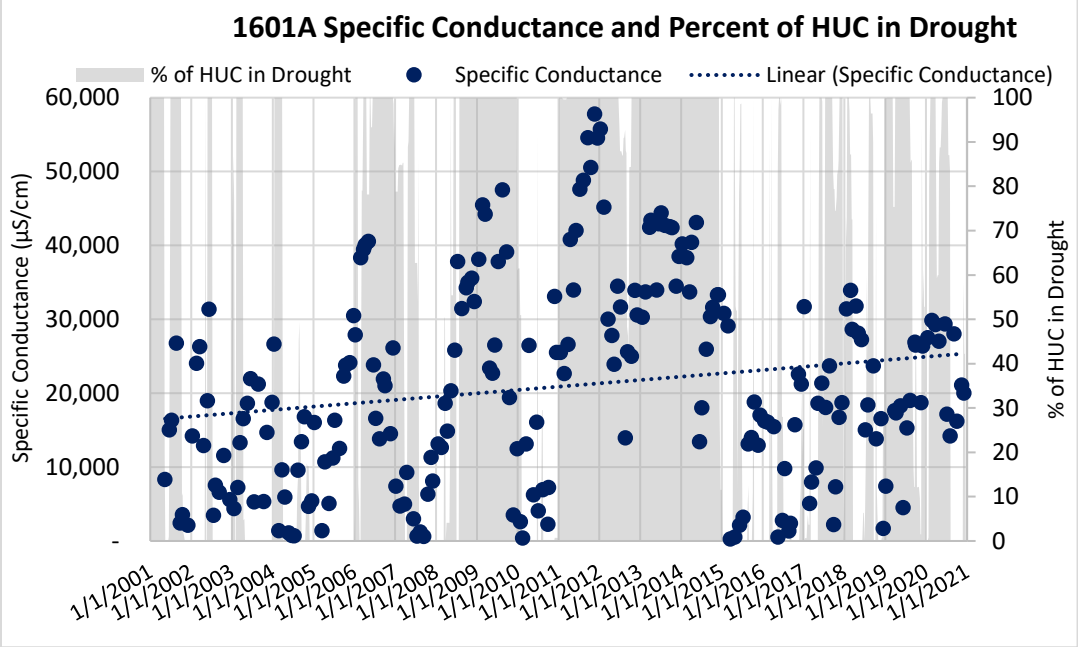

Figure 23: 1601A Specific Conductance and Percent of HUC in Drought

Data for other parameters collected at station 15369 met the criteria for trend analysis, but no statistically significant trends were identified.

Segment 1605 - Navidad River Above Lake Texana

Segment 1605 is reach of the Navidad River located above Lake Texana and extends from its confluence with the reservoir to its origin near Schulenburg. Many tributaries drain into this segment, including one in the northern portion of the basin which channels treated effluent from the City of Schulenburg WWTP. The watershed is mostly rural and sparsely populated. The cities of Schulenburg and Weimer are the major population centers along with the unincorporated communities of Sublime, Sheridan, and Speaks. Along much of the riparian corridor of Segment 1605 are woodlands. Land use in the upper portion from the headwaters to Speaks is predominantly rangeland and pastureland. From Speaks to the confluence with Lake Texana, agriculture practices transition to a mixture of rangeland, pastureland, and cropland.

The USGS maintains a gage number 08164390 in the Navidad River near Edna. The median flow rate over the past twenty years was 24.4 cfs with a peak flow of 24,000 cfs on August 29, 2017 during Hurricane Harvey.

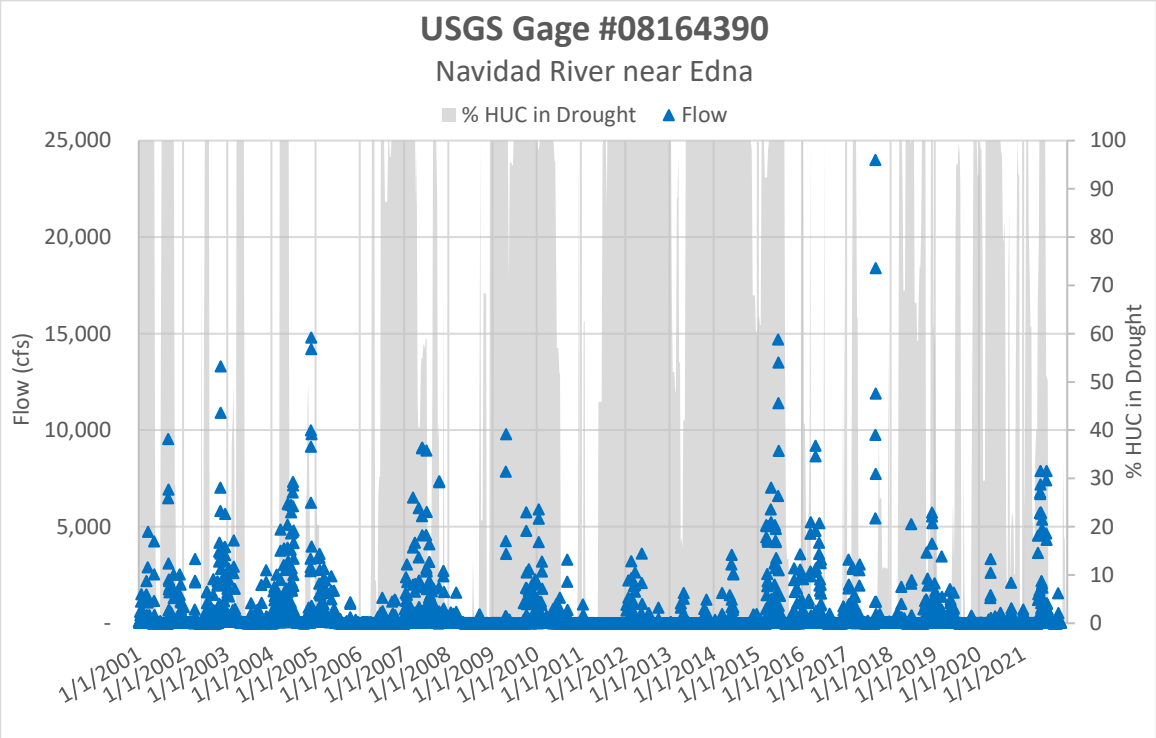

Figure 24: Stream Flow and Percent of HUC in Drought in the Navidad River near Edna, 2001 - 2021

Monitoring is conducted quarterly by the LNRA at three stations in the Navidad River for field parameters, flow, laboratory parameters, and bacteria. Monthly field parameters and flow are obtained by LNRA at station 15380. LNRA contracts the USGS to collect organics in water (pesticides and herbicides) samples twice per year and metals in water annually at station 15380.

Table 11: FY 2022 Coordinated Monitoring Schedule in Segment 1605

Segment 1605 - Navidad River above Lake Texana									
Station	**Description**	**Segment**	**Entity**	**Field**	**Lab**	**Bacteria**	**Flow**	**Metal Water**	**Organic Water**
15698	NAVIDAD RIVER AT FM 530	1605	LNRA	4	4				
15380	NAVIDAD RIVER AT CR 401	1605	LNRA	12	4		12		
22161	NAVIDAD RIVER AT CR 142	1605	LNRA	4	4	4	4		
15380	NAVIDAD RIVER AT CR 401	1605	USGS	2			2	1	2

Figure 25: Station 22161 - Navidad River at CR 142

Unclassified Segment 1605A - West Navidad River

Unclassified Segment 1605A is a 26.7-mile-long stream that extends from the headwaters near O'Quinn to its confluence with the Navidad River, upstream of FM 532 in Colorado/Lavaca counties. This portion of the river is classified as intermittent with perennial pools and flows through the Southern Blackland Prairie.

There are no monitoring stations in this water body; therefore, there were no data available to assess in the 2020 IR or the Draft 2022 IR.

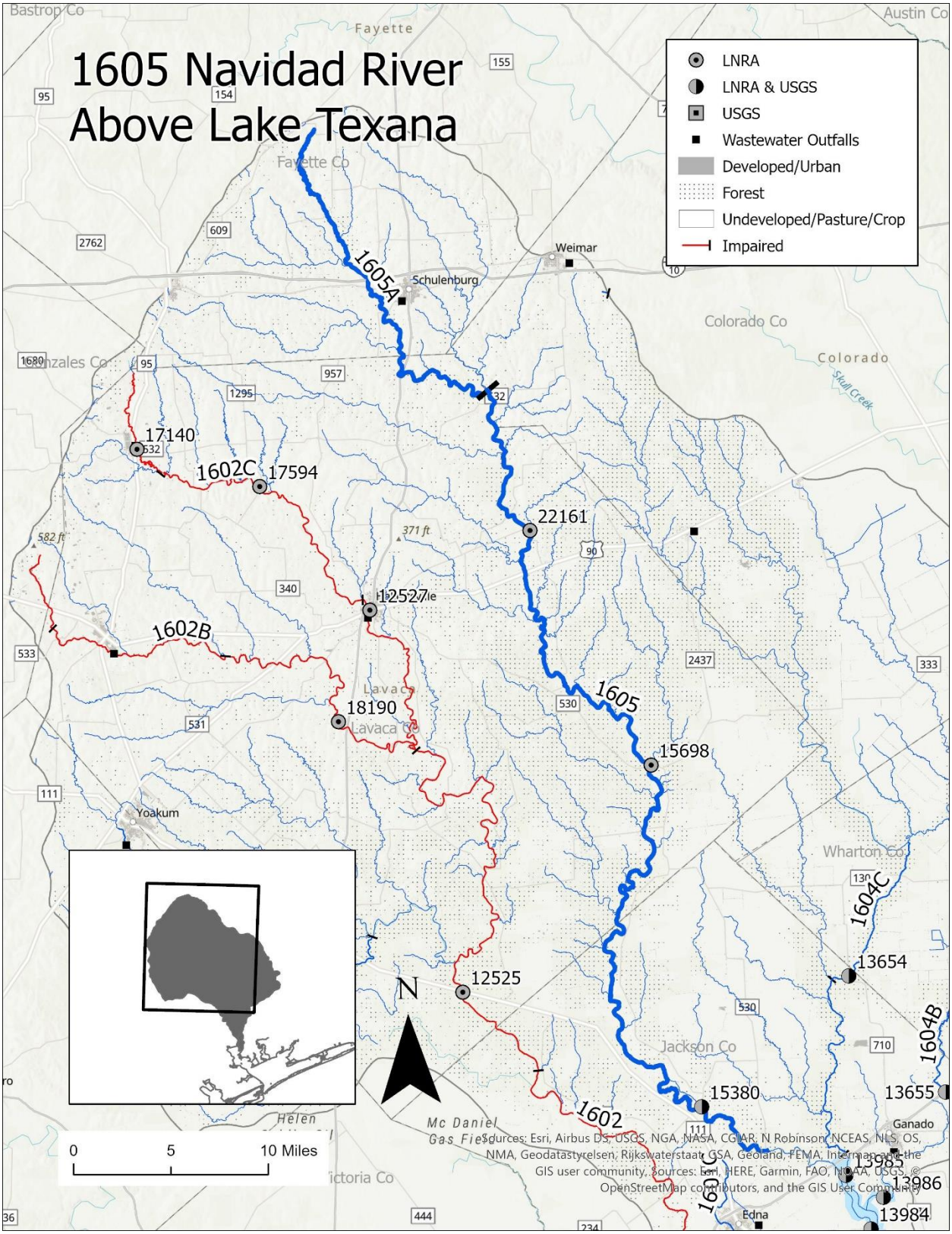

Figure 26: Map of Stations in Segment 1605 - Navidad River Above Lake Texana

Segment 1605 - Navidad River Above Lake Texana

Segment 1605 is a 63-mile-long perennial portion of the Navidad River running from the confluence of the East and West Navidad Rivers just upstream of FM 532 in Colorado/Lavaca counties downstream to a point 100 meters downstream of FM 530 in Jackson County. The headwaters of this segment drain the Southern Blackland Prairie before flowing through the Southern Post Oak Savanna. The majority of the land use in this segment is farming and ranching.

There are three assessment units in this segment:

- AU 1605_01 upper 14.5 miles from the confluence of the East and West Navidad Rivers downstream to the confluence with Sandy Branch.
- AU 1605_02 middle 16 miles from the confluence with Sandy Branch downstream to the confluence with Sandies Creek.
- AU 1605_03 lower 31 miles from the confluence with Sandies Creek downstream to the confluence with Lake Texana.

The LNRA collects laboratory and bacteria samples quarterly at station 22161 in AU 1605_01, while only laboratory samples are collected station 15698 in AU 1605_02 and at station 15380 in AU 1605_03. In addition, the LNRA measures field parameters and flow at station 15380 monthly.

There were no impairments or concerns shown for Segment 1605 and its tributary streams in the 2020 IR or the Draft 2022 IR indicating that the watershed fully supports its designated uses. A review of all data collected in Segment 1605 during the 2022 assessment period revealed that none of the nutrient samples or DO results exceeded their screening levels nor fell below the criterion.

Table 12: 2020 Texas Integrated Report Summary for Segment 1605

Designated Use	Parameter	Criterion	1605_01	1605_02	1605_03
Aquatic Life Use	DO Grab Minimum	3 mg/L		FS	FS
Aquatic Life Use	DO Grab Screening Level	5 mg/L		NC	NC
General Use	Chloride	100 mg/L	FS	FS	FS
General Use	Sulfate	50 mg/L	FS	FS	FS
General Use	TDS	550 mg/L	FS	FS	FS
General Use	pH	6.5 - 9 S.U.		FS	FS
General Use	Ammonia	0.33 mg/L		NC	NC
General Use	Nitrate	1.95 mg/L		NC	NC
General Use	Total Phosphorus	0.69 mg/L		NC	NC
Water Supply Use	Nitrate	10 mg/L	FS	FS	FS

Station 15698 in AU 1605_02 and station 15380 in AU 1605_03 met the criteria for trend analysis; however, no statistically significant trends were identified for either station.

Trends for total phosphorus, alkalinity, hardness, and chloride that were identified in the 2017 *Lavaca Basin River Authority Basin Summary Report* did not continue into this analysis. The trends for alkalinity, hardness, and chloride were likely a result of the extended drought. Although not increasing at a statistically significant rate, total phosphorus has continued to increase over the past twenty years. It is important to note that all reported data for this parameter were below the screening level of 0.69 mg/L, and that the higher concentrations tend to be collected during drought periods. Nutrient monitoring should continue in this assessment unit.

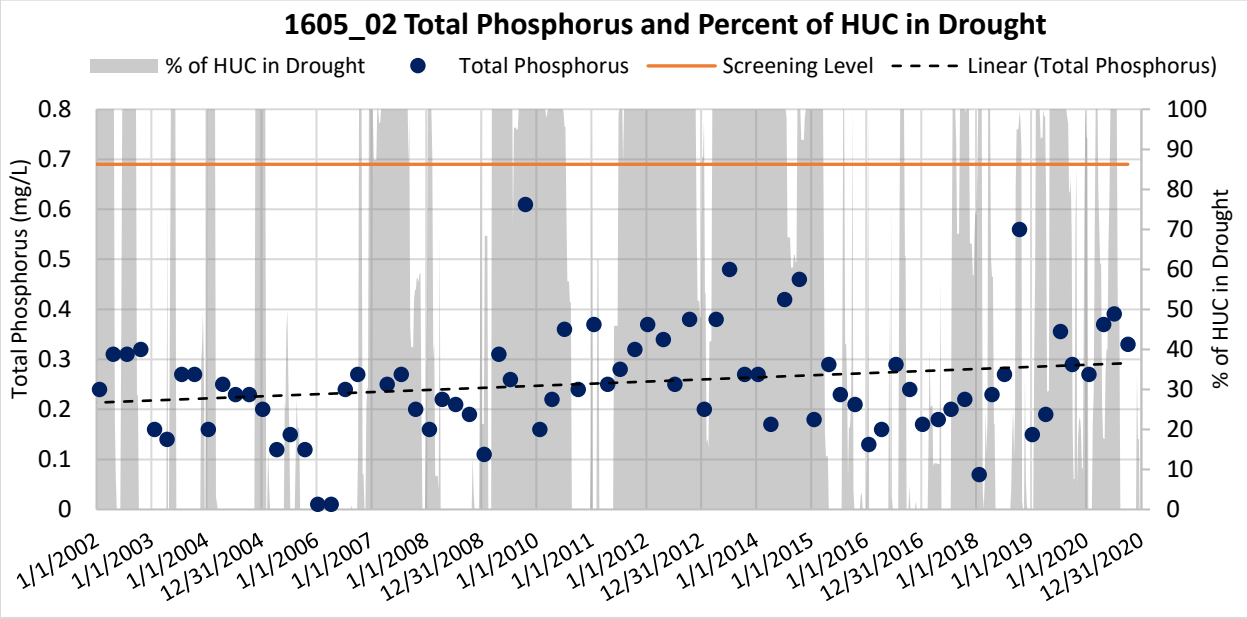

Figure 27: 1605_02 Total Phosphorus and Percent of HUC in Drought

Segment 1604 – Lake Texana

Segment 1604 is comprised of Lake Texana its primary tributary streams: East Mustang Creek (1604A), West Mustang Creek (1604B), Sandy Creek (1604C). As with the much of the Lavaca Basin, the watershed around Lake Texana is rural and land use is predominately agricultural. Population centers in the Lake Texana drainage include the cities of Ganado, Louise, and Sheridan with populations of approximately 2,136, 963, and 910 residents, respectively.

Irrigation canals provide water for rice fields in the Sandy Creek watershed while the branches of Mustang Creek drain the portion of the watershed from the Garwood Irrigation Service Area to Lake Texana. Effluents from the WWTPs in Ganado and the lakeside parks discharge into Lake Texana. The Louise WWTP discharges into East Mustang Creek while West Mustang Creek receives treated effluent from the Wharton County WWTP.

Monitoring in the tributary streams of Lake Texana is conducted monthly by the LNRA at stations in Sandy Creek, East Mustang Creek, and West Mustang Creek for field parameters and flow. Laboratory samples are collected quarterly. The LNRA contracts the USGS to collect samples at these stations semi-annually for organics in water (pesticides and herbicides) and annually for metals in water.

Table 13: FY 2022 Coordinated Monitoring Schedule in Segment 1604 Tributaries

Segment 1604 - Lake Texana Tributaries									
Station	**Description**	**Segment**	**Entity**	**Field**	**Lab**	**Bacteria**	**Flow**	**Metals**	**Organics**
15382	EAST MUSTANG CREEK AT FM 647	1604A	LNRA	12	4		12		
13655	WEST MUSTANG CREEK AT US 59	1604B	LNRA	12	4		12		
13654	SANDY CREEK AT FM 710	1604C	LNRA	12	4		12		
15382	EAST MUSTANG CREEK AT FM 647	1604A	USGS	2			2	1	2
13655	WEST MUSTANG CREEK AT US 59	1604B	USGS	2			2	1	2
13654	SANDY CREEK AT FM 710	1604C	USGS	2			2	1	2

There were no impairments or concerns shown in the 2020 IR or the Draft 2022 IR for the unclassified waterbodies in Segment 1604 indicating that these streams fully support their designated uses.

Table 14: 2020 Texas Integrated Report Summary for Segment 1604A, 1604B, and 1604C.

Designated Use	Parameter	Criteria	1604A	1604B	1604C
Aquatic Life Use	DO Grab Minimum	3 mg/L	FS	FS	FS
Aquatic Life Use	DO Grab Screening Level	4*, 5 mg/L	NC*	NC	NC
General Use	Ammonia	0.33 mg/L	NC	NC	NC
General Use	Nitrate	1.95 mg/L	NC	NC	NC
General Use	Total Phosphorus	0.69 mg/L	NC	NC	NC

Figure 28: View of Lake Texana from the Palmetto Bend Dam

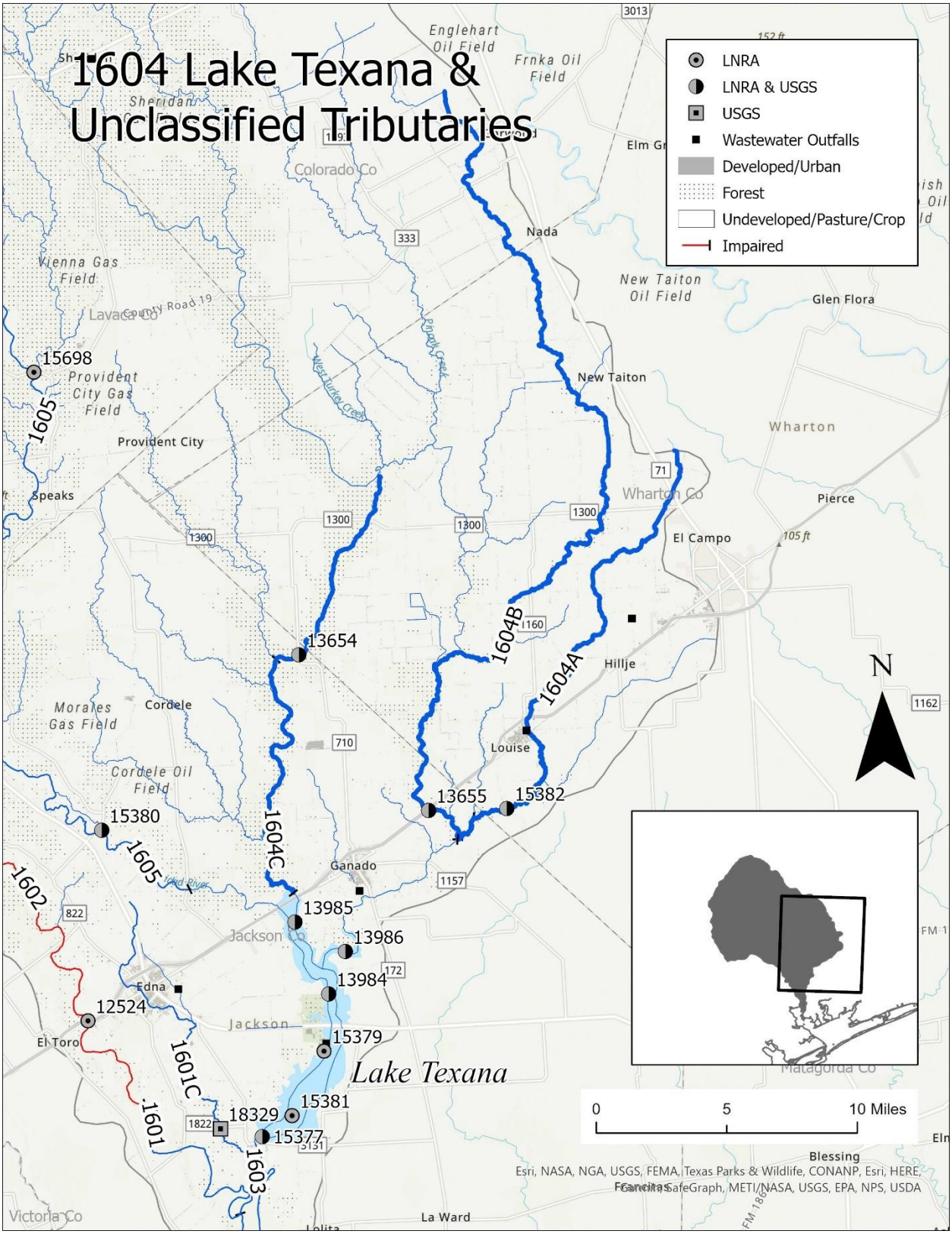

Figure 29: Map of Stations in Segment 1604 - Lake Texana

Unclassified Segment 1604C - Sandy Creek

Unclassified Segment 1604C is the 22.3-mile-long perennial portion of the stream running from a point northwest of El Campo in Wharton County downstream to the confluence with Lake Texana west of Ganado in Jackson County. The headwaters of this stream drain the Southern Post Oak Savanna before flowing through the Northern Humid Gulf Coastal Plains and the Floodplains and Low Terraces of the Western Gulf Coastal Plain. The Sandy Creek watershed is riparian woodland immediately surrounding the water body with a mixture of rangeland, pastureland, and cropland consisting mostly of rice production.

Sandy Creek consists of two assessment units:

- AU 1604C_01 upper 9.8 miles from Middle Turkey Creek downstream to the confluence with Goldenrod Creek
- AU 1604C_02 lower 12.5 miles from Goldenrod Creek downstream to the confluence with Lake Texana

Monitoring is conducted in AU 1604C_01 at station 13654 by LNRA and USGS. The LNRA measures field parameters and flow on a monthly basis and collects laboratory samples quarterly. The USGS samples at this station semi-annually for organics in water (pesticides and herbicides) and annually for metals in water.

Data for this station met the criteria for trend analysis; however, no statistically significant trends were identified. The *2017 Lavaca Basin Summary Report* identified a significant increasing trend for Dissolved Oxygen. The data review for this report period showed that DO is still increasing but not at a statistically significant rate.

Sample results reported during the 2020 assessment period showed only one of the 77 DO records were reported below the 3 mg/L DO grab minimum. Of the 26 samples for ammonia, nitrate, and total phosphorus, one ammonia sample exceeded the 0.33 mg/L screening level while no total phosphorus or nitrate samples were reported over their screening level.

Data collected since 2000 showed that total phosphorus and nitrate values have remained relatively stable while ammonia has increased slightly. The average ammonia concentration was 0.10 mg/L during this time period while total phosphorus and nitrate were 0.21 mg/L and 0.17 mg/L, respectively.

Unclassified Segment 1604B - West Mustang Creek

Unclassified Segment 1604B is the 47.2-mile-long perennial portion of West Mustang Creek extending from a point north of El Campo to the confluence with Lake Texana east of Ganado. This stream flows through the Northern Humid Gulf Coastal Plains and the Floodplains and Low Terraces of the Western Gulf Coastal Plain. Unlike other reaches in the basin, this stream has a very small riparian woodland corridor. The upper portion of the waterbody consists mainly of rice farms but transitions to a greater mix of row crops and eventually rangeland near its confluence with East Mustang Creek.

The LNRA and USGS sample at station 13655 at US 59. The LNRA measures field parameters and flow on a monthly basis and collects laboratory samples quarterly. The USGS samples at this station semi-annually for organics in water (pesticides and herbicides) and annually for metals in water.

Station 13655 met the criteria for trend analysis, but no statistically significant trends were identified.

Sample results reported during the 2020 assessment period showed only one of the 76 DO records were reported below the 5 mg/L DO grab screening level. Of the 27 samples for ammonia, nitrate, and total phosphorus, three ammonia samples exceeded the 0.33 mg/L screening level while one nitrate sample of 2.33 mg/L exceeded the 1.95 mg/L screening level. All total phosphorus results were reported below 0.69 mg/L screening level. During the assessment period for the Draft 2022 IR, three DO readings fell below the DO grab screening level while three ammonia samples were reported above the screening level with mean of 0.46 mg/L. None of the nitrate or total phosphorus values were recorded above their screening levels.

Similar to Sandy Creek, data collected since 2000 showed that total phosphorus and nitrate values have remained relatively stable while ammonia has been increasing *(Figure 30)*. The average ammonia concentration was 0.10 mg/L while total phosphorus was 0.30 mg/L and 0.45 mg/L for nitrate.

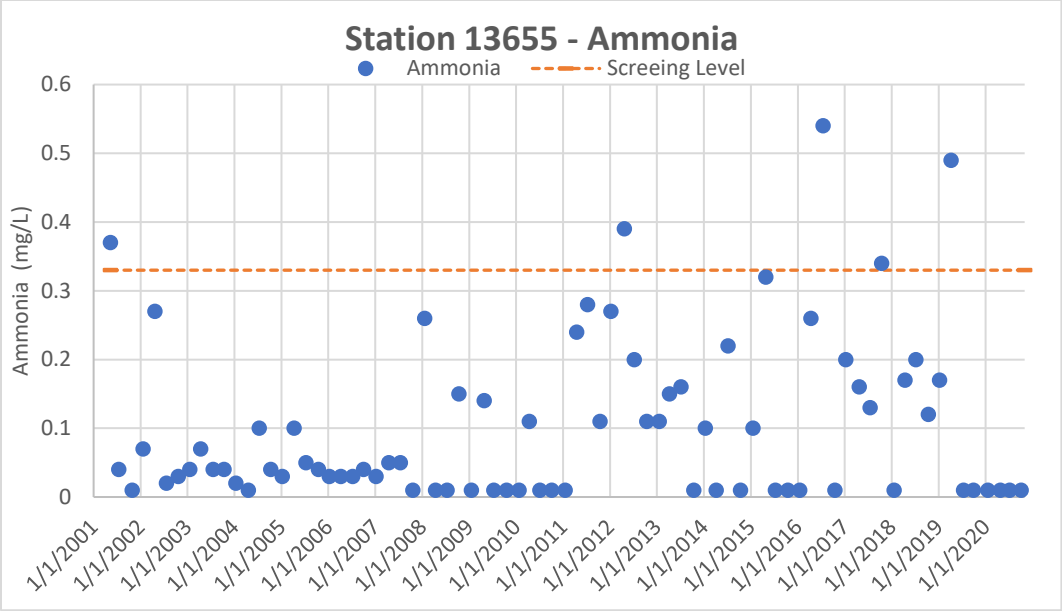

Figure 30: Ammonia Results at Station 13655

Figure 31: Station 13655 - West Mustang Creek at US 59

Unclassified Segment 1604A - East Mustang Creek

Unclassified Segment 1604A is a 25.2-mile-long stream running from 2.4 miles upstream of SH 71 north of the city of El Campo downstream to the confluence with Lake Texana. The upper assessment unit of this stream is classified as intermittent with perennial pools while the lower assessment units are perennial. This stream flows through the Northern Humid Gulf Coastal Plains and the Floodplains and Low Terraces of the Western Gulf Coastal Plain. Within this watershed, land use is mainly cropland with corn as the most common crop grown within this watershed. As the stream meanders towards the confluence with Lake Texana, pastureland gradually becomes more dominant.

There are three assessment units in this segment:

- AU 1604A_01 intermittent stream with perennial pools from the confluence with Middle Mustang Creek upstream to the confluence with an unnamed tributary approximately 4.2 km upstream of US 59 northeast of the City of Louise
- AU 1604A_02 from the confluence with an unnamed tributary approximately 4.2 km upstream of US 59 northeast of the City of Louise to 3.9 km upstream of TX-71
- AU 1604A_03 lower 1.6 miles from the confluence with Middle Mustang Creek downstream to the confluence with Lake Texana

Water quality monitoring is conducted by LNRA and USGS at station 15382 in AU 1604A_01. The LNRA measures field parameters and flow on a monthly basis and collects laboratory samples quarterly at this location. The USGS samples at this station semi-annually for organics in water (pesticides and herbicides) and annually for metals in water.

Data for station 15382 met the criteria for trend analysis; however, no statistically significant trends were identified. The 2017 Basin Summary Report identified a statistically significant increasing trend for pH. No results were reported over 9.0 S.U. since 2014, and the median pH for the 2020 assessment period was 8.0 S.U.

There were 74 DO measurements reported in the 2020 IR. Two were reported below the 4 mg/L DO grab screening level. For the Draft 2022 IR, there were three results below 4 mg/L while one was less than 3 mg/L DO grab minimum. DO concentrations reported below the screening levels generally occurred during drought periods.

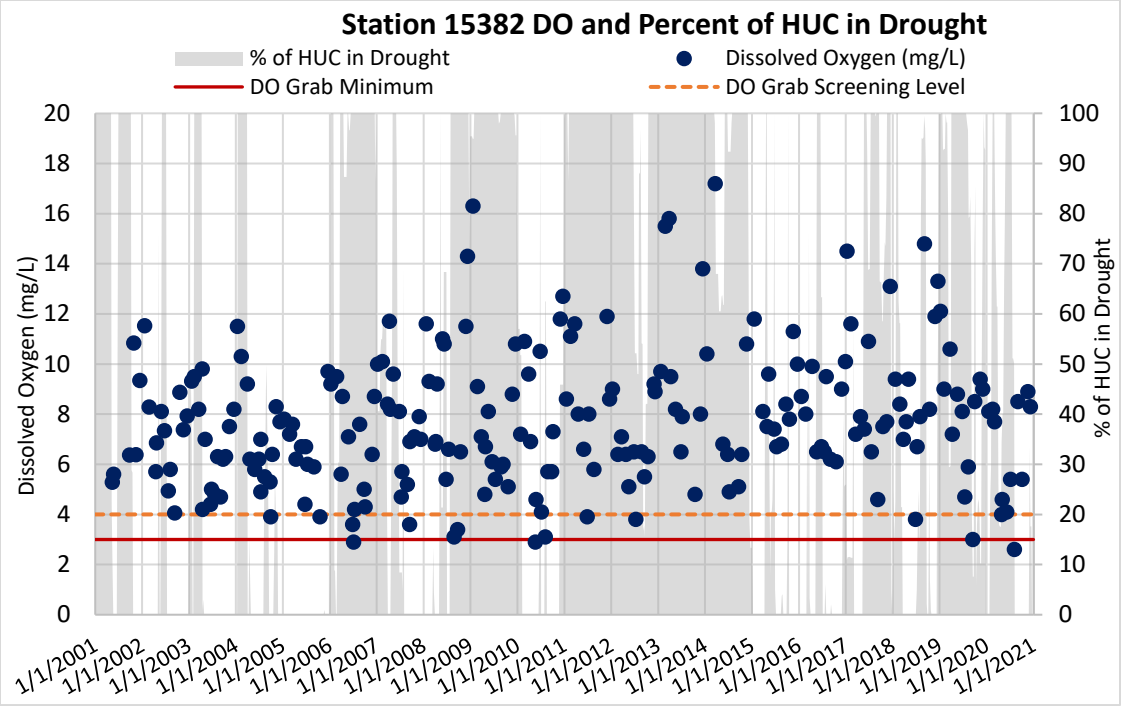

Figure 32: Station 15382 - Dissolved Oxygen and Percent of HUC in Drought

There were 27 samples each for ammonia, total phosphorus, and nitrate reported during the 2020 assessment period. None of the ammonia samples exceeded the 0.33 mg/L screening level while four results were over the total phosphorus and nitrate screening levels of 0.69 mg/L and 1.95 mg/L. The mean of the exceedances was 0.76 mg/L for total phosphorus and 6.33 mg/L for nitrate. For the Draft 2022 IR assessment period, one total phosphorus concentration was reported at 0.75 mg/L while the mean of the three nitrate exceedances was 7.48 mg/L. None of the 27 ammonia samples were above the screening level. For samples collected since 2001, the mean ammonia concentration at station 15382 was 0.11 mg/L while total phosphorus was 0.40 mg/L and nitrate was 1.15 mg/L.

Nutrients were not well-correlated to flow. Although all correlations were positive, the highest correlation was for total phosphorus with a correlation coefficient of 0.44. Correlation coefficients between flow and ammonia and nitrate were both less than 0.25. Because the nutrients did not display the typical pattern seen below point source discharges (higher concentrations at lower flows), it is unlikely that the Wharton County WWTP, located upstream of station 15382, was a primary contributor of these parameters. A likely source of the nutrients was commercial fertilizers used for the row crop agriculture activities that predominate land use in this watershed.

Sediment and nutrient loading into Lake Texana are of great interest to the LNRA since high concentrations of nutrients can perturb water quality, drinking water sources, and aquatic life while an increase in sediment loads can reduce water clarity and light penetration within the

water column. During runoff events, nutrients bound to soil particles are transported into waterbodies through the process of soil erosion.

Figure 33: Side View (left) and Top View (right) of the Turbidity Monitor in East Mustang Creek at Station 15382

In 2020, LNRA contracted with the USGS to install and maintain a turbidity sensor at the existing gauge house located at station 15382. Turbidity is a measure of water clarity. An increase in turbidity is an indication of an increase in suspended matter. The sensor was installed to monitor the turbidity of the water in East Mustang Creek due to concerns about sediment and nutrient loadings into the Mustang Arm of Lake Texana. At the time of this writing, the sensor is offline due to bridge construction on FM 64, located upstream of the station.

Segment 1604 Lake Texana

Lake Texana is a 9,243-acre reservoir that runs from a point 110 yards downstream of FM 530 to the Palmetto Bend Dam in Jackson County. Originally named Palmetto Bend Reservoir, Lake Texana was later named for the ghost town of Texana which was once located within the boundaries of the reservoir. The dam retained its name of the Palmetto Bend Dam which is named for the bottom land plant commonly found in the area. The Palmetto Bend Dam impounds the Navidad River up to a normal pool elevation of 44 feet and controls approximately 1,404 square miles of drainage area. Lake Texana is managed by the LNRA for municipal and industrial water supply along with recreational purposes. Construction began in 1976 and was completed in 1979. Based upon the findings of the 2010 volumetric survey conducted by the Texas Water Development Board, the reservoir can store 161,085 acre-feet across its 9,676 surface acres.

There are five assessment units in this segment:

- AU 1604_01 Navidad River arm - 1,958.8 acres of the upper western region
- AU 1604_02 East Mustang Creek arm - 1,088 acres of the upper eastern area
- AU 1604_03 upper middle portion - 1,465.5 acres of the upper main body downstream of the confluence of the two arms
- AU 1604_04 downstream middle portion - 2,905.9 acres of the middle main body
- AU 1604_05 downstream portion - 1,824.8 acres of the main body near the dam.

The LNRA samples monthly for field parameters at six stations located in all assessment units of the reservoir. Samples for laboratory analysis are collected quarterly at these same stations. The LNRA contracts the USGS to collect samples at three stations semi-annually for organics in water (pesticides and herbicides) and quarterly at one station for metals in water.

Table 15: Segment 1604 FY 2022 Monitoring Stations

Segment 1604 - Lake Texana								
Station	**Description**	**AU**	**Entity**	**Field**	**Lab**	**Bacteria**	**Metals**	**Organics**
13985	LAKE TEXANA NEAR EAST BANK	01	LNRA/USGS	12	4	4		2
13986	LAKE TEXANA MUSTANG CREEK ARM	02	LNRA/USGS	12	4	4		2
13984	LAKE TEXANA 2 KM UPSTREAM OF SH 111	03	LNRA/USGS	12	4	4		2
15379	LAKE TEXANA RIVER CHANNEL DOWNSTREAM OF SH 111	04	LNRA	12	4	4		
15377	LAKE TEXANA NEAR SPILLWAY INLET	05	LNRA/USGS	12	4		4	
15381	LAKE TEXANA MID LAKE IN OLD NAVIDAD RIVER CHANNEL	05	LNRA	12	4			

There were no concerns or impairments identified in the 2020 IR or the Draft 2022 IR. Lake Texana lies within the Floodplains and Low Terraces of the Western Gulf Coastal Plain and was classified as mesotrophic by the 2020 Trophic Classification of Texas Reservoirs.

Table 16: 2020 Texas Integrated Report Summary for Segment 1604

Designated Use	Parameter	Criterion	AU_01	AU_02	AU_03	AU_04	AU_05
Aquatic Life Use	DO Grab Minimum	3 mg/L	FS	FS	FS	FS	FS
Aquatic Life Use	DO Grab Screening Level	5 mg/L	NC	NC	NC	NC	NC
Recreation Use	*E. coli*	126 MPN/ 100 mL	FS	FS	FS	FS	
General Use	Chloride	100 mg/L	FS	FS	FS	FS	FS
General Use	Sulfate	50 mg/L	FS	FS	FS	FS	FS
General Use	TDS	500 mg/L	FS	FS	FS	FS	FS
General Use	pH	6.5 - 9 S.U.	FS	FS	FS	FS	FS
General Use	Ammonia	0.11 mg/L	NA	NA	NA	NA	NA
General Use	Chlorophyll-a	26.7 ug/L	NA	NA	NA	NA	NA
General Use	Nitrate	0.37 mg/L	NA	NA	NA	NA	NA
General Use	Total Phosphorus	0.2 mg/L	NA	NA	NA	NA	NA
Water Supply Use	Nitrate	10 mg/L	FS	FS	FS	FS	FS

From 2001 through 2021, there were 1,464 DO samples combined from all assessment units of Lake Texana. Of those results, 38 were reported below the DO Grab screening level of 5 mg/L while only two were less than the 3 mg/L DO Grab minimum criterion. For the samples below 5 mg/L, 29 were collected in the two upper arms of the reservoir. Although very weakly inversely correlated, low dissolved oxygen generally occurred when the reservoir elevation was also low.

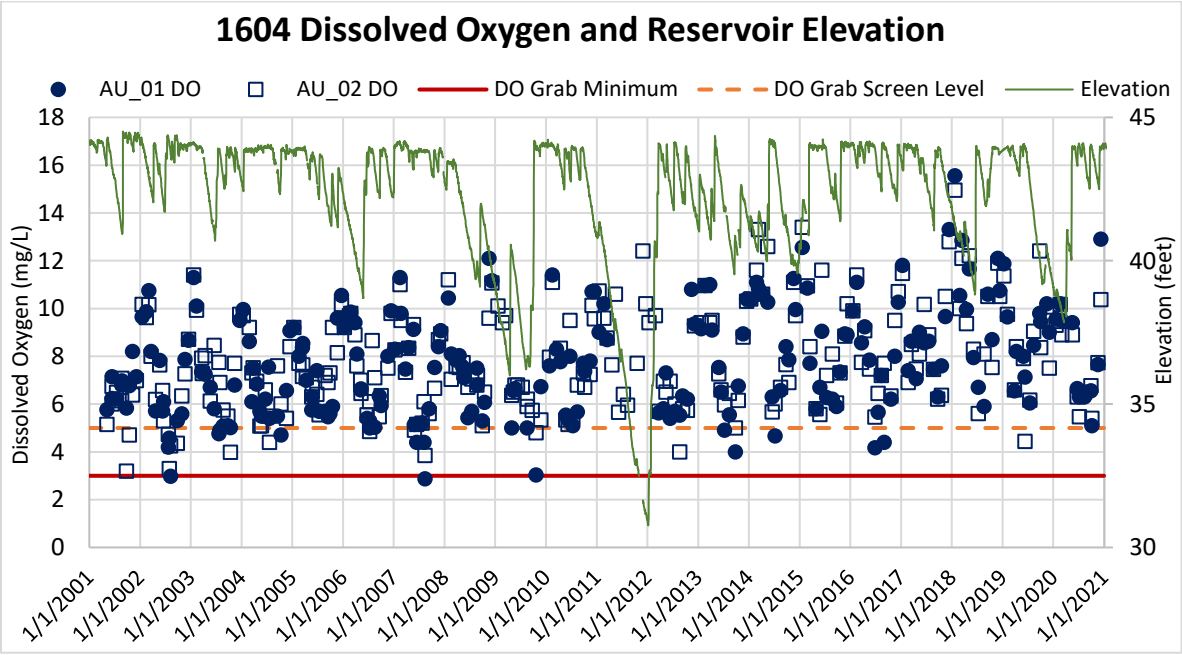

Figure 34: 1604 Dissolved Oxygen and Reservoir Elevation

The pH criteria for Lake Texana ranges from 6.5 to 9.0 S.U. across the reservoir. A total of 1,464 pH samples were collected in the reservoir over the past twenty years. Of those samples, six results were reported below 6.5 S.U. while eleven were over the 9.0 S.U. criterion. In eutrophic reservoirs, algae consume the available carbon dioxide during the process of photosynthesis. Once the available carbon dioxide is exhausted, carbon dioxide is then broken away from carbonic acid, thereby increasing the pH in the water column. When sunlight is not available for photosynthesis, carbon dioxide, released through respiration, will bond with available hydrogen ions to reform carbonic acid, thereby lowering the pH.

The 2020 Trophic Classification of Texas Reservoirs ranked Lake Texana as mesotrophic for having one of the lowest concentrations of chlorophyll-*a* in the state. With a mean chlorophyll-*a* concentration of 4.0 µg/L, Lake Texana is in the top ten percent out of 138 reservoirs for the lowest amount of chlorophyll-*a*. However, the reservoir falls into the bottom ten percent statewide for highest concentration of total phosphorus and lowest transparency.

Although TCEQ no longer assesses nutrients and chlorophyll-*a* in the same way as they have in past, nutrient enrichment is still an important issue in Lake Texana. Table 17 is a summary of the nutrients and chlorophyll-*a* results for samples collected from 2001 through 2020 in each assessment unit.

Table 17: Summary of Nutrient and Chlorophyll-a in 1604, Number of Samples (n) and Number of Exceedances (#), 2001 - 2020

	Nitrate		Ammonia		Total Phosphorus		Chlorophyll-*a*	
Assessment Unit	**n**	**# Exceed**	**n**	**# Exceed**	**n**	**# Exceed**	**n**	**# Exceed**
1604_01	56	15	72	15	72	45	60	3
1604_02	62	20	79	18	79	67	66	1
1604_03	60	14	0	0	76	44	64	0
1604_04	60	16	0	0	76	34	64	0
1604_05	122	36	0	0	154	57	130	0

Ammonia samples were reported for the Navidad and Mustang arms of Lake Texana but not for the other assessment units. Approximately twenty percent of the samples in each arm exceeded the 0.11 mg/L screening level. Both assessment units averaged 0.06 mg/L ammonia while the maximum result was 0.29 mg/L in the Navidad Arm (AU 1604_01) and 0.38 mg/L in the Mustang Arm (AU 1604_02).

On average, nitrate exceeded its screening level of 0.37 mg/L in almost one-third of all samples collected in Lake Texana over the past twenty years while total phosphorus surpassed its 0.20 mg/L screening level in over half of all samples. The highest percentage of exceedances occurred in the upper two assessments units.

For the Navidad Arm (AU 1604_01), 27 percent of all nitrate and 63 percent of the total phosphorus values were reported over their respective screening levels. Nitrate values from station 13985 had a mean of 0.20 mg/L while total phosphorus averaged of 0.22 mg/L. The

maximum sample concentration was 1.0 mg/L of nitrate and 0.50 mg/L of total phosphorus. Nutrient concentrations did not correlate with lake elevation.

The highest percentage of exceedances for nutrients occurred in the Mustang Arm (AU 1604_02) with 32 percent of all nitrate and 85 percent of the total phosphorus results reported above their respective screening levels. The mean nitrate concentration at station 13986 was 0.43 mg/L while total phosphorus had an average of 0.30 mg/L. The maximum sample result obtained during this period was 2.98 mg/L of nitrate and 1.04 mg/L of total phosphorus. The nutrient results also had a moderate inverse correlation with lake elevation meaning that as lake elevation decreased, nutrient concentrations increased. Nitrate had a correlation coefficient of -0.48 while total phosphorus correlated to lake elevation at -0.46. Land owner education and implementation of agricultural best management practices should be considered to reduce the amount of nutrients entering this arm of the reservoir.

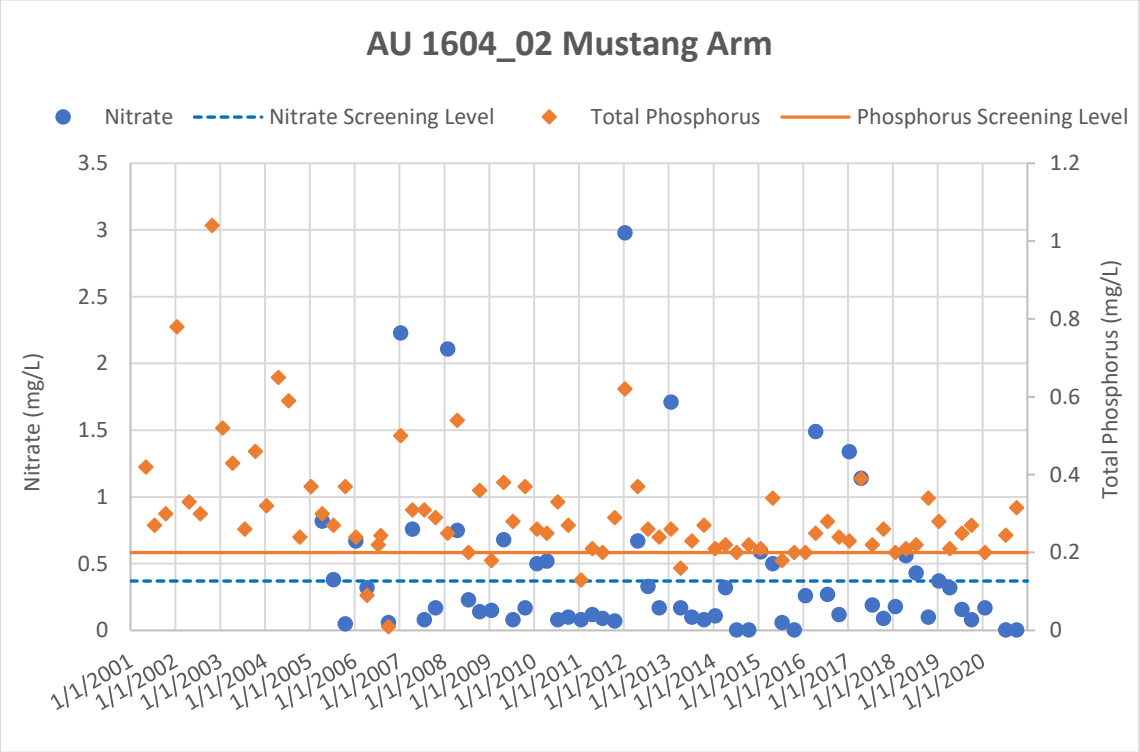

Figure 35: Nitrate and Total Phosphorus results in AU 1604_02 Mustang Arm from 2001 - 2020

Despite the high levels of nutrients throughout the entire reservoir, chlorophyll-*a* concentrations rarely exceeded the 26.7 µg/L screening level. Out of 384 samples collected over the past twenty years, only four elevated chlorophyll-*a* values were reported. Those high values were obtained in the upper two arms of the reservoir while none of the samples collected in assessment units 03, 04, or 05 exceeded the screening level. Despite nearly one-third of all nitrate and over half of all total phosphorus results exceeding their respective screening levels, no chlorophyll-*a* sample was reported over the screening level in these three

assessment units. In fact, the mean chlorophyll-*a* result for the assessment units combined was 4.06 µg/L.

As mentioned previously, transparency is very limited in Lake Texana. Transparency is a measure of water clarity and is used to estimate the depth of light penetrance in water. The greater the transparency, the greater amount of light is available for algal productivity and photosynthesis. The mean secchi depth in the reservoir was 0.26 meters (less than one foot) and ranged from a low of 0.23 meters in the Mustang Arm to a high of 0.29 meters near the dam. The poor water clarity in the reservoir limits the amount of sunlight in the water column available for algal production. This minimal photic zone has most likely limited the extent of the excessive algal bloom impacts on water quality in the reservoir. Despite the low water clarity, excessive algal production has affected water quality.

Data from all five assessment units met the criteria for trend analysis; however, no significant trends were identified. In the 2017 Lavaca Basin Summary Report, an increasing pH trend was identified in AU 1604_03. Although pH was generally trending higher, it was no longer increasing at a statistically significant rate. It is interesting to note that the exceedances of the high pH criterion in the reservoir occurred in 2019 and 2020. In fact, high pH was measured in all assessment units in September 2019 while all but the Navidad Arm exceeded the high pH criterion in June 2020. Although no chlorophyll-*a* samples were collected on those dates, field notes stated that there were algal blooms present at the time of sampling. In September 2019, DO ranged from 129.4 percent saturation to 178.9 percent in all five assessment units. These super-saturated DO values corroborate the field notes that excessive algal production was the likely cause for the high pH exceedances on that date.

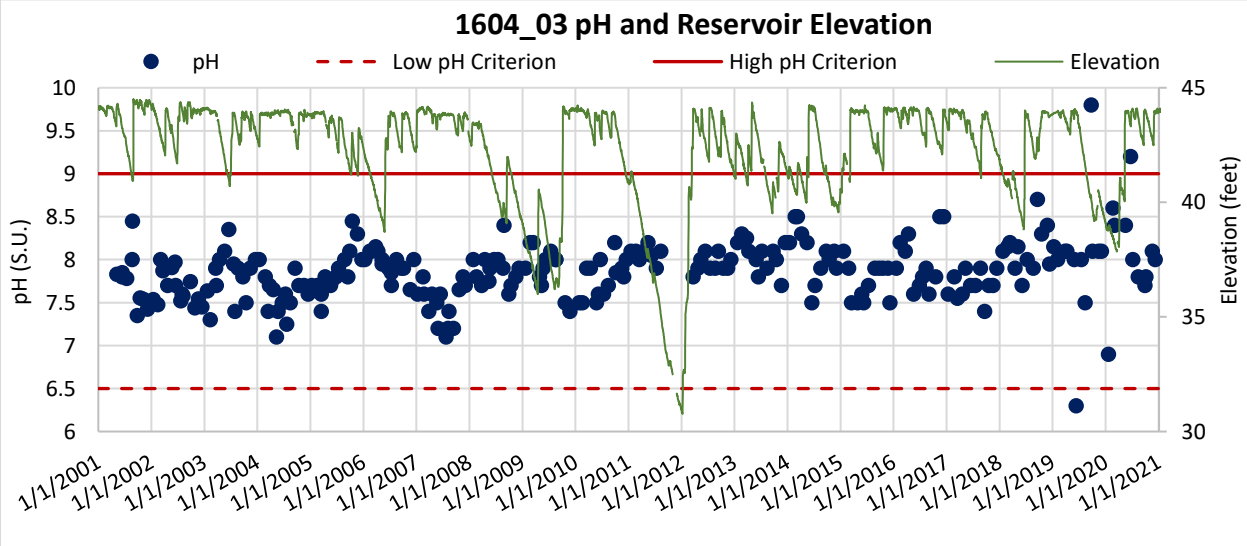

Figure 36: 1604_03 pH and Reservoir Elevation

The 2017 Lavaca Basin Summary Report identified decreasing trends for nitrate and total phosphorus in AU 1604_03 and for total phosphorus in AU 1604_01. These parameters

continue to be decreasing but not at a statistically significant rate. The 2017 report also identified an increasing trend for sulfate in AU 1604_02. The trend did not persist into this analysis and was likely due to the extended drought conditions since sulfate concentrations had a strong inverse correlation with lake elevation at -0.78.

Segment 1603 - Navidad River Tidal

Segment 1603 is a 5.6-mile tidal portion of the Navidad River that extends from its confluence with the Lavaca River upstream to the Palmetto Bend Dam and flows through the Mid-Coastal Barrier Islands and Coastal Marshes of the Western Gulf Coastal Plain ecoregions. Like Segment 1601, this portion of the Navidad River is classified as a tidal segment influenced by conditions present in Lavaca Bay. In addition to impounding the Navidad River, the Palmetto Bend Dam also serves as a saltwater barrier preventing saline waters from moving further upstream. Releases from Lake Texana and flows from groundwater sources (such as seepages and springs) introduce freshwater into this reach. The watershed is almost entirely undeveloped consisting primarily of forested land and marshes.

Water quality sampling is conducted by the LNRA at station 15374 monthly for field parameters and quarterly for laboratory conventionals. Station 15374 is located approximately 30 meters upstream of the confluence with the Lavaca River (Segment 1601). Note that sampling is conducted about 0.6 mile downstream of the confluence at station 15372, located in Segment 1601.

Table 18: Segment 1603 FY 2022 Monitoring Stations

Segment 1603 - Navidad River Tidal					
Station	**Description**	**Segment**	**Entity**	**Field**	**Lab**
15374	NAVIDAD RIVER TIDAL MID CHANNEL UPSTREAM OF LAVACA RIVER CONFLUENCE	1603	LNRA	12	4

A review of the 2020 IR and Draft 2022 IR showed that there were no concerns or impairments in the segment.

Table 19: 2020 Texas Integrated Report Summary for Segment 1603

Designated Use	Parameter	Criteria	Status
Aquatic Life Use	DO Grab Minimum	3 mg/L	FS
Aquatic Life Use	DO Grab Screening Level	4 mg/L	NC
General Use	pH	6.5 - 9 S.U.	FS
General Use	Ammonia	0.46 mg/L	NC
General Use	Nitrate	1.1 mg/L	NC
General Use	Total Phosphorus	0.66 mg/L	NC

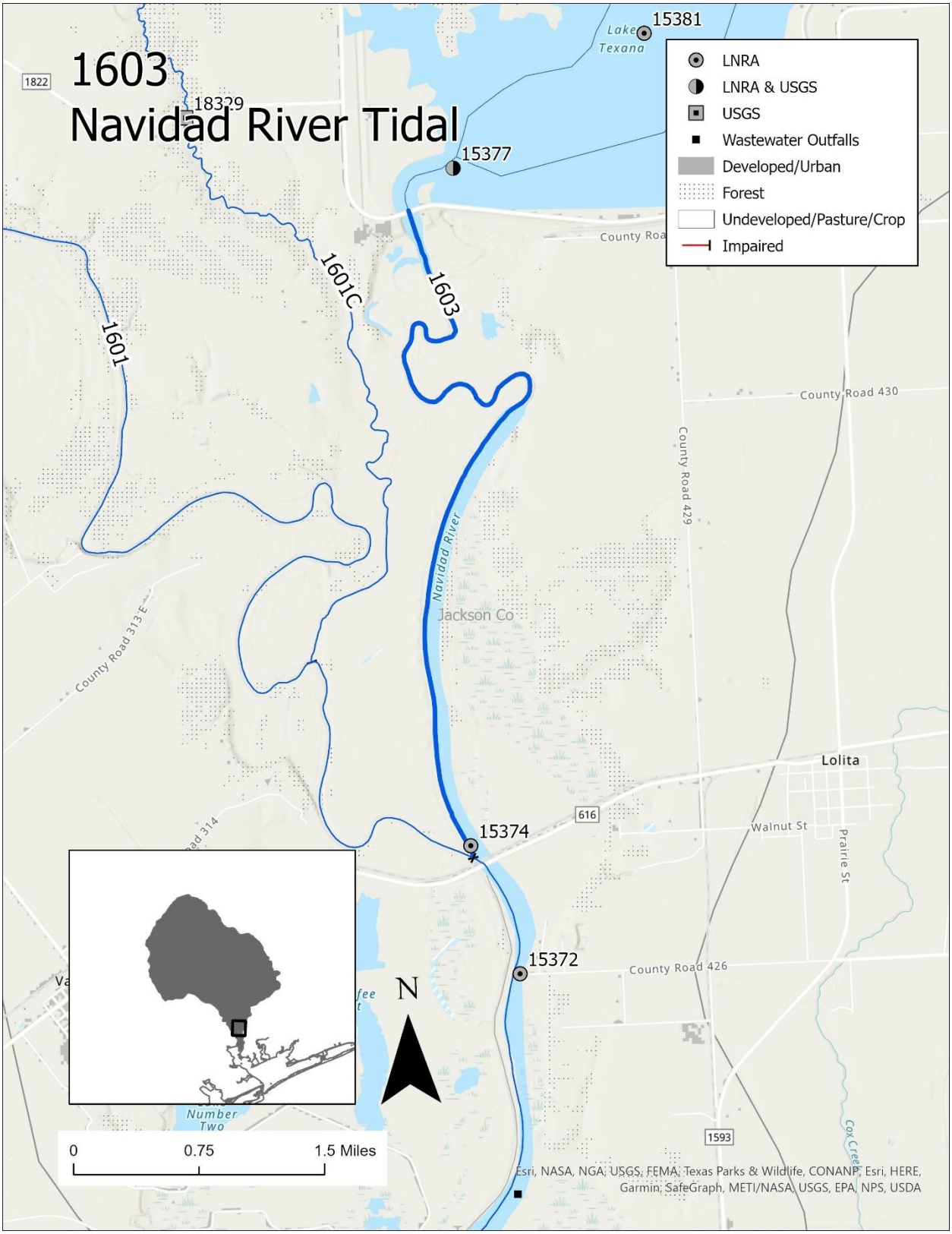

Figure 37: Map of Stations in Segment 1603 - Navidad River Tidal

Sample results from station 15374 met the criteria for trend analysis, but no statistically significant trends were identified.

Of 227 DO values, only two were reported below the 4 mg/L DO Grab screening level. One was collected under exceptional drought conditions in 2011 while the other was obtained during abnormally dry conditions in 2020 indicating that drought conditions were the likely cause for low DO readings. None of the DO concentrations fell below the 3 mg/L DO Grab Minimum criterion.

Three of 62 nitrate results were reported above the screening level of 1.1 mg/L. These samples were collected under moderate to exceptional drought conditions. None of the 79 total phosphorus records exceeded the 0.66 mg/L screening level. Since the elevated levels of these parameters were obtained during drought conditions, it is likely that upstream wastewater treatment plants and/or on-site septic systems were the source of nutrients in the stream.

Figure 38: Confluence of Segment 1601 – Lavaca River Tidal and Segment 1603 - Navidad River Tidal

CONCLUSIONS AND RECOMMENDATIONS

Protecting and preserving water quality in the Lavaca Basin is of upmost importance. Water in the Navidad River flows into Lake Texana which serves as a drinking water source to the surrounding communities. Preservation of water quality ensures lower water treatment costs and provides a reliable source of drinking water for the future.

The Lavaca River is one of the few remaining unrestricted rivers in Texas. The Lavaca and Navidad rivers provide critical freshwater inflow into Lavaca Bay, a secondary embayment of the Matagorda Bay system. These marshes, bays, and estuaries provide critical habitat for the reproduction of aquatic species including fish, shrimp and other invertebrates, such as blue crab. These organisms not only support recreational and commercial fisheries along the Texas Gulf Coast, they also provide critical habitat and food supplies for local and migratory waterfowl including the endangered whooping crane.

With only three waterbodies included in the 2020 Texas §303(d) List, the Lavaca Basin maintains some of the highest water quality in the state. The 2020 Texas Integrated Report evaluated waterbodies based upon samples collected from December 1, 2011 through November 30, 2018. During this time period, data were collected during periods of extreme and near historic droughts followed by periods of near historic flooding along with the landfall of the first direct hit by a Category 4 hurricane in over fifty years.

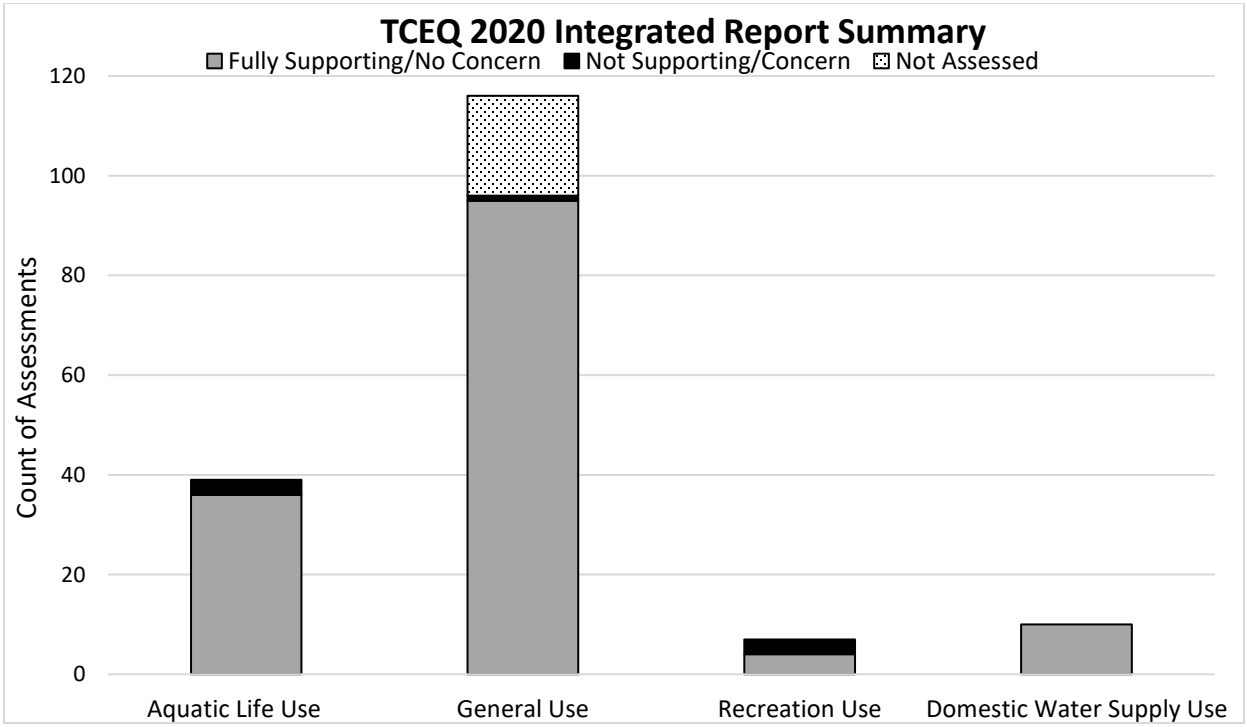

Figure 39: Summary of the 2020 Texas Integrated Report in the Lavaca Basin

TCEQ evaluated these sample results to determine if the waterbodies met their associated designated uses which included Aquatic Life, General, Recreation, and Domestic Water Supply uses. Of the 148 assessments performed, seven were found to not meet the associated designated use. Those not meeting their uses included three impairments for bacteria and two for low dissolved oxygen while one concern each was identified for low dissolved oxygen grab and for total phosphorus. All of the other evaluations revealed that the waterbodies fully supported their designated uses.

All of the impairments and concerns occurred in Segment 1602 – Lavaca River above Tidal. Two assessment units of Segment 1602 and Unclassified Segment 1602B – Rocky Creek were impaired for bacteria. Assessment Units 1602_02 and 1602_03 had bacteria geometric means in excess of the 126 MPN/100 mL criterion with 202.7 MPN/100 mL and 175.5 MPN/100 mL, respectively. The Draft 2022 IR showed similar values. While the bacteria results had a moderate correlation with stream flow, the sources of bacteria were likely the result of both direct animal deposition and from runoff during storm events. Since the riparian corridor is mostly wooded, wildlife was one probable bacteria source. Due to cattle trails leading to the stream and the observance of livestock in the waterway, livestock are another likely source.

Unclassified Segment 1602B – Rocky Creek was added to the §303(d) List for bacteria in 2014. The 2020 IR reported a geometric mean of 279.8 MPN/100 mL while the geometric mean was 339.8 MPN/100 mL in the Draft 2022 IR. Based upon the regular sightings of cattle in the stream by field staff during sampling, livestock were a likely source of bacteria through direct deposition. Wildlife, including feral hogs, were another probable source of the impairment.

A Recreational Use Attainability Analysis was performed in 2017 to evaluate the use of Rocky Creek for primary contact recreation through data collection, observation, and interviews with land owners and the general public. The results of the study showed that primary contact recreation in the river was rare and that most contact with the waterbody was incidental through fishing and hunting activities.

The Lavaca River Watershed Protection Plan commenced in 2016 and was developed to address water quality issues throughout the entire length of the Lavaca River and its tributary streams. The stakeholders of the Lavaca River Basin developed a strategy to restore water quality in the river. Stakeholders dedicated considerable time and effort in discussing the watershed, influences on water quality and potential methods to address water quality concerns, and selecting appropriate strategies to improve water quality.

The WPP determined that no single source of bacteria was the primary cause of the impairment. A variety of bacteria sources were identified by stakeholders including livestock, wildlife, domestic pets, improperly functioning on-site septic systems, sanitary sewer overflows, illicit dumping, and urban stormwater. Stakeholders identified management measures to reduce and feasibly manage instream bacteria levels. Stakeholders are responsible for the

implementation of these voluntary management strategies and the Watershed Coordinator will continue to lead the efforts to implement the plan.

Both assessment units of Unclassified Segment 1602C – Lavaca River Above Campbell Branch were included on the §303(d) List for 24-Hour Dissolved Oxygen Average. The impairment was carried forward from previous assessments since no diel data were collected during the assessment period. In FY 2021, the LNRA began performing diels six times per year to address the impairment and to provide data for the assessment.

Trend analyses were conducted using data collected from 2001 through 2020 for flow, temperature, transparency (secchi depth), DO, specific conductance, pH, alkalinity, total suspended solids, ammonia, total Kjeldahl nitrogen, nitrate, total phosphorus, total organic carbon, hardness, chloride, sulfate, *E. coli*, total dissolved solids, and chlorophyll-*a*. There were 285 data sets that met the criteria for trend analysis. Of those data sets, 57 were mathematically normally distributed while statistically significant trends were identified for eighteen. However, only four of these trends met the analysis criteria of being both normally distributed and statistically significant. Statistically significant decreasing trends were identified for pH and flow in Segment 1602 – Lavaca River Above Tidal and for total Kjeldahl nitrogen and hardness in Unclassified Segment 1602B - Rocky Creek. Many of the trends that had been identified in the 2012 and 2017 Basin Summary Reports were caused by the pervasive drought and did not persist into this evaluation.

For Segment 1602 – Lavaca River Above Tidal, a statistically significant decreasing trend for pH at station 12527 was identified. Although there were no chlorophyll-*a* data available to review, algal productivity may have been affecting pH levels. Total phosphorus and nitrate exhibit higher concentrations at lower flows which is frequently observed downstream of wastewater treatment plants. The City of Moulton treatment plant, located upstream of this station, may be a source of excess nutrients. The physical conditions of the river upstream of the monitoring station along with elevated levels of nutrients at lower flows are ideal for promoting algal productivity. It also should be noted that about ninety percent of samples were collected before noon. Due to the lack of photosynthesis after dark, algal respiration decreases pH throughout the night, thus samples collected in the morning hours tend to have low pH levels than those obtained midday.

A statistically significant decreasing trend for stream flow was also found at station 12527. The decreasing trend appeared to be the result of the drought periods of 2005 through 2006 and 2011 through 2014. Stream flow was often reported near zero during periods of drought.

Decreasing trends for Total Kjeldahl Nitrogen and hardness were identified in Unclassified Segment 1602B – Rocky Creek. Both decreasing trends may be a result of the pervasive drought followed by having more stream flow to dilute the parameter. The trend for total Kjeldahl nitrogen may also be due to improvements at the City of Shiner WWTP or a combination of both.

Hardness levels appear to decrease during prolonged droughts and then increase during the recovery periods. The decreasing trend is likely due to decreased runoff during the drought periods.

Rain events wash calcium and magnesium compounds from the surrounding land into the stream by leaching these constituents from rocks and soils during precipitation events. Irrigation of surrounding land could also introduce hardness to the stream. Evaporation of irrigation water can leave behind minerals on the soil's surface. Precipitation then washes these minerals into the stream, thereby increasing their concentrations. In recent years, drought periods have been shorter which would require less irrigation. In turn, the build-up of minerals on irrigated land would be lower than in the past fifteen years.

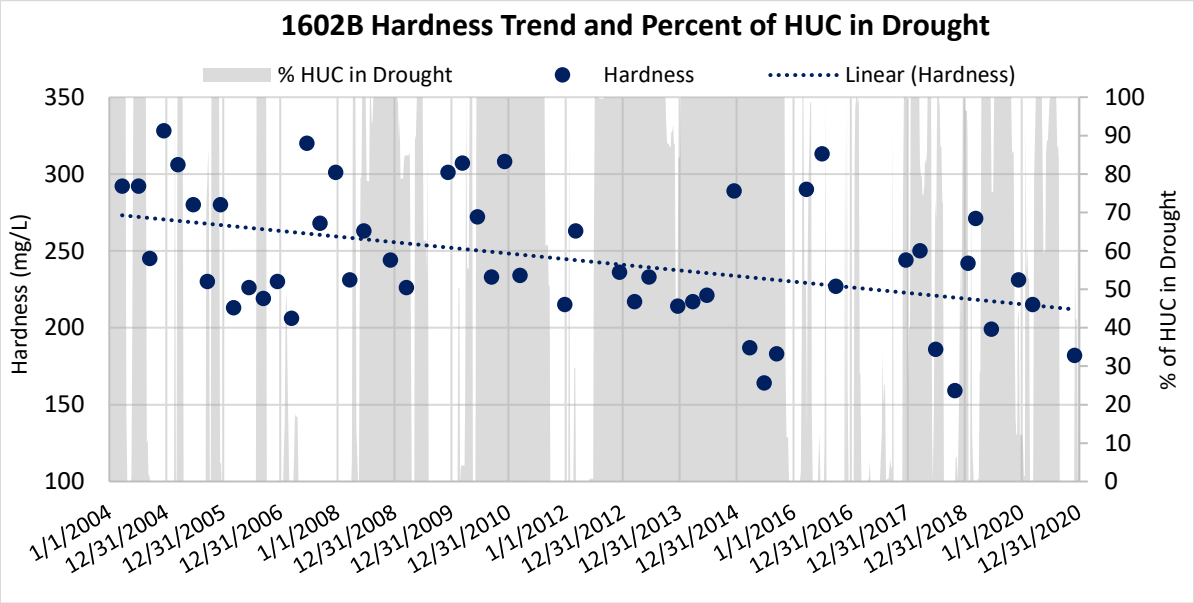

Figure 40: 1602B Decreasing Hardness Trend and Percent *of HUC in Drought*

Samples for total phosphorus and nitrate collected during the 2020 assessment period in Segment 1604A – West Mustang Creek were reported over the screening levels. The mean of the exceedances was 0.76 mg/L for total phosphorus and 6.33 mg/L for nitrate. Data collected during the Draft 2022 IR assessment period showed one total phosphorus result at 0.75 mg/L and three nitrate exceedances with a mean of 7.48 mg/L.

Sediment and nutrient loading into Lake Texana are of great interest for the LNRA since high concentrations of nutrients can perturb water quality, drinking water sources, and aquatic life, while an increase in sediment loads can reduce water clarity and light penetration within the water column. During runoff events, nutrients bound to soil particles are transported into waterbodies through the process of soil erosion.

The 2020 Trophic Classification of Texas Reservoirs ranked Lake Texana as mesotrophic for having one of the lowest concentrations of chlorophyll-*a* in the state. With a mean chlorophyll-*a* concentration of 4.0 µg/L, Lake Texana is in the top ten percent out of 138 reservoirs for the

lowest amount of chlorophyll-*a*. However, the reservoir falls into the bottom ten percent statewide for highest concentration of total phosphorus and lowest transparency.

On average, nitrate exceeded its screening level of 0.37 mg/L in almost one-third of all samples collected in Lake Texana over the past twenty years while total phosphorus surpassed its 0.20 mg/L screening level in over half of all samples. The highest percentage of exceedances occurred in the upper two assessment units which are the Navidad Arm and the Mustang Arm. The highest percentage of nutrient exceedances occurred in the Mustang Arm (AU 1604_02) with 32 percent of all nitrate and 85 percent of the total phosphorus results reported above their respective screening levels. The mean nitrate concentration was 0.43 mg/L while total phosphorus had an average of 0.30 mg/L. The maximum sample result obtained during this period was 2.98 mg/L of nitrate and 1.04 mg/L of total phosphorus. The nutrient results also had a moderate inverse correlation with lake elevation, meaning that as the lake elevation decreased, the nutrient concentrations increased. Nitrate had a correlation coefficient of -0.48 while total phosphorus correlated to lake elevation at -0.46.

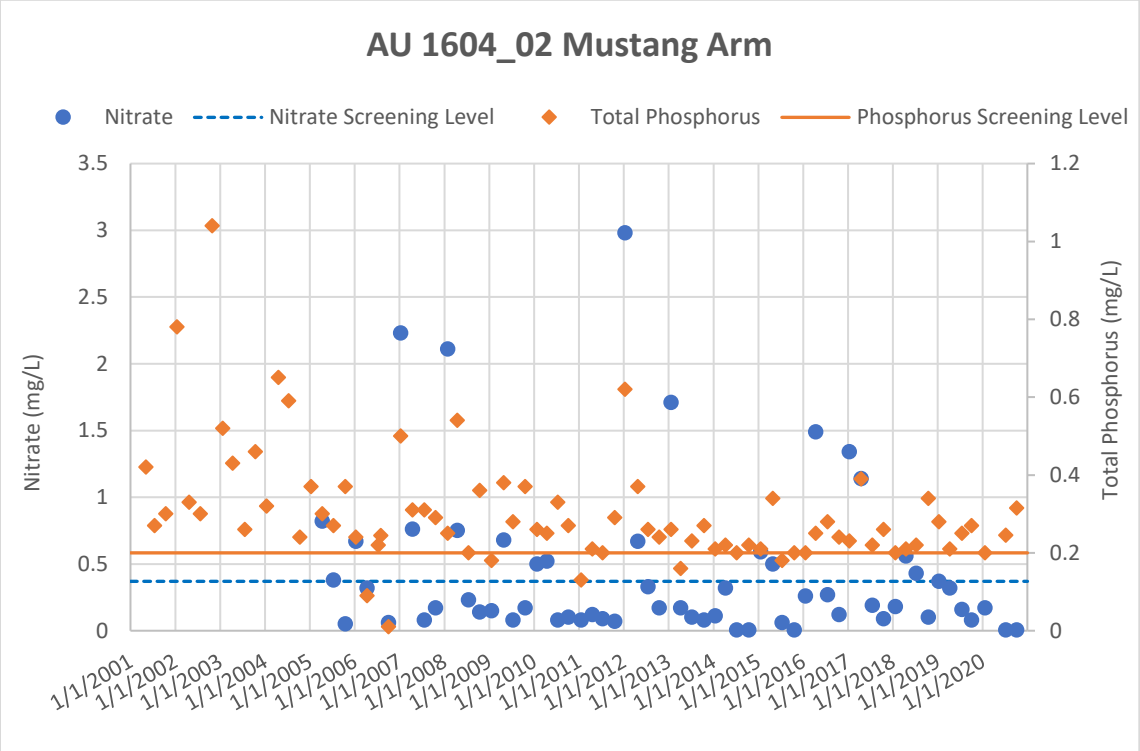

Figure 41: Nitrate and Total Phosphorus results in AU 1604_02 Mustang Arm from 2001 - 2020

Despite the high levels of nutrients throughout the entire reservoir, chlorophyll-*a* concentrations rarely exceeded the screening level. Out of 384 samples collected over the past twenty years, only four elevated chlorophyll-*a* values were reported. Those high values were obtained in the upper two arms of the reservoir.

Transparency, a measure of water clarity, is very limited in Lake Texana with a mean secchi depth of 0.26 meters (less than one foot). This poor water clarity in the reservoir limits the

amount of light penetrating the water column, thereby limiting algal productivity. This has most likely prevented excessive algal blooms and its associated water quality issues including low dissolved oxygen and high pH.

During the process of photosynthesis, carbonic acid is reduced, thereby increasing the pH of the water column. Since grab samples are often collected near midday, pH readings reported to CRP tend to be higher than when collected soon after daybreak.

Although pH was generally trending higher in Lake Texana, it was no longer increasing at a statistically significant rate as observed in the 2017 Basin Highlights Report. However, it should be noted that all exceedances of the high criterion occurred in 2019 and 2020. In fact, high pH was measured in all assessment units in September 2019 while all but the Navidad Arm exceeded the high pH criterion in June 2020. Although no chlorophyll-*a* samples were collected on those dates, field notes stated that there were algal blooms present at the time of sampling. In September 2019, DO ranged from 129.4 percent saturation to 178.9 percent in all five assessment units. These super-saturated DO values corroborate the field notes that excessive algal production was the likely cause for the high pH exceedances throughout the reservoir. These results further indicate that high pH, caused by excessive algal productivity, could become a larger issue in Lake Texana in the future.

Since Lake Texana serves as a domestic drinking water supply, the reduction of nutrient inputs into the reservoir is of great value to the LNRA. Excessive nutrients lead to algal blooms which cause taste and odor issues in treated drinking water, as well as the potential for the formation of trihalomethanes, depending upon the treatment process.

Recommendations

After a thorough review of all data collected over the past twenty years in the Lavaca Basin, the following items are recommended:

- Continue the current LNRA monitoring program to address water quality concerns, impairments, and data needs for the basin.
- Continue to support the development of new watershed protection plans and advancement of existing Watershed Protection Plan in the Lavaca, Colorado-Lavaca, and Guadalupe-Lavaca Coastal River Basins.
- Support stakeholder outreach and landowner education programs to reduce the impacts of failing on-site septic systems and agricultural activities to reduce contributions of bacteria and nutrients in the watershed.
- Consider performing a Recreational Use Attainability Analysis in the Lavaca River to assess its use for primary contact recreation.
- Consider performing a nutrient special study or monthly nutrient sampling over a period of one to two years in Mustang and East Mustang creeks to thoroughly evaluate their contributions into Lake Texana.

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