TCEQ Grant Agreement 582-16-60126

The Impacts of Assimilative Capacity of Reservoirs on Coastal Inflows

Deliverable: Final Report

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April 2019

The preparation of this report was financed through grants from the Texas Commission on Environmental Quality and the U.S. Environmental Protection Agency

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Executive Summary

Lake Livingston, a multipurpose reservoir, is situated amongst mixed pine and hardwood forests in southeast Texas. In 1969 the reservoir was created when the Lake Livingston Dam was constructed. As a result of impoundment, the Trinity River was divided into two sections; the Upper and Lower Trinity. The goal of the Impacts of Assimilative Capacity of Reservoirs on Coastal Inflows project was to assess assimilative capacity of the Lake Livingston reservoir and related impacts on freshwater inflows to the Galveston Bay estuary. This project sampled inflow from the Upper Trinity to the north and outflow from the Lower Trinity south of the Lake Livingston Dam to quantify nutrient and suspended sediment concentrations, deployed a GPS drifter to track flow patterns and currents, and collected depth profiles to determine degree of stratification.

Water quality sampling was conducted during six sampling events between May 2016 and August 2018. Samples were collected during base, moderate, and high flow conditions. The sampling events do not show elevated nutrient or sediment concentrations leaving the lake during high or base flow conditions. This could be due to a lack of samples collected during high flow events, time between sample collection, or turnover patterns in the lake. The majority of suspended sediments, phosphorus, and total nitrogen sample events resulted in a decreasing pattern from north to south with maximum concentrations detected at the Trinity River Riverside - North site. These results suggest that the Lake Livingston Reservoir, an artificial impoundment, is a nutrient and sediment sink.

This report details methodology and sample design for water quality sampling, collection of depth profiles, and drifter deployment. A summary of the data is presented, with findings on nutrients, lake flow patterns and depth profiles. The appendices contain tabular data from the study, a data dictionary, spatial figures of the drifter pathways, and graphed results of water quality parameters.

Introduction

Lake Livingston, a multipurpose reservoir, is located in the South-Central Plains ecoregion. The reservoir is situated amongst mixed pine and hardwood forested habitat (Figure 1). The reservoir was created when the Lake Livingston Dam was constructed, impounding the Trinity River in 1969. The dam is an earthen spillway. It was not designed as flood infrastructure – flow through the dam is controlled by twelve tainter gates in a concrete and steel spillway. As flow through Trinity River increases, so too does flow over the spillway (TRA, 2019). Lake Livingston has a storage capacity of 1,788,000 acre-feet and a drainage area of 16,616 square miles (HTO, 2010). The lake was created for water supply and but is also used for water-based recreation.

Figure 1 Trinity River near Riverside, TX

Project Significance and Background

The 2017 Texas State Water Plan (TWDB, 2017) projected that in order to meet the State's water need for 2070, over 45% of the recommended supply strategies should come from surface water resources, including new reservoirs. However, reservoirs are costly to build and have ecologic and hydrologic impacts such as affecting freshwater inflow and the supply of sediment and nutrients to Texas coastal ecosystems.

The goal for the project was to assess the assimilative capacity of the Lake Livingston reservoir and related impacts on freshwater inflows to the Galveston Bay estuary (Figure 2). More than half of Galveston Bay's freshwater inflows come from the Trinity River. The USGS, in cooperation with the Texas Water Development Board, has evaluated several high flow events on the Trinity River; to assesses the variability of nutrient and suspended sediment concentrations during elevated flow conditions. Initial results from the USGS study indicated that releases from the Lake Livingston Dam may play an important role in controlling sediment and nutrient load variability to the Galveston Bay ecosystem. However, the effect Lake Livingston has on the retention of sediment and nutrients is not well understood. Quantifying the assimilative capacity of Lake Livingston is critical in understanding the impacts of reservoirs on the health of the Galveston Bay ecosystem.

The Impacts of Assimilative Capacity of Reservoirs on Coastal Inflows project sampled inflow from the Trinity River north of Lake Livingston and Trinity River outflow south of the Lake Livingston Dam to quantify pre and post reservoir nutrient and sediment concentrations. The surface water data sampled during the project period was analyzed to assess how the assimilative capacity of the reservoir affects the nutrient and sediment supply to the Galveston Bay ecosystem.

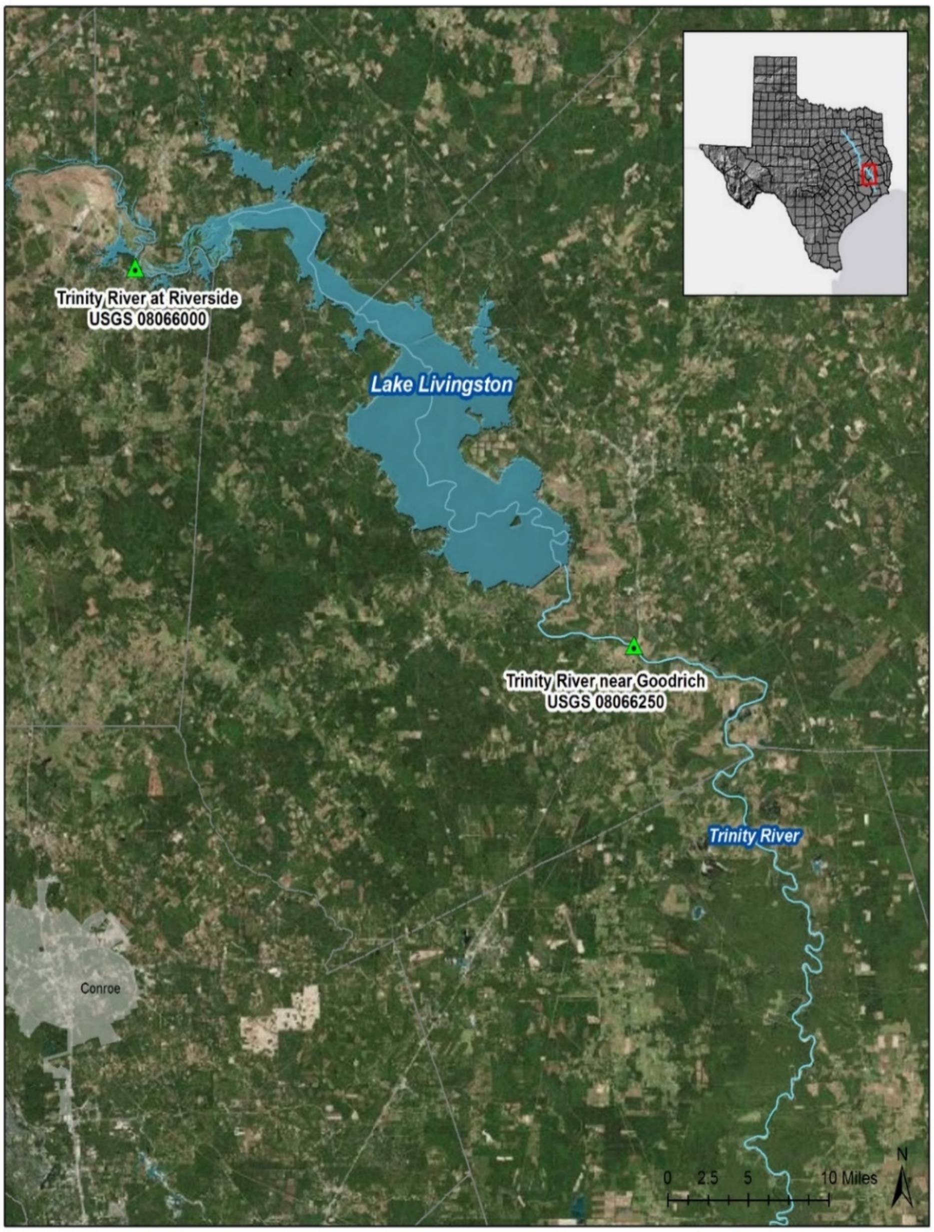


Figure 2 Study Site – Lake Livingston Reservoir and USGS stream gage stations

Methods

GTRI subcontracted with USGS to perform surface water quality sampling (Figure 3). The sampling was performed under a Texas Commission on Environmental Quality (TCEQ) approved Quality Assurance Project Plan (QAPP) based on the TCEQ QAPP template. GTRI and USGS collaborated to create a new QAPP, to ensure the high standard of data quality objectives of this project were met and maintained through quality assurance and quality control (QA/QC). The QAPP was reviewed and amended as necessary throughout the project. GTRI and USGS developed a monitoring plan to determine a sampling methodology in conformity with the QAPP and project objectives. The monitoring plan established site selection criteria and identified specific sampling locations. It determined sampling design, including sample collection frequency, target flows, specific sampling procedures, and laboratory methods for water quality analyses.

Sampling

Balancing the limitations faced by project scope with the need to collect representative samples across spatial and temporal scales, that can also describe stratification, it was determined that four water quality sampling sites supplemented by the collection of relevant constituents across a depth gradient at two sites would best meet project objectives. Four sampling sites were selected for this project spanning Lake Livingston from north to south (Figure 4). The locations of all sites were determined to optimize sampling efforts. The far north end station is **Trinity River Riverside – North** (USGS 08066000), the above middle station is **Livingston DC Upper** (USGS 304521095075501), the below middle station is **Livingston BC Lower** (USGS 303935095055401), and the fourth station located below the dam is **Trinity River Goodrich - South** (USGS 08066250) (Figure 4).

Figure 3 USGS Collecting Water Quality Samples near Riverside

The sample design rationale incorporated a north/south gradient that was utilized to spatially represent Trinity River inflow/outflow as well as the main body of the reservoir. As described in the monitoring plan, samples were collected at all four sites per each sampling trip. Field parameters collected with a multi-parameter sonde, at the time of sample collection were Specific Conductance (μS/cm at 25ºC), pH (pH units), dissolved oxygen (mg/L), dissolved oxygen (% saturation), and Turbidity (FNU). The purpose of collecting field parameters was to assess general water quality conditions at the sampling site. Additional lab water quality nutrient parameters sampled were ammonia as N, nitrite, nitrite + nitrate, phosphorus, orthophosphate, total nitrogen (NH_3 + NO_2 + NO_3 + Organic), dissolved organic carbon, total organic carbon, and UV-absorbing organic constituents. The purpose of collecting water quality parameters such as nutrients and suspended sediment is to characterize the assimilative capacity of Lake Livingston. The reported methods resulted in the collection of 24 water quality samples during six sampling events with additional QA/QC samples consisting of field blanks and duplicates.

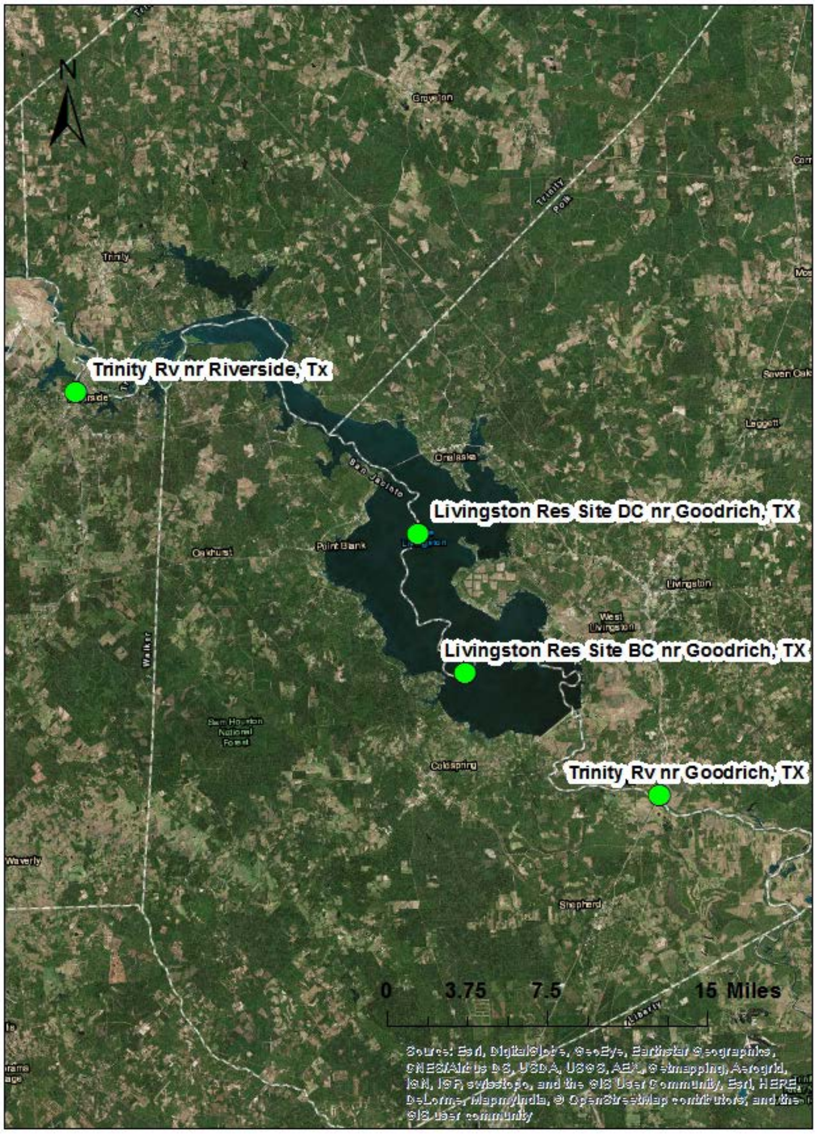


Figure 4 Lake Livingston Sampling Locations
(Trinity River nr Riverside, TX = ***Trinity River Riverside – North****, Livingston Res Site DC nr Goodrich, TX =* ***Livingston DC Upper****, Livingston Res Site BC nr Goodrich, TX =* ***Livingston BC Lower****, Trinity River nr Goodrich, TX =* ***Trinity River Goodrich - South****)*

Due to the distance between sampling sites the six sampling events occurred over multiple days from:

- 5/3 to 5/9/2016,
- 10/25 to 11/1/2016,
- 1/23 to 1/31/2017,
- 6/9 to 6/20/2017,
- 2/25 to 3/6/2018, and
- 8/8 to 8/21/2018.

One sample was collected at each of four sites per sampling event resulting in 24 samples. The six sample events included additional collection of depth profiles for the two stations in the main body of the reservoir (Livingston DC Upper and Livingston BC Lower) resulting in 12 sets of additional field parameter samples (Specific Conductance [µS/cm at 25ºC], pH [pH units], dissolved oxygen [mg/L], dissolved oxygen [% saturation], and Turbidity [FNU]).

The USGS collected water-quality samples for the sample events as listed below:

- **5/3 to 5/9/2016**
    - 5/3/2016 Trinity River Riverside - North
    - 5/5/2016 Livingston DC Upper and Livingston BC Lower
    - 5/9/2016 Trinity River Goodrich - South
- **10/25 to 11/1/2016**
    - 10/25/2016 Trinity River Riverside - North
    - 10/27/2016 Livingston DC Upper and Livingston BC Lower
    - 11/1/2016 Trinity River Goodrich - South
- **1/23 to 1/31/2017**
    - 01/23/2017 Trinity River Riverside - North
    - 01/26/2017 Livingston DC Upper and Livingston BC Lower
    - 01/31/2017 Trinity River Goodrich - South
      Note: The drifter was not deployed during this event due to previous problems. Instead, the timing of this sample was based upon: previous drifter data, velocity measurements from Riverside, and reservoir retention time calculations. While sampling, high turbidity (117.1 FNU) was observed at site Livingston DC Lower, while a turbidity of 12.35 FNU was observed at Livingston BC Upper.
- **6/9 to 6/20/2017**
    - 06/09/2017 Trinity River Riverside - North
    - 06/15/2017 Livingston DC Upper and Livingston BC Lower
    - 06/20/2017 Trinity River Goodrich - South
- **2/25 to 3/6/2018**
    - 02/25/2018 Trinity River Riverside - North
    - 02/28/2018 Livingston DC Upper
    - 03/01/2018 Livingston BC Lower
    - 03/06/2018 Trinity River Goodrich - South
- **8/8 to 8/21/2018**
    - 08/08/2018 Trinity River Riverside - North
    - 08/14/2018 Livingston DC Upper and Livingston BC Lower
    - 08/21/2018 Trinity River Goodrich – South

USGS reviewed events that were previously collected to reassess targeting thresholds:

- 05/03/2016 to 05/09/2016 discharge of 43,590 cf/s at Riverside
- 10/25/2016 to 11/01/2016 low discharge, @ 1,500 cf/s
- 01/23/2017 to 01/31/2017 discharge of 17,514 cf/s at Riverside
- 06/09/2017 to 06/20/2017 discharge of 15,954 cf/s at Riverside

Drifter

The Impacts of Assimilative Capacity of Reservoirs on Coastal Inflows project utilized a Microstar Drifter equipped with Globalstar Simplex telemetry. The drifter system is comprised of a surface float connected by tether to a drogue to track currents at a depth of one meter (m) (Figure 5). The drifter collects coordinates at 10 second intervals. The drifter was released on five occasions at the far north end of Lake Livingston. Drifter data collected during early deployments (which occurred from 11-03-15 to 11-06-15 and 12-15-15 to 12-21-15) was analyzed to obtain baseline information for future sample collection and refine the sampling plan for later deployments. USGS conducted exploratory monitoring by deploying the drifter to estimate residence times in Lake Livingston. To assess currents in Lake Livingston during a variety of flow regimes, the drifter was deployed from 11-03-15 to 11-06-15, 12-15-15 to 12-21-15, 3-14-16 to 3-18-16, 6-11-17 to 6-13-17, and 2-25-18 to 2-28-18. However, problems with shallow depth, high density of vegetative material, slow drift, and shoreline obstructions such as boat docks and finger piers resulted in a series of short drifter runs that were restricted to the northern portion of the lake or to the Trinity River channel.

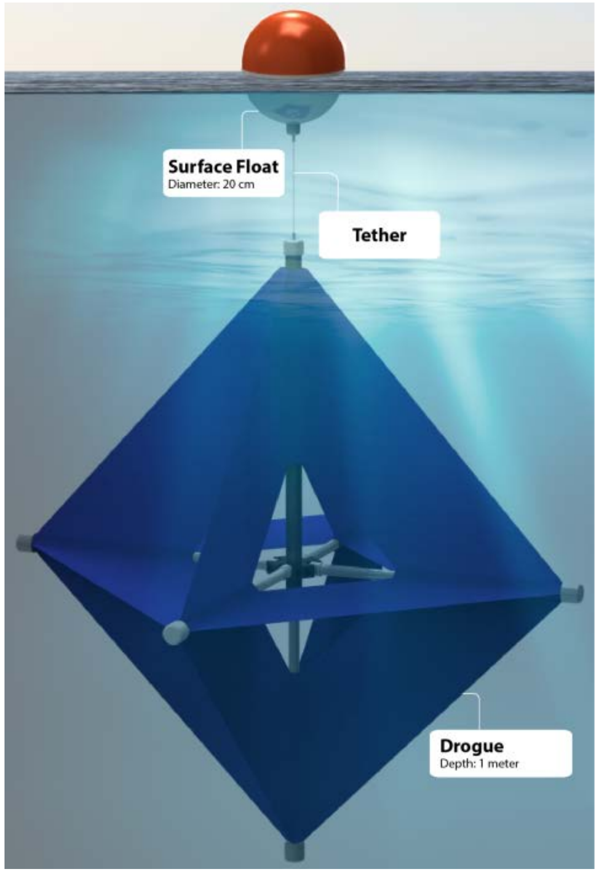


Figure 5 Microstar Drifter Schematic

Results and Observations

Sample Results

USGS delivered the lab analysis results to GTRI (see Table 1 in Appendix A). See Appendix D for graphs displaying results for all constituents. The constituents are grouped by sampling event, with samples displayed in a gradient from the northern sampling site (Trinity River Riverside - North), upper mid lake sampling site (Livingston DC Upper), lower mid lake sampling site (Livingston BC Lower), ending at the southern sampling site (Trinity River Goodrich - South). Results for suspended sediments, phosphorus, total nitrogen, nitrate, and ammonia are reported in this section.

The sampling events had the following discharge at the Oakwood stream gage upstream of Lake Livingston:

- May 2016: 43,590 ft^3/second – higher flow event
- November 2016:<1,000 ft^3/second – base flow
- January 2017: 17,514 ft^3/second – moderate flow event
- June 2017: 15,954 ft^3/second - moderate flow event
- February 2018: 17,730 ft^3/second - moderate flow event
- August 2018: <1,000 ft^3/second – base flow

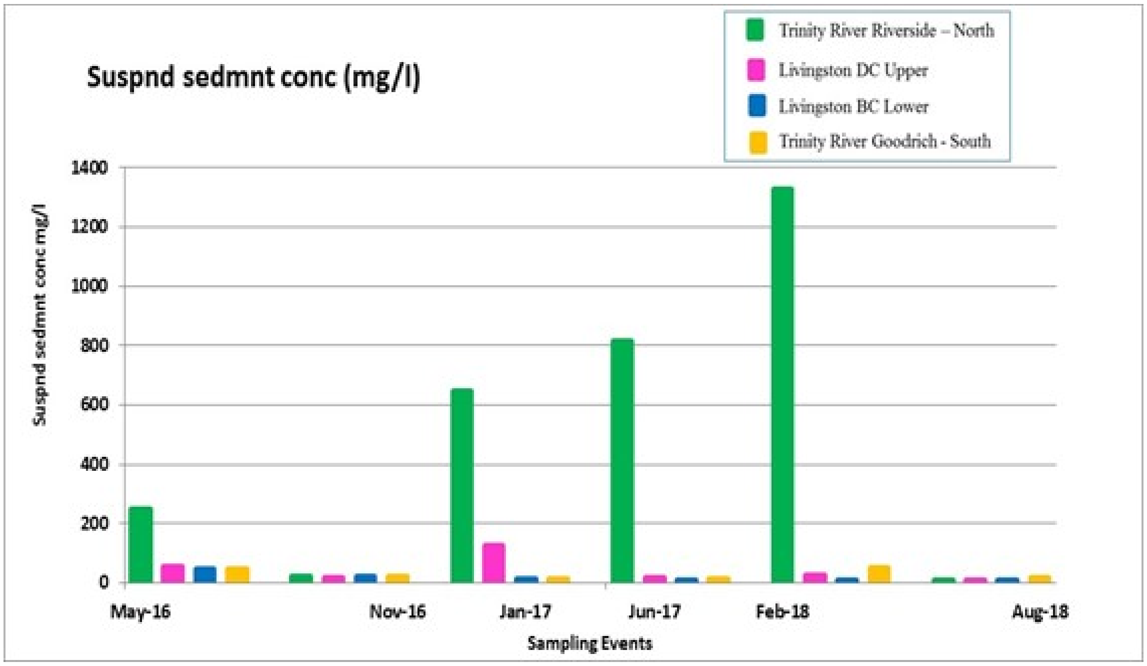


Figure 6 Suspended Sediment Concentration

During the base flow events of November 2016 and August 2018, suspended sediments were low across all four sampling sites (Figure 6). During the flow events of May 2016, January 2017, June 2017, and February 2018, an initial suspended sediments spike at the Trinity River Riverside - North site was observed but concentrations quickly dissipated along the north to south gradient of the reservoir. Nitrate concentration was observed to be highest at Trinity River Riverside – North for the base flow events of November 2016 and August 2018, and the moderate flow events of June 2017 and February 2018 (Figure 7).

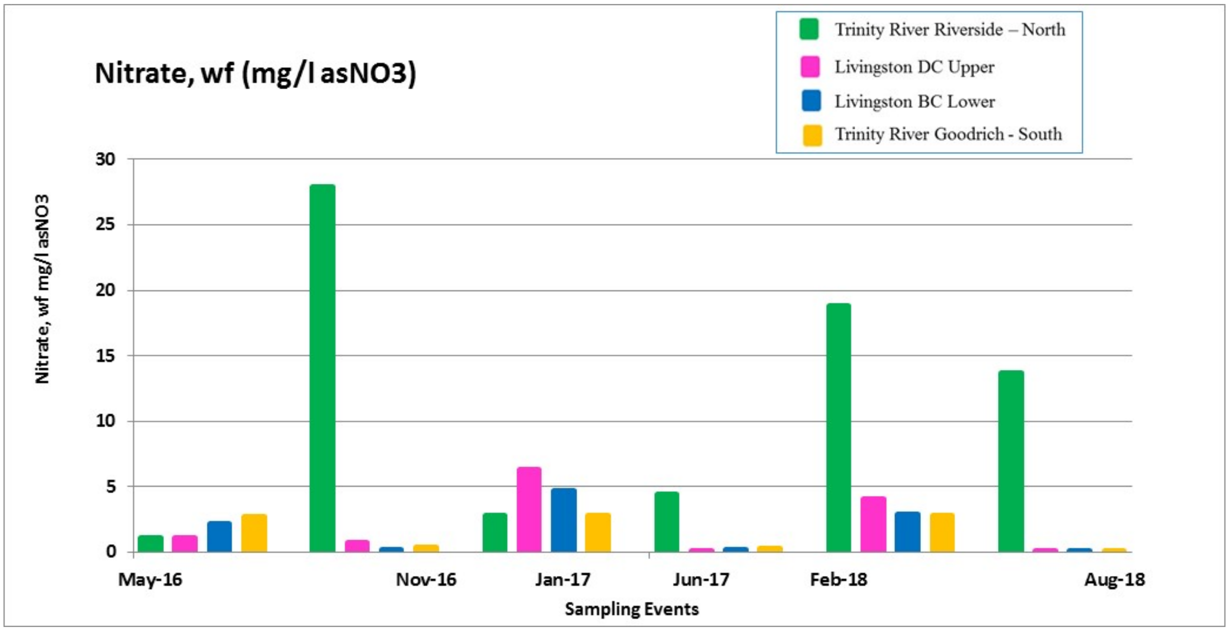


Figure 7 Nitrate Sampling Results

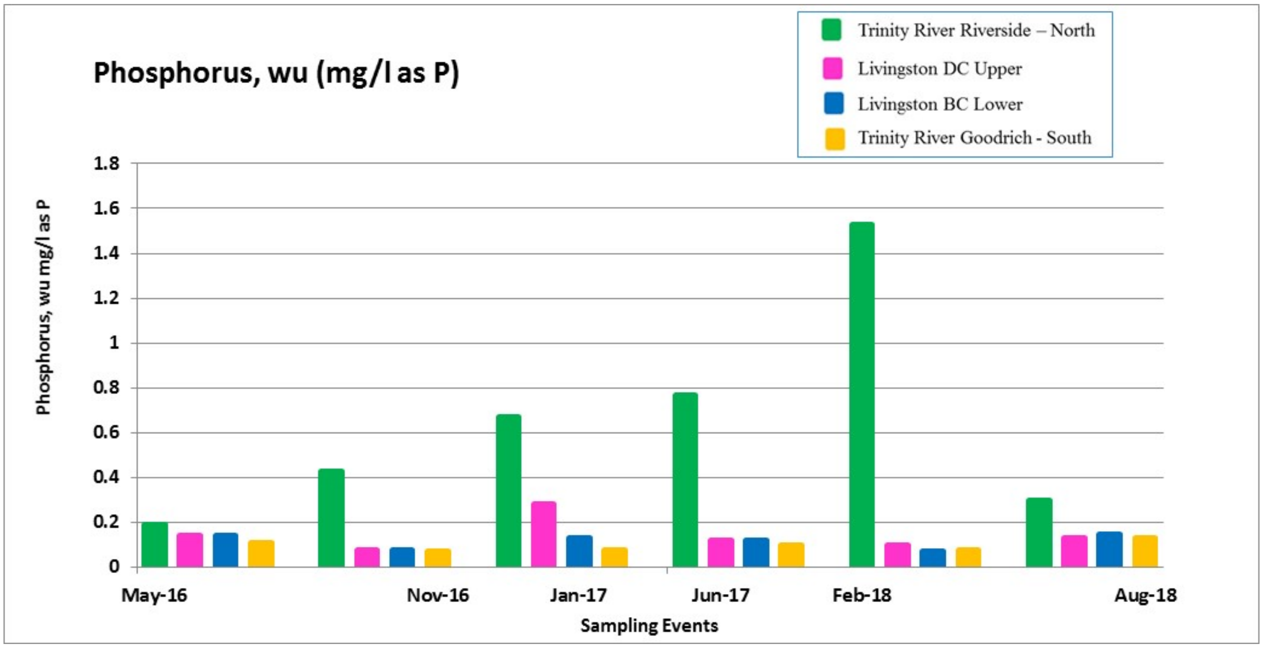


Figure 8 Phosphorus Sampling Results

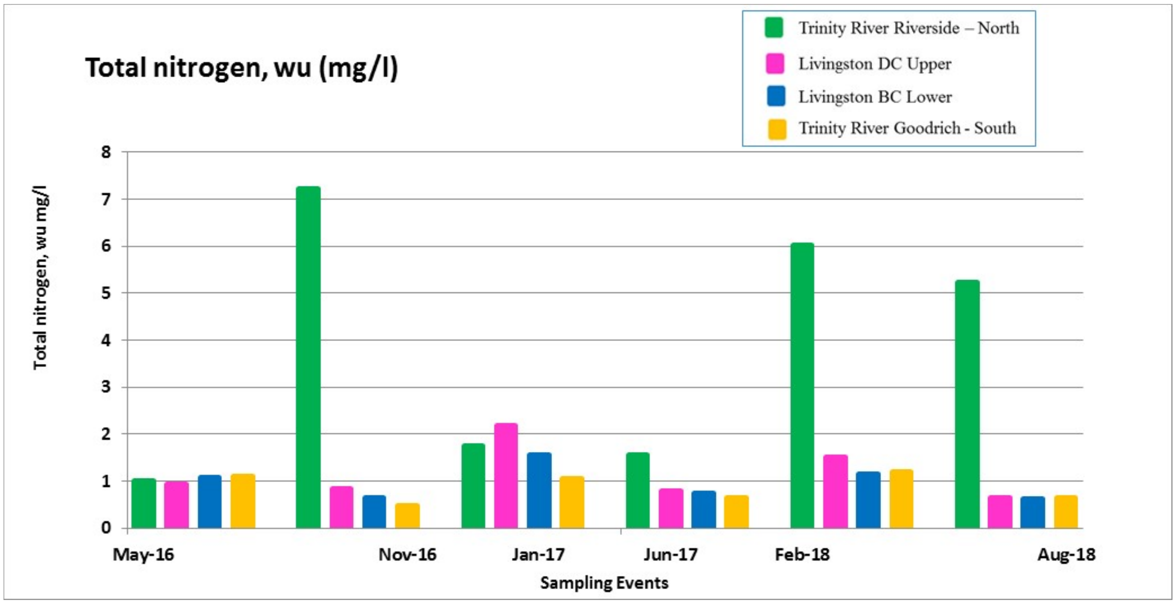


Figure 9 Total Nitrogen Sampling Results

All sampling events showed a higher concentration of phosphorus entering the lake at the Trinity River Riverside - North site (Figure 8). Total nitrogen concentration was highest at the Trinity River Riverside - North sampling site entering the lake and was the lowest at the Trinity River Goodrich - South site (Figure 9) for four of the six sampling events (two base flow events and two moderate flow events). During the highest flow event (May 2016) total nitrogen was slightly higher at the two southern stations (Livingston BC Lower and Trinity River Goodrich – South) compared to the northern stations (Trinity River Riverside – North and Livingston DC Upper) but overall did not show a substantial difference between stations (Figure 9).

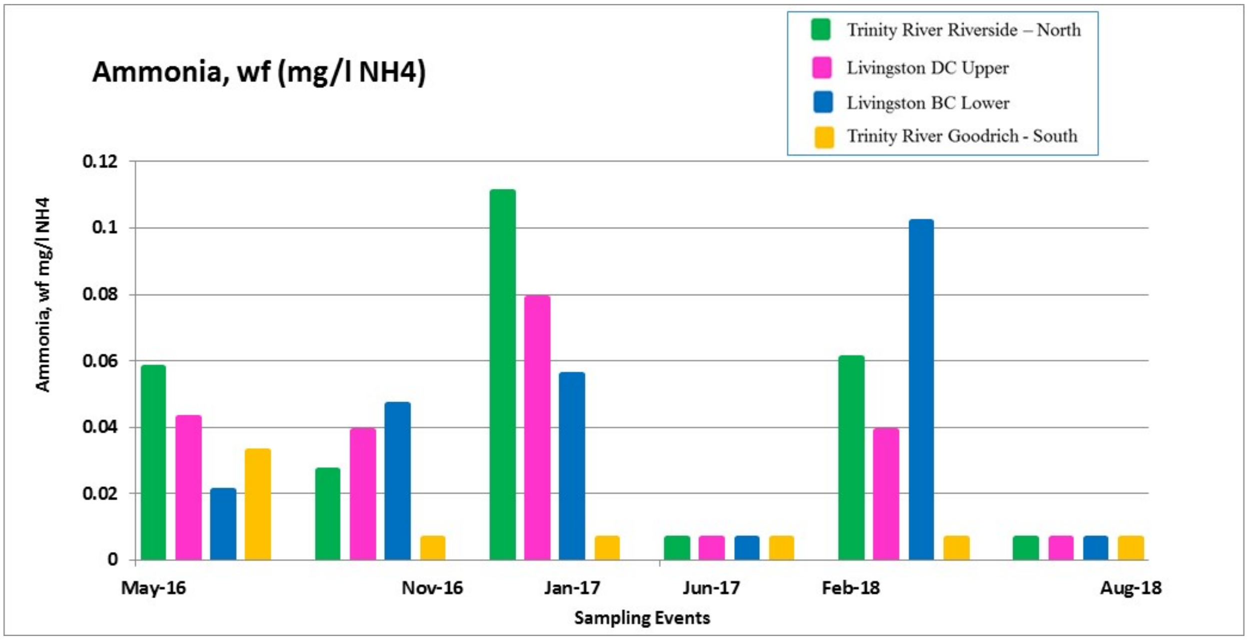
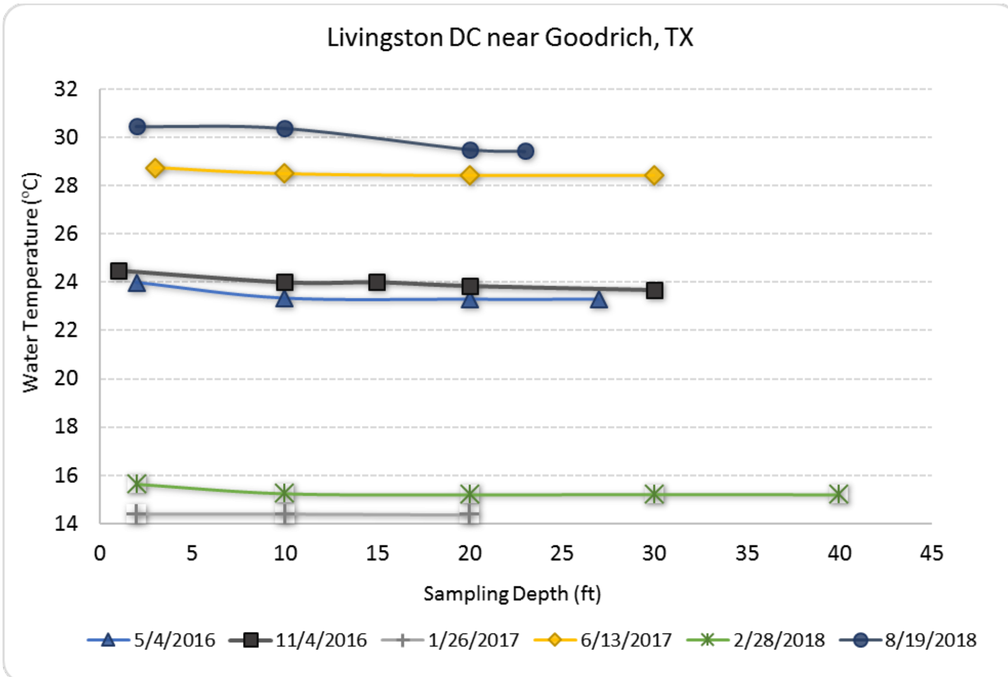


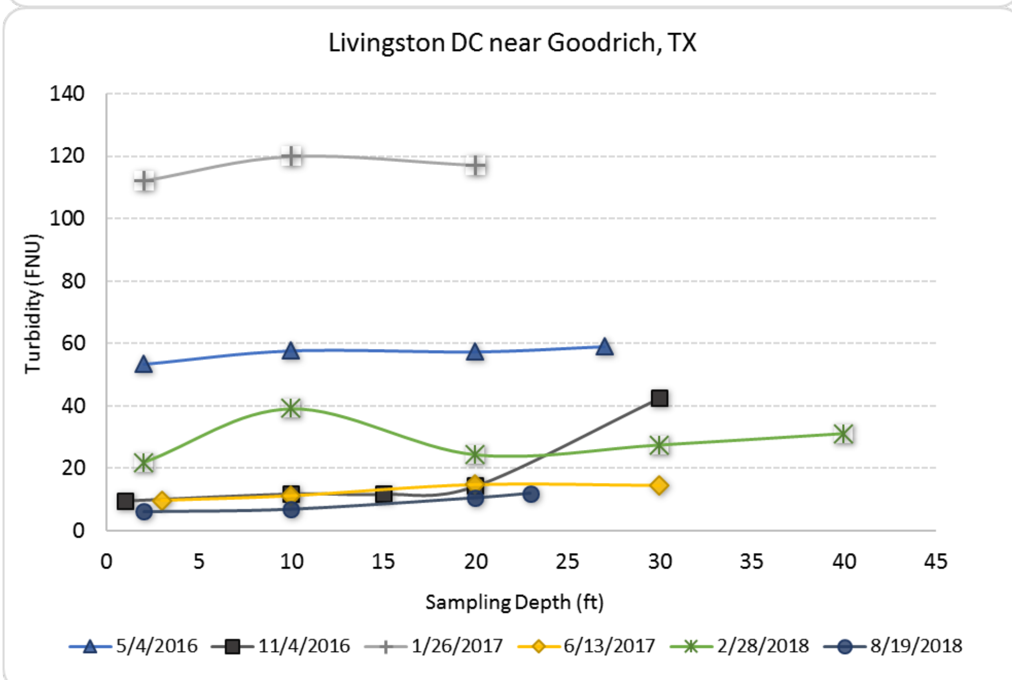
Figure 10 Ammonia Sampling Results

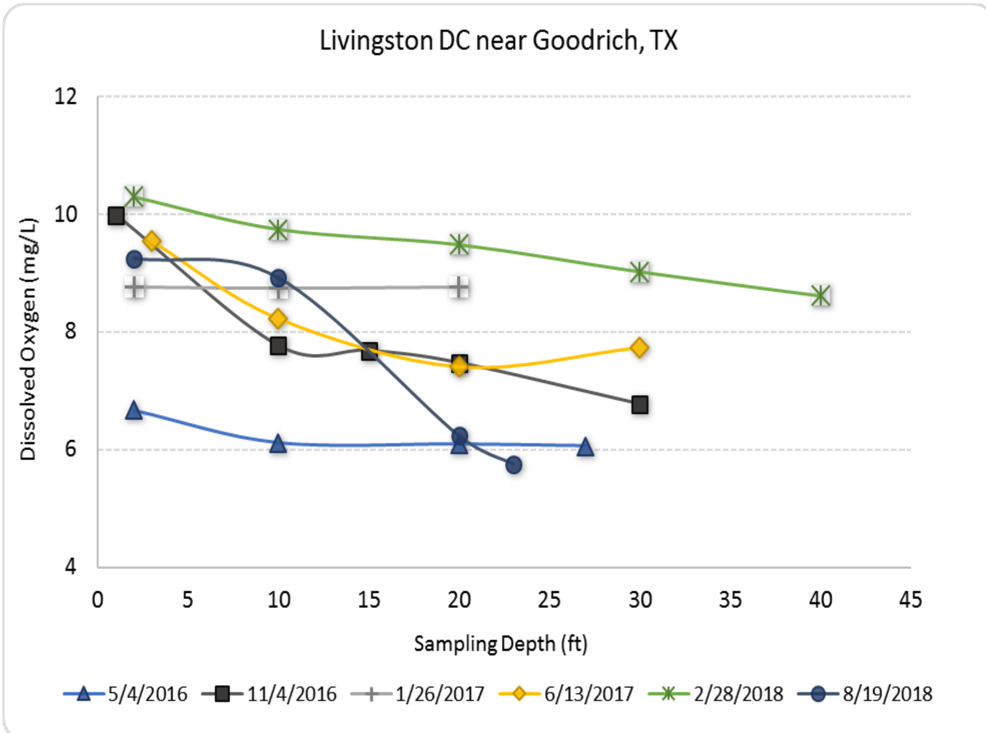
Compared to the other nutrient sampling results ammonia exhibited a variable pattern (Figure 10). Overall, nutrient samples peaked in concentration at the Trinity River Riverside – North site and declined in concentration in the main body of the reservoir, suggesting the reservoir assimilates nutrients through deposition to sediments and nutrient cycling processes. The Lower Trinity River below reservoir consistently had reduced nutrient and sediment concentrations compared to the inflow of the Upper Trinity River.

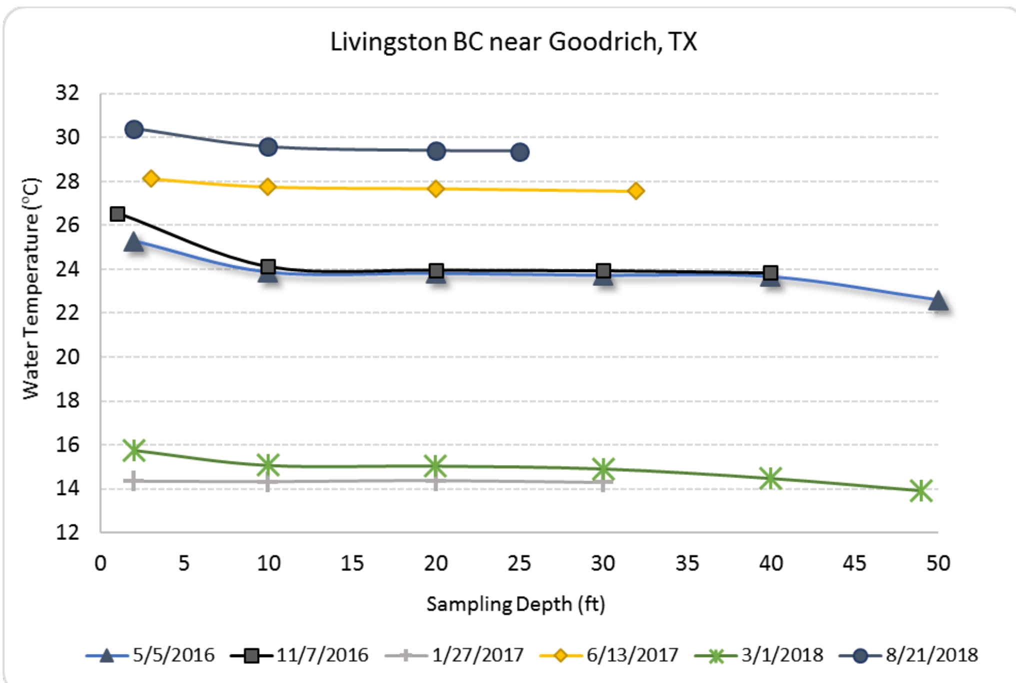
Depth Profile Results

USGS field notes logged the May 2016 sampling event as an early summer event. Water temperature, dissolved oxygen, and turbidity held nearly constant across depth at the Livingston DC Upper. Similarly, at the Livingston BC Lower water temperature exhibited minimal variation across depth. However, dissolved oxygen decreased at 10- and 40-foot intervals and turbidity increased slightly with depth from 39.5 FNU at the surface to 69.2 FNU at 50 feet (Figure 11). The November 2016 sampling event was collected under base flow conditions. Only slight stratification was evident during this sampling event; both sites showed elevated turbidity near the lake bed. The January 2017 sampling event recorded moderate lake volume. Turbidity at the Livingston BC Lower site was dramatically lower than turbidity at the Livingston DC Upper site for all depths (Figure 11). The June 2017 sampling event showed moderate lake volume. Stratification appeared disturbed at the Livingston DC Upper, while the Livingston BC Lower retained a light to moderate stratification profile, with lower turbidities (Figure 11). The February 2018 sampling event recorded moderate lake volume. Turbidity at the Livingston BC Lower site was slightly lower than those observed at the Livingston DC Upper across all depths. The August 2018 sampling event was collected during baseflow conditions. Both stations exhibited a pattern of decreasing dissolved oxygen concentration with increased depth, although water temperate held constant, and turbidity remained low across the depth gradient (Figure 11).


Livingston DC near Goodrich, TX
Water Temperature (°C)
32
30
28
26
24
22
20
18
16
14
0
5
10
15
20
25
30
35
40
45
Sampling Depth (ft)
5/4/2016
11/4/2016
1/26/2017
6/13/2017
2/28/2018
8/19/2018


Livingston DC near Goodrich, TX
Turbidity (FNU)
140
120
100
80
60
40
20
0
0
5
10
15
20
25
30
35
40
45
Sampling Depth (ft)
5/4/2016
11/4/2016
1/26/2017
6/13/2017
2/28/2018
8/19/2018


Livingston DC near Goodrich, TX
Dissolved Oxygen (mg/L)
12
10
8
6
4
0
5
10
15
20
25
30
35
40
45
Sampling Depth (ft)
5/4/2016
11/4/2016
1/26/2017
6/13/2017
2/28/2018
8/19/2018


Livingston BC near Goodrich, TX
Water Temperature (°C)
32
30
28
26
24
22
20
18
16
14
12
0
5
10
15
20
25
30
35
40
45
50
Sampling Depth (ft)
5/5/2016
11/7/2016
1/27/2017
6/13/2017
3/1/2018
8/21/2018

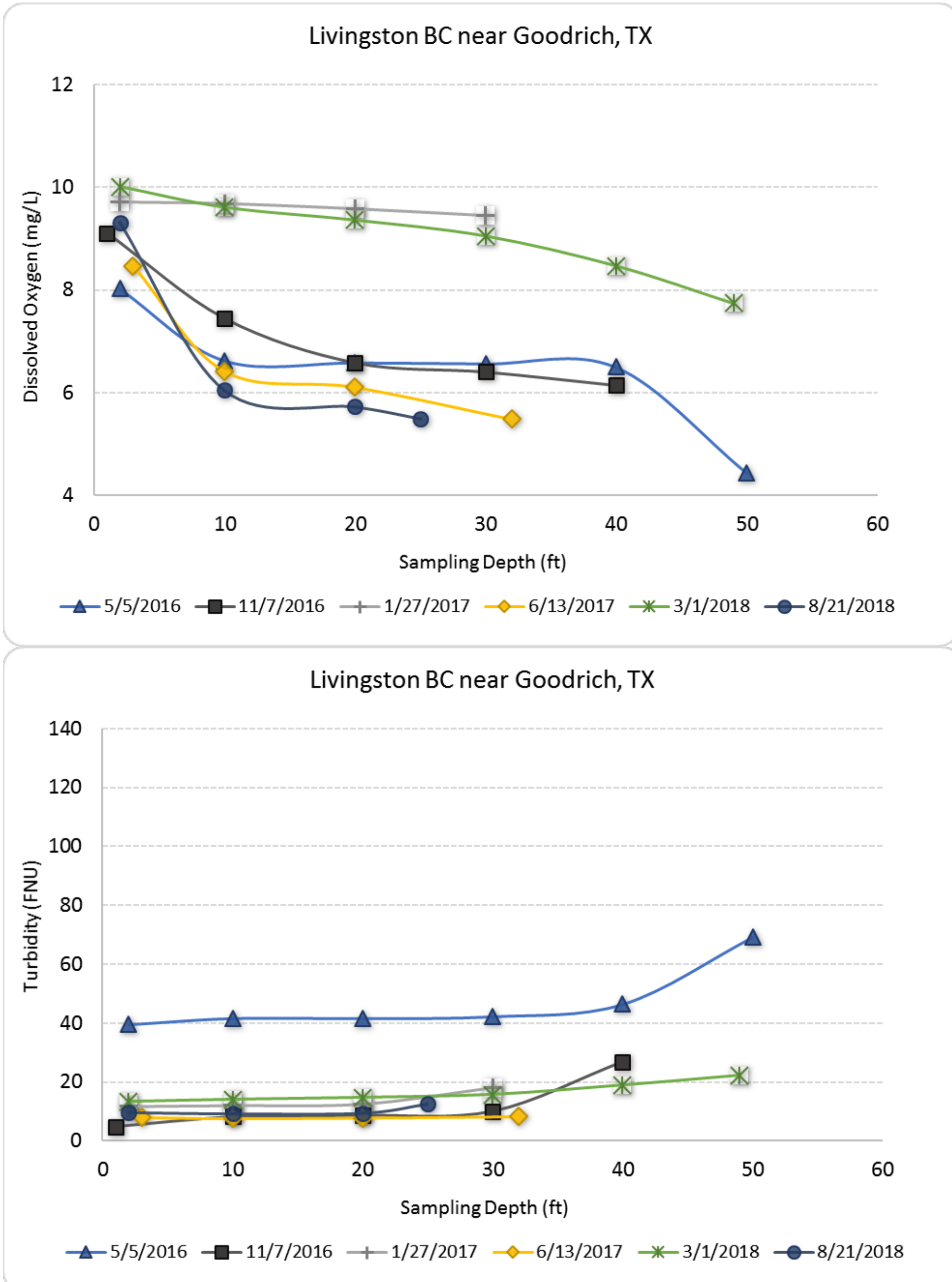


Figure 11 Depth profiles for water temperature, dissolved oxygen, and turbidity at the upper and lower mid sampling sites

Drifter and Discharge

The five drifter deployments resulted in the capture of three distinct discharge events - one low, one normal and three high; however, the flow regime was weather dependent. USGS monitored the USGS Oakwood stream gage upstream of Lake Livingston to monitor discharge to assess events for downstream sampling. The longest duration and distance drifter run occurred from 12-15-15 to 12-21-15 for a total of seven days and 28.8 miles (Figure 12) (see Appendix C for Drifter Paths by Deployment). Over the course of the run, 854 pairs of coordinates were recorded. The drifter closely followed the Trinity River channel in the northern portion of the system, loosely in the middle portion, and began to diverge from the river channel in the southern end of the lake. When the drifter was released on 12-15-15 at 17:38, discharge at the USGS Goodrich gage was 69,500 cf/s. By the end of the run, discharge had fallen to 50,200 cf/s. Discharge was at the lowest point (58,800 cf/s) on 12-21-15 at 15:45 when the drifter stalled in the southern portion of the lake. This run occurred during the highest observed discharge out of all five drifter runs.

Table 1 Drifter deployments profiles and associated discharge at the Trinity River Goodrich station

Run Date	Min Discharge (cf/s)	Max Discharge (cf/s)	Avg Discharge (cf/s)	Duration (days)	Distance (mi)
12/15/2015	58,800	70,300	66,459	5.9	28.8
3/14/2016	47,800	53,900	50,720	4.0	11.1
11/3/2015	42,000	53,300	49,420	3.1	9.9
2/25/2018	27,300	40,400	34,928	2.9	7.7
6/11/2017	14,500	14,700	14,609	1.9	6.8

Figure 12 Flow path for drifter deployment 12/15/2015 to 12/21/2015

Over the course of the two-year sampling period (01/01/2016 to 12/31/2018), the discharge at the Trinity River Goodrich USGS gage station averaged 12,238 cf/s and ranged from a minimum of 941 cf/s to a maximum of 110,000 cf/s (Figure 13). The highest recorded discharge occurred during the Hurricane Harvey event in August of 2017 while the second highest discharge event occurred during the heavily wet period of spring 2016.

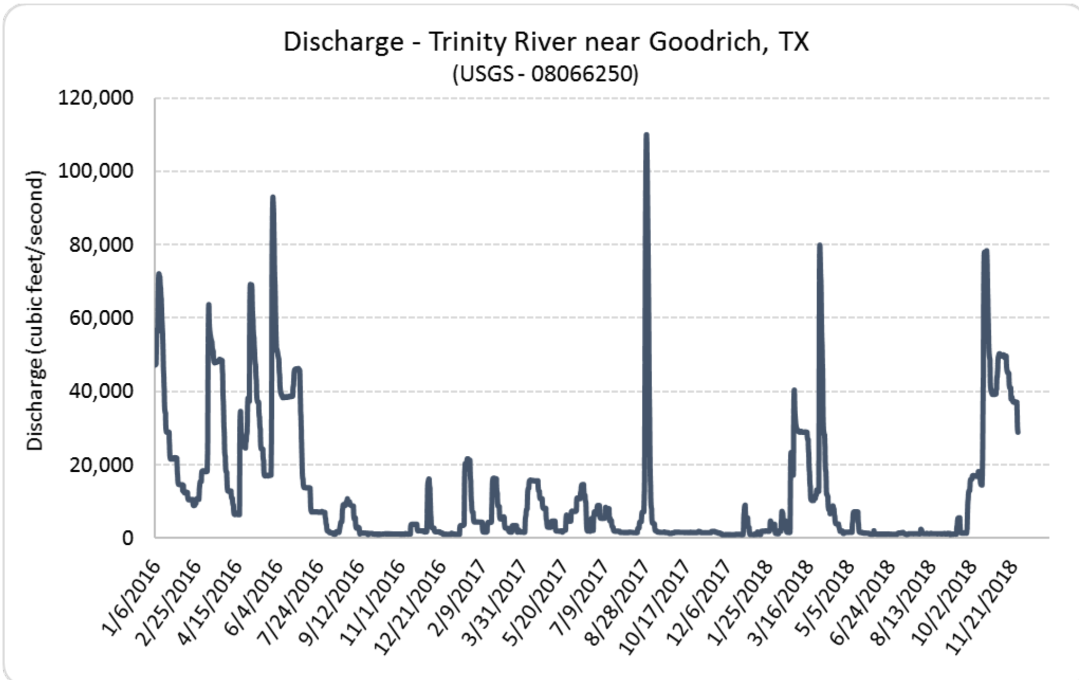


Figure 13 Discharge at the Trinity River Goodrich station during the water quality sampling period

Discussion and Data Summary

USGS field notes from observations while sampling combined with the sampling data collected across a depth gradient (Figure 11) suggested some patterns in the way the lake behaves when it receives event inflow. USGS field observations noted that turbid plumes of water quickly dissipated during deployment of the drifter indicating that suspended sediments began to drop out of suspension. For the June 2017 event, the gradient of dissolved oxygen in the water column was greater at Livingston BC Lower than at Livingston DC Upper (Figure 11). Oxygen depletion at depth was dispersed at Livingston DC Upper, but not at Livingston BC Lower – suggesting the incoming sediment plume stirred the waters at Livingston DC Upper but did not influence Livingston BC Lower to the same extent.

The February 2018 sampling event showed high turbidity at the Trinity River Riverside - North site (see Turbidity in Appendix D Table of graphs for selected constituents sampled in Lake Livingston during Project Period) – USGS field notes indicated a high amount of debris were present. Overall this event, coupled with USGS field observation and the drifter flow path, suggest turbidity plumes were carried along the Western shore of the lake. The previous event (June 2017) produced plumes that tracked near the middle of the lake. The drifter results showed flow patterns that slowed down considerably as it reached Livingston BC Lower. This could possibly be due to the 190 causeway just north of Livingston BC Lower disrupting flow; it also could be to channel differences – Livingston DC Upper is approximately 30 feet in depth and Livingston BC Lower is about 45 feet in depth but Livingston BC Lower is in a narrow channel with 35 foot depths around it. A report entitled "Analysis of Use and Nutrient Data on Selected Reservoirs of the Trinity River Basin "(PBS&J, 2003), suggested that the northern part of Lake

Livingston is turbid with higher concentrations of suspended sediments. This led the authors to conclude that even though results showed high concentrations of nutrients in this area of Lake Livingston, the high concentration of sediments in the water column blocked light and prevented algal growth. The report also stated that north of the 190 causeway, Lake Livingston operated characteristically as a river, while south of the causeway it operated as a reservoir.

Nutrients are important to the plant growth cycles in an ecosystem; however, too many nutrients can lead to excess algal growth. Nitrogen and Phosphorus are usually the most dominant nutrients in the cycle because they are the most likely to be in limited supply. Algal growth can be limited by cold temperatures, lack of nutrients, or lack of light. The form of nutrients available for algal uptake is the dissolved inorganic state - dissolved orthophosphate (PO_4 as P) or nitrate-N (NO_3 as N). Total Nitrogen and Total Phosphorus are often easier and more cost-effective to measure and are typically correlated with levels of algae. An older report (Rawson, USGS, 1979) detailed the studies of nutrient depth profiling in Lake Livingston and concluded that seasonal temperature differences and dissolved oxygen cycles have resulted in significant recycling of many constituents, including nutrients, within the reservoir. The concentrations of nutrients at the bottom depths during summer stagnation were found to be much higher than more shallow depths. A recent report (Zulimar and Lee, USGS 2017) assessed the results of a study analyzing nutrients entering Galveston Bay from the Trinity River. The study indicates nutrient delivery is likely controlled by high flow releases from the Lake Livingston reservoir. In particular, the authors noted that the concentration of total phosphorus and percentage of nitrate measured south of Lake Livingston increased during high flow release events from Lake Livingston.

Drifter

A relationship between the duration and distance of the drifter deployments and discharge at the Goodrich gage station was observed (Table 1). The longest duration and distance traveled by the drifter corresponds to the highest average discharge recorded for the 12/15/2015 run. This pattern holds true for all drifter runs and ends with the 6/11/2017 event that had an average discharge of 14,609 cf/s traveling only 6.8 miles over 1.9 days. As discharge slackens, it is likely that winds become the dominate driving force controlling surface water currents, subsequently influencing the path of the drifter. The lack of flow observed for most of the drifter deployments caused the drifter to move shoreward, resulting in snags and obstacles. Due to complications with obstructions and lack of currents, it is recommended to phase drifter runs into shorter segments during targeted flow events instead of long-range tracking.

Story Map

A story map was created as part of the project effort to communicate the project significance and results in an intuitive and user-friendly interface https://www.harcresearch.org/lakelivingstonapp. The story map contains multi-media such as maps, figures, graphs, pictures, and discussion that convey the project's efforts and results (Figure 14 Lake Livingston Story Map and Figure 15 Lake Livingston Story Map Water Quality Results).

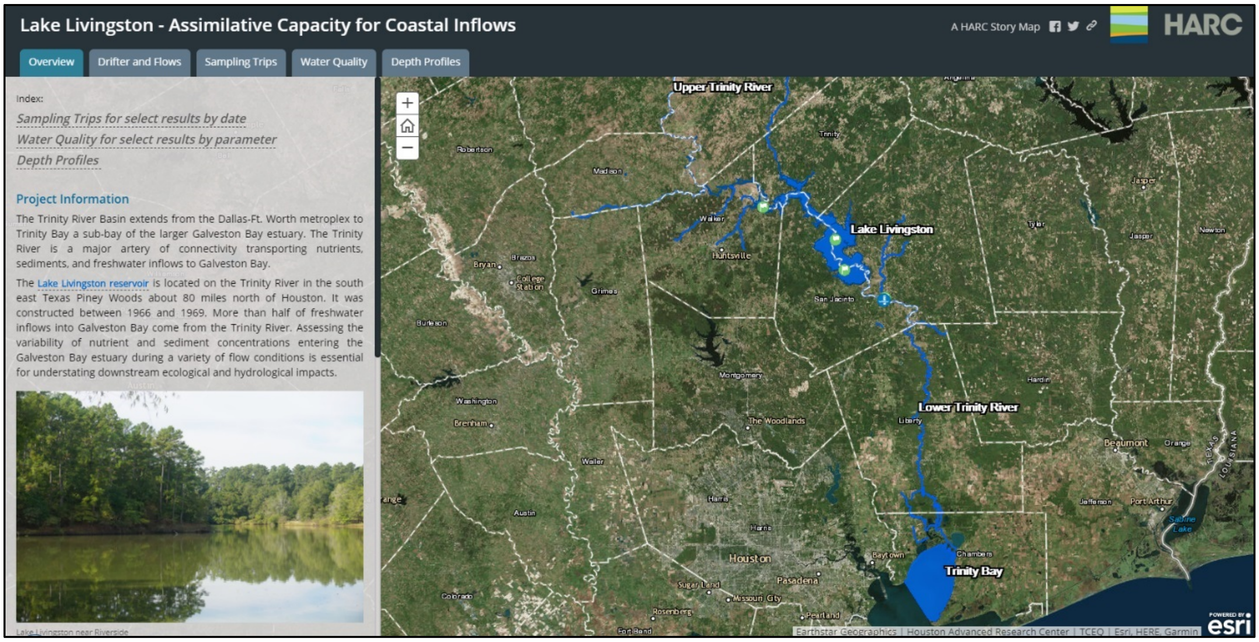


Figure 14 Lake Livingston Story Map

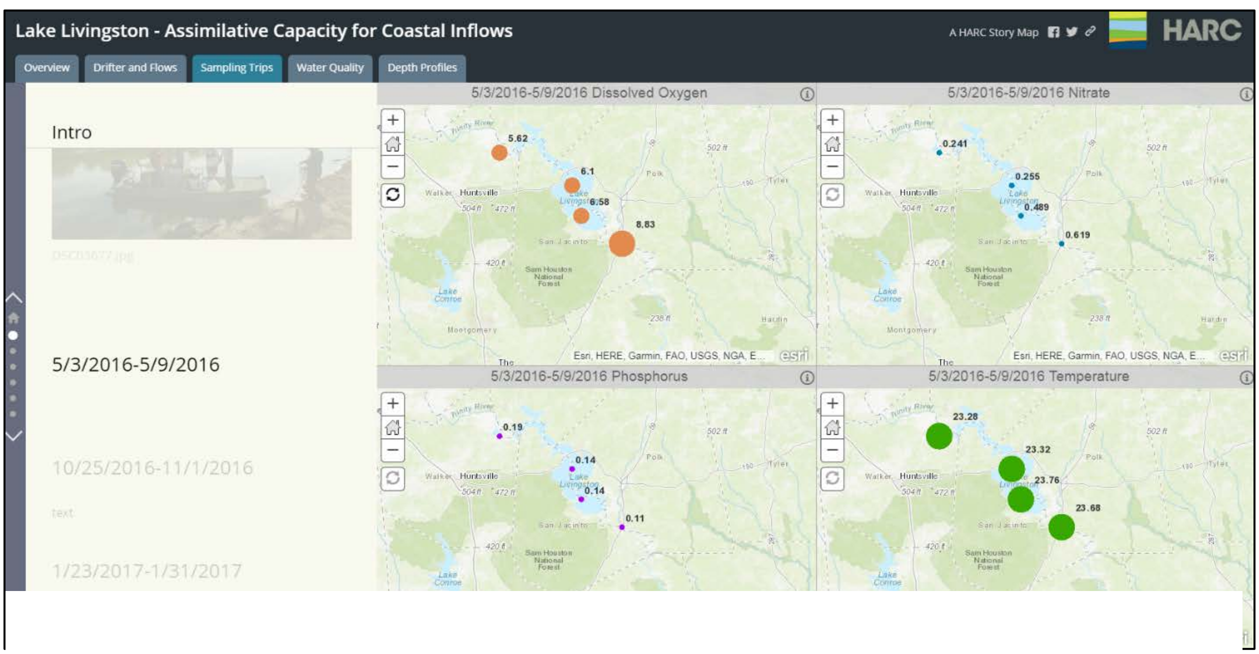


Figure 15 Lake Livingston Story Map Water Quality Results

Summary

Lake Livingston, a multipurpose reservoir, is situated amongst mixed pine and hardwood forests in southeast Texas. In 1969 the reservoir was created when the Lake Livingston Dam was constructed. As a result of impoundment, the Trinity River was divided into two sections; the Upper and Lower Trinity. The goal of the Impacts of Assimilative Capacity of Reservoirs on Coastal Inflows project was to assess assimilative capacity of the Lake Livingston reservoir and related impacts on freshwater inflows to the Galveston Bay estuary. This project sampled inflow from the Upper Trinity to the north and outflow from the Lower Trinity south of the Lake Livingston Dam to quantify nutrient and suspended sediment concentrations, deployed a GPS drifter to track flow patterns and currents, and collected depth profiles to determine degree of stratification.

A Microstar Drifter equipped with Globalstar Simplex telemetry was released on five occasions at the far north end of Lake Livingston. The drifter encountered several problems such as high density of vegetative material and slow drift that resulted in a series of short drifter runs which were restricted to the northern portion of the lake or to the Trinity River channel. The most successful drifter run occurred from 12-15-15 to 12-21-15 for a total of seven days and 28.8 miles. This run had a longer distance and duration because the average discharge at the Trinity River Goodrich gage station exceeded that of the other four drifter deployments. The relationship between average discharge, duration of deployment, and distance covered is an indication that flow in the Trinity River south of the dam is a primary driver of current strength and flow patterns within the Lake Livingston Reservoir. Due to complications with obstructions and lack of current shorter drifter runs, a drifter release regime targeting high flow events within specific lake segments should be utilized instead of attempting long-range tracking for a variety of flow regimes.

In addition, water quality sampling was conducted during six sampling events between May 2016 and August 2018. Samples were collected during base (Nov. 2016 and Aug. 2018 sample events), moderate (Jan. 2017, June 2017 and Feb. 2018 sample events), and high (May 2016 sample event) flow conditions. During the base flow events of November 2016 and August 2018, suspended sediments were low across all four sampling sites. However, the flow events of May 2016, January 2017, June 2017, and February 2018, resulted in a high concentration of suspended sediment at the Trinity River Riverside - North site. The concentration of suspended sediments quickly dissipated at the Livingston DC Upper site and remained low at the Livingston BC Lower and Trinity River Goodrich – South sites. A similar pattern occurred for nutrients; however, high nutrient concentrations at the Trinity River Riverside - North site were less dependent on high flow conditions compared to suspended sediments. For example, phosphorus concentrations were highest at the Trinity River Riverside - North site, quickly declined at the Livingston DC Upper and Livingston BC Lower sites and remained low at the Trinity River Goodrich – South site for all 100% (6/6) of the sampling events. Total nitrogen was highest at the Trinity River Riverside – North site during 67% (4/6) of the sampling events (two were base flow, two were moderate flow). Concentrations of ammonia were more variable across sites and did not follow a similar pattern as phosphorus and total nitrogen. Expect for one sampling event (May 2016) ammonia had the lowest concentration below the Lake Livingston Dam. However, the concentrations of suspended sediment, phosphorus, and total nitrogen was the lowest at the

Trinity River Riverside - North site compared to the other flow event sampling which had lower discharge. In one case during the high flow event total nitrogen was slightly elevated at the Trinity River Goodrich – South compared to the Trinity River Riverside - North site. During high flow events the Upper Trinity River may not be the primary source of suspended sediment and nutrients into Lake Livingston.

Lastly, depth profiles for select water quality parameters were collected at two stations within the reservoir: Livingston DC Upper and Livingston BC Lower. Turbidity depth profiling suggests the northern portion of the lake is more turbid across depth. An indication a higher rate of mixing occurs due to turbulent flow patterns from the Trinity River. At both Livingston DC Upper and Livingston BC Lower turbidity tended to increase near the bottom of the lake. Conversely, dissolved oxygen decreased with depth and exhibited a higher degree of seasonal variation at the Livingston Upper DC site compared to Livingston Lower BC, another sign of increased mixing at the northern end of the lake. Water temperature was less variable than turbidity and dissolved oxygen across depth. The largest decrease of water temperature (2.7 ºC) across depth occurred at the Livingston BC Lower site on 5/05/2016.

Overall, the sampling events do not show elevated nutrient or sediment concentrations leaving the lake during high or base flow conditions. That could be due to a lack of samples collected during high flow events, time between sample collection, or turnover patterns in the lake. This study is limited by a lack of sample size and only one water quality sample collection during a high flow event (May 2016). However, the results suggest that Lake Livingston is a nutrient and sediment sink. Nutrients and sediments are likely deposited from the water column in the main body of the reservoir as mixing decreases allowing stratification to increase from north to south. The majority of suspended sediments, phosphorus, and total nitrogen sample events resulted in a decreasing pattern from north to south with maximum concentrations detected at the Trinity River Riverside - North site. These early results suggest that as nutrients enter Lake Livingston, they are assimilated into the reservoir.

Future research should be conducted to further increase understating of relationships between currents, nutrients, and sediments during high flow conditions within and downstream of Lake Livingston. Additional samples should be collected during high flow events to determine persistence of the described pattern and detect whether or not nutrients and sediments are transported downstream during high flow. Additional samples would allow for statistical analysis to determine significance of results supporting or rejecting the conclusions reached in this project. Future studies could include sampling and analysis of chlorophyll-a to determine availability of nutrients for algal uptake and growth in water; sampling for Fecal Indicator Bacteria (*E. coli*) to determine behavior within and downstream of the reservoir; and, sediment sampling of nutrients to determine potential for sequestration and subsequent re-suspended into the water column.

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Appendices

Appendix A: USGS Data Report

Sample Summary

Date	Time	Site Number	Site Name	Calculated Arrival Date	Calculated Arrival Time	Gage Height (ft)	Res Elevation (ft)	Discharge (ft^3/sec)	Velocity ft/sec	Reservoir Storage (acre-ft)	Sampling Depth (ft)	Depth to Bottom (ft)	Temp, Water (°C)	Sp Cond (µS/cm @ 25)	pH (pH units)	DO (mg/l)	DO % (% sat)	Turbidity (FNU)	Temp, Air (°C)	Air Pressure (mm/Hg)
5/3/2016	11:05	08066000	Trinity Rv nr Riverside, Tx	-	-	135.77	132.03	43590	3.89	1829000	-	41.9	23.28	280	7.40	5.62	66	86.9	19.90	760.4
			190 Bridge	5/4/2016	8:59															
5/5/2016	10:40	304521095075501	Livingston Res Site DC nr Goodrich, TX	5/4/2016	19:36	-	131.51	-	-	1785000	2	29	23.99	280	7.55	6.67	79	53.5	24.97	760.3
						-	131.51	-	-	1785000	10	29	23.34	281	7.50	6.11	72	57.7		
						-	131.51	-	-	1785000	20	29	23.29	282	7.50	6.09	71	57.4		
						-	131.51	-	-	1785000	27	29	23.29	282	7.49	6.06	71	59.0		
5/5/2016	13:20	303935095055401	Livingston Res Site BC nr Goodrich, TX	5/5/2016	1:59	-	131.50	-	-	1784000	2	54	25.28	288	7.93	8.03	98	39.5	21.32	759.1
						-	131.50	-	-	1784000	10	54	23.86	285	7.67	6.63	79	41.6		
						-	131.50	-	-	1784000	20	54	23.80	287	7.67	6.59	78	41.6		
						-	131.50	-	-	1784000	30	54	23.71	290	7.66	6.57	78	42.2		
						-	131.50	-	-	1784000	40	54	23.65	291	7.63	6.50	77	46.4		
						-	131.50	-	-	1784000	50	54	22.59	313	7.51	4.44	51	69.2		
5/9/2016	11:08	08066250	Trinity Rv nr Goodrich, Tx	5/5/2016	7:11	27.70	131.11	36800		1751000	-		23.68	301	7.81	8.83	105	35.0	22.78	755.2
						Early summer event, stratification has been almost completely disturbed. Only BC at 50' is different from other readings.														

Date	Time	Site Number	Site Name	Calculated Arrival Date	Calculated Arrival Time	Gage Height (ft)	Res Elevation (ft)	Discharge (ft^3/sec)	Velocity ft/sec	Reservoir Storage (acre-ft)	Sampling Depth (ft)	Depth to Bottom (ft)	Temp, Water (°C)	Sp Cond (µS/cm @ 25)	pH (pH units)	DO (mg/l)	DO % (% sat)	Turbidity (FNU)	Temp, Air (°C)	Air Pressure (mm/Hg)
10/25/2016	10:12	08066000	Trinity Rv nr Riverside, Tx	-	-	130.80	131.26	E 1000	E 0.5	1764000	-	E 37	24.39	643	7.59	6.10	73	20.3	19.55	764.3
			190 Bridge	11/1/2016	12:35															
10/27/2016	12:16	304521095075501	Livingston Res Site DC nr Goodrich, TX	11/4/2016	23:15	-	131.29	-	-	1766000	1	41	24.48	314	8.53	9.98	119	9.7	22.70	763.6
						-	131.29	-	-	1766000	10	41	24.00	318	8.28	7.76	92	11.9		
						-	131.29	-	-	1766000	15	41	24.00	317	8.22	7.68	92	11.8		
						-	131.29	-	-	1766000	20	41	23.85	330	8.20	7.47	88	14.4		
						-	131.29	-	-	1766000	30	41	23.68	351	8.12	6.77	80	42.5		
10/27/2016	14:17	303935095055401	Livingston Res Site BC nr Goodrich, TX	11/7/2016	0:56	-	131.28	-	-	1766000	1	E 50	26.55	312	8.34	9.11	113	4.9	23.56	762.5
						-	131.28	-	-	1766000	10	E 50	24.13	313	8.14	7.45	88	8.2		
						-	131.28	-	-	1766000	20	E 50	23.97	314	7.98	6.59	78	8.7		
						-	131.28	-	-	1766000	30	E 50	23.94	314	7.97	6.41	76	10.1		
						-	131.28	-	-	1766000	40	E 50	23.84	316	7.96	6.15	73	26.9		
11/1/2016	12:15	08066250	Trinity Rv nr Goodrich, Tx	11/8/2016	17:25	4.95	131.17	1220		1756000	-		24.05	320	7.91	8.75	104	11.2	24.08	761.6
						Fall sample collected under base flow conditions. Only slight stratification evident. Both sites show elevated turbidity near the bed.														

Date	Time	Site Number	Site Name	Calculated Arrival Date	Calculated Arrival Time	Gage Height (ft)	Res Elevation (ft)	Discharge (ft^3/sec)	Velocity ft/sec	Reservoir Storage (acre-ft)	Sampling Depth (ft)	Depth to Bottom (ft)	Temp, Water (°C)	Sp Cond (µS/cm @ 25	pH (pH units)	DO (mg/l)	DO % (% sat)	Turbidity (FNU)	Temp, Air (°C)	Air Pressure (mm/Hg)
1/23/2017	12:15	08066000	Trinity Rv nr Riverside, Tx	-	-	132.39	132.05	17514	1.71	1831000	-	39	13.94	282	7.68	7.53	73	237.6	10.82	756.8
			190 Bridge	1/25/2017	14:04															
1/26/2017	10:30	304521095075501	Livingston Res Site DC nr Goodrich, TX	1/26/2017	14:14	-	131.49	-	-	1783000	2	24	14.40	362	7.73	8.76	85	112.0	9.85	766.3
						-	131.49	-	-	1783000	10	24	14.40	361	7.74	8.74	85	120.0		
						-	131.49	-	-	1783000	20	24	14.38	361	7.76	8.76	85	117.1		
1/26/2017	12:30	303935095055401	Livingston Res Site BC nr Goodrich, TX	1/27/2017	4:46	-	131.48	-	-	1782000	2	36	14.34	397	7.97	9.71	94	11.8	10.14	766.3
						-	131.48	-	-	1782000	10	36	14.33	398	7.96	9.68	94	12.1		
						-	131.48	-	-	1782000	20	36	14.36	398	7.96	9.58	93	12.6		
						-	131.48	-	-	1782000	30	36	14.30	397	7.95	9.45	92	18.0		
						-														
1/31/2017	10:12	08066250	Trinity Rv nr Goodrich, Tx	1/27/2017	16:36	8.98	131.38	4460		1774000	-		13.46	370	7.73	10.56	101	10.0	13.77	763.4
						Winter sample, moderate volume. Little to no stratification evident. Inflow water temp below lake temps. Turbidities at BC dramatically lower than those observed at DC.														

Date	Time	Site Number	Site Name	Calculated Arrival Date	Calculated Arrival Time	Gage Height (ft)	Res Elevation (ft)	Discharge (ft^3/sec)	Velocity ft/sec	Reservoir Storage (acre-ft)	Sampling Depth (ft)	Depth to Bottom (ft)	Temp, Water (°C)	Sp Cond (µS/cm @ 25	pH (pH units)	DO (mg/l)	DO % (% sat)	Turbidity (FNU)	Temp, Air (°C)	Air Pressure (mm/Hg)
6/9/2017	14:10	08066000	Trinity Rv nr Riverside, Tx	-	-	132.00	131.68	15954	1.5	1799000	-	34.3	26.24	324	7.54	4.40	55	296.0	25.30	757.7
6/11/2017	14:00		190 Bridge	6/11/2017	22:57															
6/15/2017	10:50	304521095075501	Livingston Res Site DC nr Goodrich, TX	6/13/2017	2:31	-	131.28	-	-	1766000	3	33	28.73	367	8.80	9.54	124	9.6	32.45	758.5
						-	131.28	-	-	1766000	10	33	28.51	369	8.67	8.22	106	11.1		
						-	131.28	-	-	1766000	20	33	28.44	370	8.58	7.40	96	14.7		
						-	131.28	-	-	1766000	30	33	28.45	370	8.58	7.73	100	14.4		
6/15/2017	12:15	303935095055401	Livingston Res Site BC nr Goodrich, TX	6/13/2017	19:04	-	131.27	-	-	1765000	3	33	28.12	370	8.56	8.47	109	8.0	33.06	758.6
						-	131.27	-	-	1765000	10	33	27.75	372	8.29	6.42	82	7.6		
						-	131.27	-	-	1765000	20	33	27.67	372	8.23	6.11	78	7.8		
						-	131.27	-	-	1765000	32	33	27.55	373	8.17	5.49	70	8.3		
6/20/2017	13:05	08066250	Trinity Rv nr Goodrich, Tx	6/14/2017	8:34	5.60	131.28	1548		1766000	-		28.44	375	8.09	8.17	105	8.9	29.48	759.2
						Summer sample, moderate volume. Stratification appears disturbed at DC, while BC retains a light to moderate stratification profile, and lower turbidities.														

Date	Time	Site Number	Site Name	Calculated Arrival Date	Calculated Arrival Time	Gage Height (ft)	Res Elevation (ft)	Discharge (ft^3/sec)	Velocity ft/sec	Reservoir Storage (acre-ft)	Sampling Depth (ft)	Depth to Bottom (ft)	Temp, Water (°C)	Sp Cond (µS/cm @ 25)	pH (pH units)	DO (mg/l)	DO % (% sat)	Turbidity (FNU)	Temp, Air (°C)	Air Pressure (mm/Hg)
2/25/2018	11:50	08066000	Trinity Rv nr Riverside, Tx	-	-	132.20	131.72	17730	1.76	1803000	-	34.5	14.04	499	7.64	6.41	62	470.0	11.66	758.3
			190 Bridge	2/27/2018	12:14															
2/28/2018	11:36	304521095075501	Livingston Res Site DC nr Goodrich, TX	2/28/2018	11:43	-	131.96	-	-	1823000	2	43	15.63	374	8.21	10.29	104	21.9	19.21	759.7
						-	131.96	-	-	1823000	10	43	15.25	374	8.09	9.74	97	39.2		
						-	131.96	-	-	1823000	20	43	15.21	375	8.04	9.48	95	24.3		
						-	131.96	-	-	1823000	30	43	15.22	376	7.96	9.02	90	27.5		
						-	131.96	-	-	1823000	40	43	15.21	389	7.80	8.61	86	31.2		
3/1/2018	11:10	303935095055401	Livingston Res Site BC nr Goodrich, TX	3/1/2018	1:50	-	131.85	-	-	1814000	2	55	15.75	355	7.95	10.01	101	13.3	16.37	759.2
						-	131.85	-	-	1814000	10	55	15.07	356	7.82	9.61	96	14.0		
						-	131.85	-	-	1814000	20	55	15.04	356	7.79	9.36	93	14.7		
						-	131.85	-	-	1814000	30	55	14.91	357	7.70	9.05	90	15.7		
						-	131.85	-	-	1814000	40	55	14.48	358	7.62	8.47	83	18.9		
						-	131.85	-	-	1814000	49	55	13.92	362	7.50	7.74	75	22.2		
3/6/2018	12:47	08066250	Trinity Rv nr Goodrich, Tx	3/1/2018	13:20	23.92	131.33	29100		1770000	-		16.35	358	8.01	10.99	112	16.9	15.31	762.0
						Winter sample, moderate volume. Inflow water temp below lake temps. Turbidities at BC dramatically lower than those observed at DC.														

Date	Time	Site Number	Site Name	Calculated Arrival Date	Calculated Arrival Time	Gage Height (ft)	Res Elevation (ft)	Discharge (ft^3/sec)	Velocity ft/sec	Reservoir Storage (acre-ft)	Sampling Depth (ft)	Depth to Bottom (ft)	Temp, Water (°C)	Sp Cond (µS/cm @ 25)	pH (pH units)	DO (mg/l)	DO % (% sat)	Turbidity (FNU)	Temp, Air (°C)	Air Pressure (mm/Hg)
8/8/2018	11:00	08066000	Trinity Rv nr Riverside, Tx	-	-	130.25	130.70	E 1000	E 0.5	1717000	-	E 37	31.60	829	8.23	7.13	97	5.5	30.28	762.7
			190 Bridge	8/15/2018	13:23															
8/14/2018	12:30	304521095075501	Livingston Res Site DC nr Goodrich, TX	8/19/2018	0:03	-	130.57	-	-	1707000	2	26	30.47	356	8.72	9.24	123	6.2	26.88	761.5
						-	130.57	-	-	1707000	10	26	30.39	355	8.73	8.91	118	7.0		
						-	130.57	-	-	1707000	20	26	29.51	365	8.40	6.23	82	10.5		
						-	130.57	-	-	1707000	23	26	29.43	369	8.30	5.75	75	11.9		
8/14/2018	14:30	303935095055401	Livingston Res Site BC nr Goodrich, TX	8/21/2018	1:44	-	130.58	-	-	1708000	2	27	30.41	363	8.70	9.31	124	9.6	31.64	763.1
						-	130.58	-	-	1708000	10	27	29.57	367	8.25	6.05	79	9.2		
						-	130.58	-	-	1708000	20	27	29.39	365	8.09	5.73	75	9.4		
						-	130.58	-	-	1708000	25	27	29.37	366	8.12	5.50	72	12.5		
8/21/2018	11:00	08066250	Trinity Rv nr Goodrich, Tx	8/22/2018	18:13	4.80	130.90	1230		1734000	-		30.73	357	7.93	7.96	106	11.6	29.12	764.5
						Summer sample, baseflow conditions. Strong stratification.														

Sample Data

Date	Time	Site Number	Site Name	Gage Height (ft)	Res Elevation (ft)	Discharge (ft^3/sec)	Velocity ft/sec	Reservoir Storage (acre-ft)	Depth to Bottom (ft)	Temp, Water (°C)	Sp Cond µS/cm @ 25	pH (pH units)	DO (mg/l)	DO % (% sat)	Turbidity (FNU)	Temp, Air (°C)	Air Pressure (mm/Hg)
5/3/2016	11:05	08066000	Trinity Rv nr Riverside, Tx	135.77	132.03	43590	3.89	1829000	41.9	23.3	280	7.4	5.6	66	86.9	19.9	760
5/5/2016	10:40	304521095075501	Livingston Res Site DC nr Goodrich, TX	-	131.51	-	-	1785000	29	23.3	282	7.5	6.1	72	57.6	25.0	760
5/5/2016	13:20	303935095055401	Livingston Res Site BC nr Goodrich, TX	-	131.50	-	-	1784000	54	23.8	289	7.7	6.6	78	41.9	21.3	759
5/9/2016	11:08	08066250	Trinity Rv nr Goodrich, Tx	27.70	131.11	36800	-	1751000	E 33	23.7	301	7.8	8.8	105	35.0	22.8	755

Date	Time	Site Number	Site Name	Gage Height (ft)	Res Elevation (ft)	Discharge (ft^3/sec)	Velocity ft/sec	Reservoir Storage (acre-ft)	Depth to Bottom (ft)	Temp, Water (°C)	Sp Cond µS/cm @ 25	pH (pH units)	DO (mg/l)	DO % (% sat)	Turbidity (FNU)	Temp, Air (°C)	Air Pressure (mm/Hg)
10/25/2016	10:12	08066000	Trinity Rv nr Riverside, Tx	130.80	131.26	E 1000	E 0.5	1764000	E 37	24.4	643	7.6	6.1	73	20.3	19.6	764
10/27/2016	12:16	304521095075501	Livingston Res Site DC nr Goodrich, TX	-	131.29	-	-	1766000	41	24.0	318	8.2	7.7	91	11.9	22.7	764
10/27/2016	14:17	303935095055401	Livingston Res Site BC nr Goodrich, TX	-	131.28	-	-	1766000	E 50	24.0	314	8.0	6.6	78	8.7	23.6	763
11/1/2016	12:15	08066250	Trinity Rv nr Goodrich, Tx	4.95	131.17	1220	-	1756000	E 10	24.1	320	7.9	8.8	104	11.2	24.1	762

Date	Time	Site Number	Site Name	Gage Height (ft)	Res Elevation (ft)	Discharge (ft^3/sec)	Velocity ft/sec	Reservoir Storage (acre-ft)	Depth to Bottom (ft)	Temp, Water (°C)	Sp Cond µS/cm @ 25	pH (pH units)	DO (mg/l)	DO % (% sat)	Turbidity (FNU)	Temp, Air (°C)	Air Pressure (mm/Hg)
1/23/2017	12:15	08066000	Trinity Rv nr Riverside, Tx	132.39	132.05	17514	1.71	1831000	39	13.9	282	7.7	7.5	73	237.6	10.8	757
1/26/2017	10:30	304521095075501	Livingston Res Site DC nr Goodrich, TX	-	131.49	-	-	1783000	24	14.4	361	7.7	8.8	85	117.1	9.9	766
1/26/2017	12:30	303935095055401	Livingston Res Site BC nr Goodrich, TX	-	131.48	-	-	1782000	36	14.3	398	8.0	9.6	93	12.4	10.1	766
1/31/2017	10:12	08066250	Trinity Rv nr Goodrich, Tx	8.98	131.38	4460	-	1774000	E 14	13.5	370	7.7	10.6	101	10.0	13.8	763

Date	Time	Site Number	Site Name	Gage Height (ft)	Res Elevation (ft)	Discharge (ft^3/sec)	Velocity ft/sec	Reservoir Storage (acre-ft)	Depth to Bottom (ft)	Temp, Water (°C)	Sp Cond µS/cm @ 25	pH (pH units)	DO (mg/l)	DO % (% sat)	Turbidity (FNU)	Temp, Air (°C)	Air Pressure (mm/Hg)
6/9/2017	14:10	08066000	Trinity Rv nr Riverside, Tx	132.00	131.68	15954	1.5	1799000	34.3	26.2	324	7.5	4.4	55	296.0	25.3	758
6/15/2017	10:50	304521095075501	Livingston Res Site DC nr Goodrich, TX	-	131.28	-	-	1766000	33	28.5	370	8.6	8.0	103	12.8	32.5	759
6/15/2017	12:15	303935095055401	Livingston Res Site BC nr Goodrich, TX	-	131.27	-	-	1765000	33	27.7	372	8.3	6.3	80	7.9	33.1	759
6/20/2017	13:05	08066250	Trinity Rv nr Goodrich, Tx	5.60	131.28	1548	-	1766000	E 11	28.4	375	8.1	8.2	105	8.9	29.5	759

Date	Time	Site Number	Site Name	Gage Height (ft)	Res Elevation (ft)	Discharge (ft^3/sec)	Velocity ft/sec	Reservoir Storage (acre-ft)	Depth to Bottom (ft)	Temp, Water (°C)	Sp Cond µS/cm @ 25	pH (pH units)	DO (mg/l)	DO % (% sat)	Turbidity (FNU)	Temp, Air (°C)	Air Pressure (mm/Hg)
2/25/2018	11:50	08066000	Trinity Rv nr Riverside, Tx	132.20	131.72	17730	1.76	1803000	39	14.0	499	7.6	6.4	62	470.0	11.7	758
2/28/2018	11:36	304521095075501	Livingston Res Site DC nr Goodrich, TX	-	131.96	-	-	1823000	43	15.2	375	8.0	9.5	95	27.5	19.2	760
3/1/2018	11:10	303935095055401	Livingston Res Site BC nr Goodrich, TX	-	131.85	-	-	1814000	55	15.0	357	7.8	9.2	91	15.2	16.4	759
3/6/2018	12:47	08066250	Trinity Rv nr Goodrich, Tx	23.92	131.33	29100	-	1770000	29	16.4	358	8.0	11.0	112	16.9	15.3	762

Date	Time	Site Number	Site Name	Gage Height (ft)	Res Elevation (ft)	Discharge (ft^3/sec)	Velocity ft/sec	Reservoir Storage (acre-ft)	Depth to Bottom (ft)	Temp, Water (°C)	Sp Cond µS/cm @ 25	pH (pH units)	DO (mg/l)	DO % (% sat)	Turbidity (FNU)	Temp, Air (°C)	Air Pressure (mm/Hg)
8/8/2018	11:00	08066000	Trinity Rv nr Riverside, Tx	130.25	130.70	E 1000	E 0.5	1717000	E 37	31.6	829	8.2	7.1	97	5.5	30.3	763
8/14/2018	12:30	304521095075501	Livingston Res Site DC nr Goodrich, TX	-	130.57	-	-	1707000	26	31.1	356	8.7	8.6	114	6.9	26.9	762
8/14/2018	14:30	303935095055401	Livingston Res Site BC nr Goodrich, TX	-	130.58	-	-	1708000	27	29.5	365	8.2	5.9	78	9.5	31.6	763
8/21/2018	11:00	08066250	Trinity Rv nr Goodrich, Tx	4.80	130.90	1230	-	1734000	E 10	30.7	357	7.9	8.0	106	11.6	29.1	765

Date	Time	Site Number	Site Name	P50624 Absorbance, 254 nm units/cm	P61726 Absorbance at 280 nm units/cm	P00694 Total carbon, ss mg/l	P71846 Ammonia, wf mg/l NH4	P00608 Ammonia, wf mg/l as N	P00631 NO3+NO2, wf mg/l as N	P71851 Nitrate, wf mg/l asNO3	P00618 Nitrate, wf mg/l as N	P71856 Nitrite, wf mg/l asNO3	P00613 Nitrite, wf mg/l as N	P00607 Organic nitrogen, wf mg/l	P00605 Organic nitrogen, wu mg/l	P00671 Orthophosphate, wf mg/l as P	P00660 Orthophosphate, wf mg/l asPO4	P49570 Particulate-N, suspended mg/l	P00665 Phosphorus, wu mg/l as P	P62854 Total nitrogen, wf mg/l	P62855 Total nitrogen, wu mg/l	P00600 Total nitrogen, wu mg/l	P00680 Organic carbon, wu mg/l	P00681 Organic carbon, wf mg/l	P70331 Sus sed <0.0625mm,sd %	P80154 Suspnd sedmnt conc mg/l
5/3/2016	11:05	08066000	Trinity Rv nr Riverside, Tx	0.243	0.184		0.058	0.04	0.248	1.07	0.241	0.022	0.007		0.71	0.040	0.122		0.19		1.01		9.8	6.39	56	249
5/5/2016	10:40	304521095075501	Livingston Res Site DC nr Goodrich, TX	0.240	0.181	1.65	0.043	0.03	0.266	1.13	0.255	0.034	0.010	0.41	0.64	0.041	0.126	0.208	0.14	0.71	0.94	0.92	8.6	7.36	100	58
5/5/2016	13:20	303935095055401	Livingston Res Site BC nr Goodrich, TX	0.186	0.138	2.03	0.021	0.02	0.500	2.16	0.489	0.039	0.012	0.41	0.57	0.054	0.165	0.284	0.14	0.92	1.09	1.2	7.5	7.10	100	49
5/9/2016	11:08	08066250	Trinity Rv nr Goodrich, Tx	0.169	0.125	1.31	0.033	0.03	0.621	2.74	0.619	0.006	0.002	0.42	0.46	0.057	0.173	0.217	0.11	1.06	1.11	1.3	6.7	6.21	83	48

Date	Time	Site Number	Site Name	Absorbance, 254 nm units/cm	Absorbance at 280 nm units/cm	Total carbon, ss mg/l	Ammonia, wf mg/l NH4	Ammonia, wf mg/l as N	NO3+NO2, wf mg/l as N	Nitrate, wf mg/l asNO3	Nitrate, wf mg/l as N	Nitrite, wf mg/l asNO3	Nitrite, wf mg/l as N	Organic nitrogen, wf mg/l	Organic nitrogen, wu mg/l	Orthophosphate, wf mg/l as P	Orthophosphate, wf mg/l asPO4	Particulate-N, suspended mg/l	Phosphorus, wu mg/l as P	Total nitrogen, wf mg/l	Total nitrogen, wu mg/l	Total nitrogen, wu mg/l	Organic carbon, wu mg/l	Organic carbon, wf mg/l	Sus sed <0.0625mm,sd %	Suspnd sedmnt conc mg/l
10/25/2016	10:12	08066000	Trinity Rv nr Riverside, Tx	0.101	0.072	1.40	0.027	0.02	6.37	27.9	6.30	0.228	0.070	0.37	0.82	0.382	1.17	0.215	0.43	6.77	7.22	7.0	7.1	5.42	100	23
10/27/2016	12:16	304521095075501	Livingston Res Site DC nr Goodrich, TX	0.121	0.086	2.51	0.039	0.03	0.182	0.732	0.165	0.055	0.017	0.37	0.62	0.028	0.086	0.234	0.08	0.58	0.84	0.81	6.9	7.32	98	17
10/27/2016	14:17	303935095055401	Livingston Res Site BC nr Goodrich, TX	0.118	0.083		0.047	0.04	0.055	0.204	0.046	0.030	0.009	0.34	0.57	0.031	0.095		0.08	0.43	0.66		6.8	6.08	83	23
11/1/2016	12:15	08066250	Trinity Rv nr Goodrich, Tx	0.113	0.080	1.44	< 0.013	< 0.01	0.101	0.430	0.097	0.011	0.003	< 0.36	< 0.40	0.035	0.108	0.162	0.07	0.46	0.50	0.62	5.9	5.93	95	21

Date	Time	Site Number	Site Name	Absorbance, 254 nm units/cm	Absorbance at 280 nm units/cm	Total carbon, ss mg/l	Ammonia, wf mg/l NH4	Ammonia, wf mg/l as N	NO3+NO2, wf mg/l as N	Nitrate, wf mg/l asNO3	Nitrate, wf mg/l as N	Nitrite, wf mg/l asNO3	Nitrite, wf mg/l as N	Organic nitrogen, wf mg/l	Organic nitrogen, wu mg/l	Orthophosphate, wf mg/l as P	Orthophosphate, wf mg/l asPO4	Particulate-N, suspended mg/l	Phosphorus, wu mg/l as P	Total nitrogen, wf mg/l	Total nitrogen, wu mg/l	Total nitrogen, wu mg/l	Organic carbon, wu mg/l	Organic carbon, wf mg/l	Sus sed <0.0625mm,sd %	Suspnd sedmnt conc mg/l
1/23/2017	12:15	08066000	Trinity Rv nr Riverside, Tx	0.248	0.189	11.80	0.111	0.09	0.664	2.83	0.639	0.084	0.025	0.39	1.0	0.091	0.280	0.772	0.67	1.14	1.76	1.9	16.0	7.98	99	649
1/26/2017	10:30	304521095075501	Livingston Res Site DC nr Goodrich, TX	0.231	0.175		0.079	0.06	1.48	6.37	1.44	0.127	0.039	0.37	0.65	0.122	0.375		0.28	1.91	2.19		10.0	6.28	97	128
1/26/2017	12:30	303935095055401	Livingston Res Site BC nr Goodrich, TX	0.125	0.090	1.23	0.056	0.04	1.08	4.69	1.06	0.073	0.022	0.33	0.45	0.078	0.238	0.169	0.13	1.46	1.58	1.6	7.0	4.92	98	14
1/31/2017	10:12	08066250	Trinity Rv nr Goodrich, Tx	0.115	0.082	1.39	< 0.013	< 0.01	0.666	2.84	0.642	0.077	0.023	< 0.31	< 0.40	0.040	0.123	0.127	0.08	0.98	1.07	1.1	6.5	4.40	93	13

Date	Time	Site Number	Site Name	Absorbance, 254 nm units/cm	Absorbance at 280 nm units/cm	Total carbon, ss mg/l	Ammonia, wf mg/l NH4	Ammonia, wf mg/l as N	NO3+NO2, wf mg/l as N	Nitrate, wf mg/l asNO3	Nitrate, wf mg/l as N	Nitrite, wf mg/l asNO3	Nitrite, wf mg/l as N	Organic nitrogen, wf mg/l	Organic nitrogen, wu mg/l	Orthophosphate, wf mg/l as P	Orthophosphate, wf mg/l asPO4	Particulate-N, suspended mg/l	Phosphorus, wu mg/l as P	Total nitrogen, wf mg/l	Total nitrogen, wu mg/l	Total nitrogen, wu mg/l	Organic carbon, wu mg/l	Organic carbon, wf mg/l	Sus sed <0.0625mm,sd %	Suspnd sedmnt conc mg/l
6/9/2017	14:10	08066000	Trinity Rv nr Riverside, Tx	0.132	0.097	17.20	< 0.013	< 0.01	1.01	4.46	1.01	< 0.003	< 0.001	< 0.33	< 0.58	0.087	0.265	0.786	0.77	1.34	1.58	2.1	12.6	4.91	100	815
6/15/2017	10:50	304521095075501	Livingston Res Site DC nr Goodrich, TX	0.152	0.109	3.14	< 0.013	< 0.01	< 0.040	< 0.164	< 0.037	0.009	0.003	< 0.38	< 0.81	0.028	0.085	0.429	0.12	0.38	0.81	0.81	8.3	6.42	64	20
6/15/2017	12:15	303935095055401	Livingston Res Site BC nr Goodrich, TX	0.144	0.102	1.85	< 0.013	< 0.01	0.069	0.221	0.050	0.062	0.019	< 0.35	< 0.69	0.039	0.119	0.239	0.12	0.41	0.76	0.65	7.5	6.36	83	8
6/20/2017	13:05	08066250	Trinity Rv nr Goodrich, Tx	0.132	0.093	1.68	< 0.013	< 0.01	0.084	0.347	0.078	0.017	0.005	< 0.36	< 0.57	0.049	0.151	0.241	0.10	0.44	0.65	0.68	6.5	6.08	71	13

Date	Time	Site Number	Site Name	Absorbance, 254 nm units/cm	Absorbance at 280 nm units/cm	Total carbon, ss mg/l	Ammonia, wf mg/l NH4	Ammonia, wf mg/l as N	NO3+NO2, wf mg/l as N	Nitrate, wf mg/l asNO3	Nitrate, wf mg/l as N	Nitrite, wf mg/l asNO3	Nitrite, wf mg/l as N	Organic nitrogen, wf mg/l	Organic nitrogen, wu mg/l	Orthophosphate, wf mg/l as P	Orthophosphate, wf mg/l asPO4	Particulate-N, suspended mg/l	Phosphorus, wu mg/l as P	Total nitrogen, wf mg/l	Total nitrogen, wu mg/l	Total nitrogen, wu mg/l	Organic carbon, wu mg/l	Organic carbon, wf mg/l	Sus sed <0.0625mm,sd %	Suspnd sedmnt conc mg/l
2/25/2018	11:50	08066000	Trinity Rv nr Riverside, Tx	0.238	0.181	19.80	0.061	0.05	4.32	18.8	4.25	0.213	0.065	0.52	1.7	0.225	0.689	1.02	1.53	4.88	6.04	5.9	8.4	6.80	100	1330
2/28/2018	11:36	304521095075501	Livingston Res Site DC nr Goodrich, TX	0.148	0.106	1.57	0.039	0.03	0.933	4.06	0.918	0.048	0.015	0.36	0.56	0.016	0.142	0.206	0.10	1.32	1.52	1.5	5.8	5.13	99	25
3/1/2018	11:10	303935095055401	Livingston Res Site BC nr Goodrich, TX	0.130	0.092	0.96	0.102	0.08	0.662	2.88	0.650	0.040	0.012	0.29	0.42	0.360	0.111	0.070	0.07	1.03	1.16	1.1	5.4	4.83	100	12
3/6/2018	12:47	08066250	Trinity Rv nr Goodrich, Tx	0.133	0.094	2.04	< 0.013	< 0.01	0.655	2.84	0.641	0.047	0.014	< 0.31	< 0.54	0.025	0.076	0.217	0.08	0.96	1.20	1.2	5.6	4.97	37	54

Date	Time	Site Number	Site Name	Absorbance, 254 nm units/cm	Absorbance at 280 nm units/cm	Total carbon, ss mg/l	Ammonia, wf mg/l NH4	Ammonia, wf mg/l as N	NO3+NO2, wf mg/l as N	Nitrate, wf mg/l asNO3	Nitrate, wf mg/l as N	Nitrite, wf mg/l asNO3	Nitrite, wf mg/l as N	Organic nitrogen, wf mg/l	Organic nitrogen, wu mg/l	Orthophosphate, wf mg/l as P	Orthophosphate, wf mg/l asPO4	Particulate-N, suspended mg/l	Phosphorus, wu mg/l as P	Total nitrogen, wf mg/l	Total nitrogen, wu mg/l	Total nitrogen, wu mg/l	Organic carbon, wu mg/l	Organic carbon, wf mg/l	Sus sed <0.0625mm,sd %	Suspnd sedmnt conc mg/l
8/8/2018	11:00	08066000	Trinity Rv nr Riverside, Tx	0.114	0.081	3.74	< 0.013	< 0.01	4.02	13.70	3.090	3.05	0.929	< 0.96	< 1.2	0.184	0.565	0.618	0.30	4.98	5.24	5.6	7.0	5.89	100	10
8/14/2018	12:30	304521095075501	Livingston Res Site DC nr Goodrich, TX	0.135	0.095		< 0.013	< 0.01	< 0.040	< 0.177	< 0.040	< 0.003	< 0.001	< 0.40	< 0.65	0.079	0.241		0.13	0.40	0.65		8.1	5.28	100	8
8/14/2018	14:30	303935095055401	Livingston Res Site BC nr Goodrich, TX	0.134	0.093	-	< 0.013	< 0.01	< 0.040	< 0.177	< 0.040	< 0.003	< 0.001	< 0.37	< 0.64	0.097	0.298	-	0.15	0.37	0.64	-	7.7	5.37	100	11
8/21/2018	11:00	08066250	Trinity Rv nr Goodrich, Tx	0.137	0.099	1.57	< 0.013	< 0.01	< 0.040	< 0.157	< 0.035	0.015	0.005	< 0.50	< 0.65	0.080	0.244	0.306	0.13	0.50	0.65	0.81	6.9	5.13	98	19

Appendix B: USGS Data Dictionary

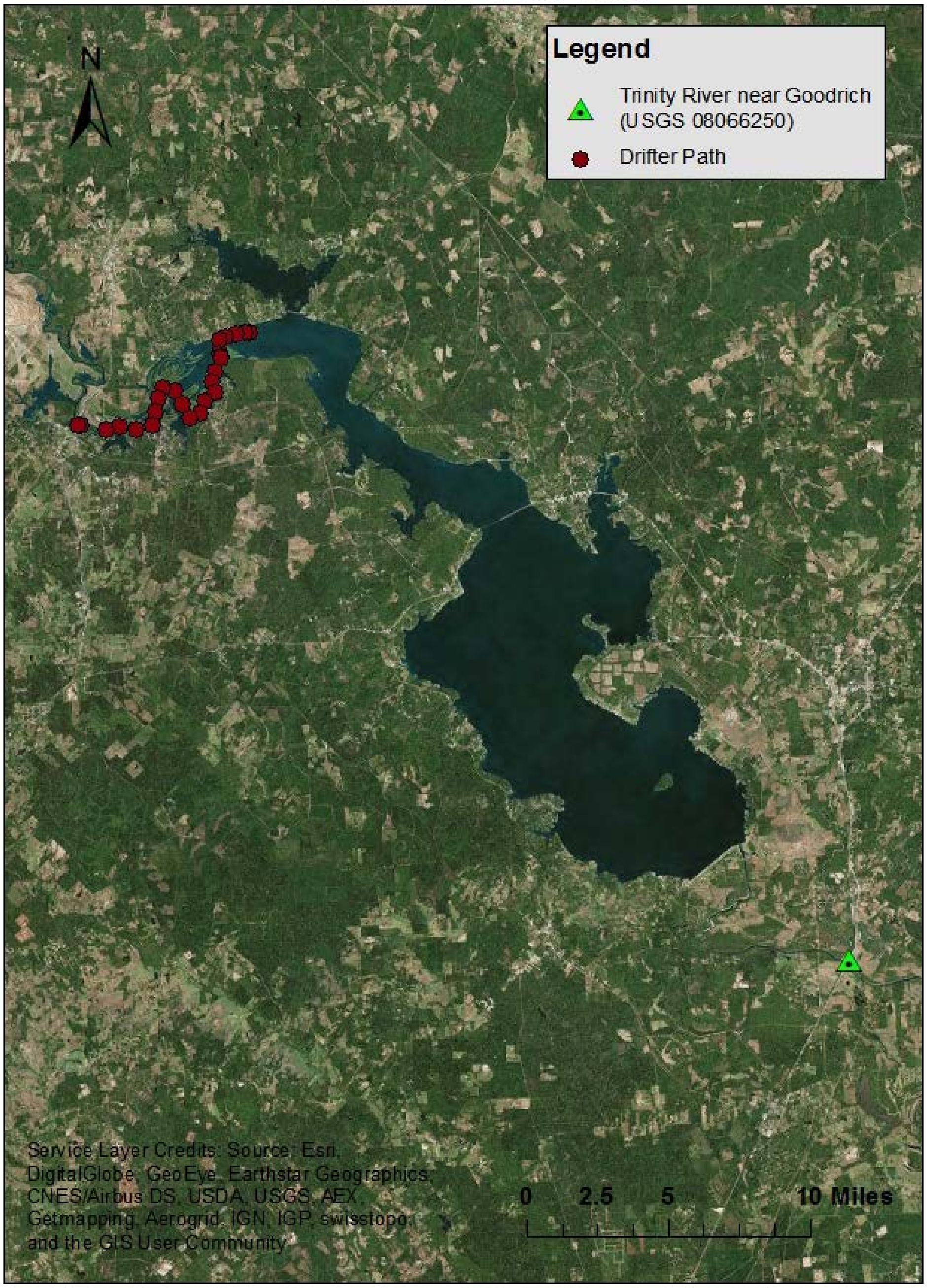
DATA DICTIONARY:

00065 - Gage height (00065): Gage height, feet
00062 - Elevation, reservoir (00062): Elevation of reservoir water surface above datum, feet
00060 - Discharge (00060): Discharge, cubic feet per second
00061 - Discharge, instant. (00061): Discharge, instantaneous, cubic feet per second
00055 - Stream velocity (00055): Stream velocity, feet per second
00054 - Reservoir storage (00054): Reservoir storage, acre feet
00010 - Temperature, water (00010): Temperature, water, degrees Celsius
00095 - Specific cond at 25C (00095): Specific conductance, water, unfiltered, microsiemens per centimeter at 25 degrees Celsius
00400 - pH (00400): pH, water, unfiltered, field, standard units
00300 - Dissolved oxygen (00300): Dissolved oxygen, water, unfiltered, milligrams per liter
00301 - Diss oxygen,%saturtn (00301): Dissolved oxygen, water, unfiltered, percent of saturation
63680 - Turbidity, Form Neph (63680): Turbidity, water, unfiltered, monochrome near infra-red LED light, 780-900 nm, detection angle 90 +-2.5 degrees, formazin nephelometric units (FNU)
00020 - Temperature, air (00020): Temperature, air, degrees Celsius
00025 - Air pressure (00025): Barometric pressure, millimeters of mercury
50624 - Absorbance, 254 nm (50624): Absorbance, 254 nm, water, filtered, absorbance units per centimeter
61726 - Absorbance at 280 nm (61726): Absorbance, UV, organic constituents, 280 nm, 1 cm path length, water, filtered, absorbance units per centimeter
00694 - Total carbon, ss (00694): Carbon [inorganic plus organic], susended sediment, total, milligrams per liter
71846 - Ammonia, wf (71846): Ammonia (NH3 + NH4+), water, filtered, milligrams per liter as NH4
00608 - Ammonia, wf (00608): Ammonia (NH3 + NH4+), water, filtered, milligrams per liter as nitrogen
00631 - NO3+NO2, wf (00631): Nitrate plus nitrite, water, filtered, milligrams per liter as nitrogen
71851 - Nitrate, wf (71851): Nitrate, water, filtered, milligrams per liter as nitrate
00618 - Nitrate, wf (00618): Nitrate, water, filtered, milligrams per liter as nitrogen

71856 - Nitrite, wf (71856): Nitrite, water, filtered, milligrams per liter as nitrite
00613 - Nitrite, wf (00613): Nitrite, water, filtered, milligrams per liter as nitrogen
00607 - Organic nitrogen, wf (00607): Organic nitrogen, water, filtered, milligrams per liter as nitrogen
00605 - Organic nitrogen, wu (00605): Organic nitrogen, water, unfiltered, milligrams per liter as nitrogen
00671 - Orthophoshate, wf (00671): Orthophoshate, water, filtered, milligrams per liter as phoshorus
00660 - Orthophoshate, wf (00660): Orthophoshate, water, filtered, milligrams per liter as PO4
49570 - Particulate-N, suspended (49570): particulate nitrogen, suspended in water, milligrams per liter
00665 - Phoshorus, wu (00665): phoshorus, water, unfiltered, milligrams per liter as phoshorus
62854 - Total nitrogen, wf (62854): Total nitrogen [nitrate + nitrite + ammonia + organic-N], water, filtered, analytically determined, milligrams per liter
62855 - Total nitrogen, wu (62855): Total nitrogen [nitrate + nitrite + ammonia + organic-N], water, unfiltered, analytically determined, milligrams per liter
00600 - Total nitrogen, wu (00600): Total nitrogen [nitrate + nitrite + ammonia + organic-N], water, unfiltered, milligrams per liter
00680 - Organic carbon, wu (00680): Organic carbon, water, unfiltered, milligrams per liter
00681 - Organic carbon, wf (00681): Organic carbon, water, filtered, milligrams per liter
70331 - Susp sed <0.0625mm,sd (70331): Suspended sediment, sieve diameter, percent smaller than 0.0625 millimeters
80154 - Suspnd sedmnt conc (80154): Suspended sediment concentration, milligrams per liter

Appendix C: Drifter Paths by Deployment

11/3/2015-11/6/2015

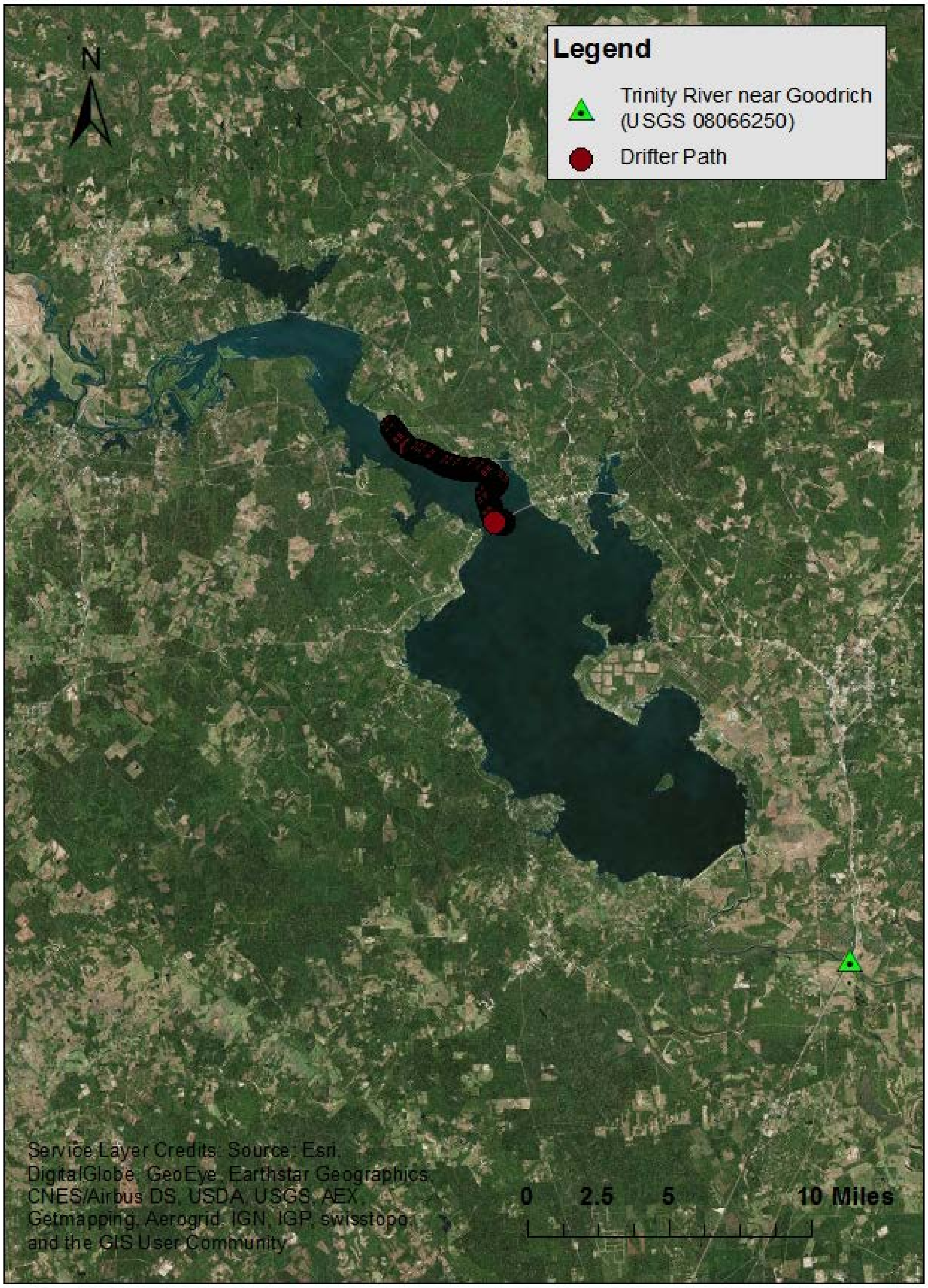


12/15/2015-12/21/2015

03/14/2016-03/18/2016

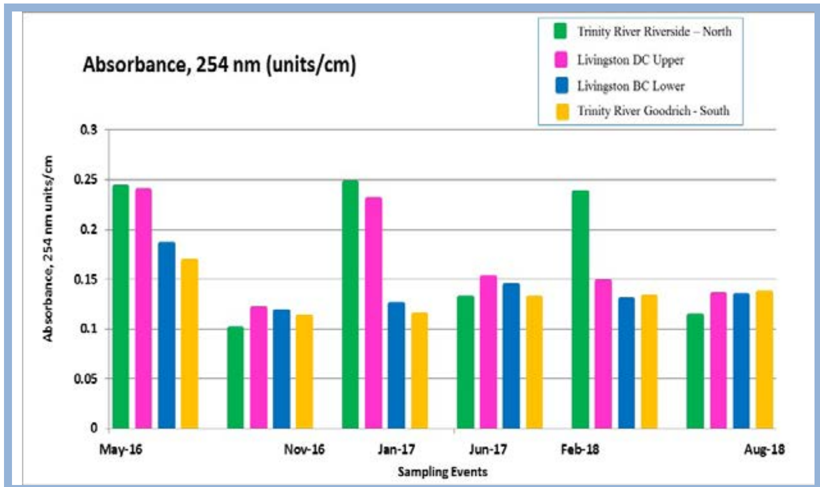
02/25/2018-02/28/2018

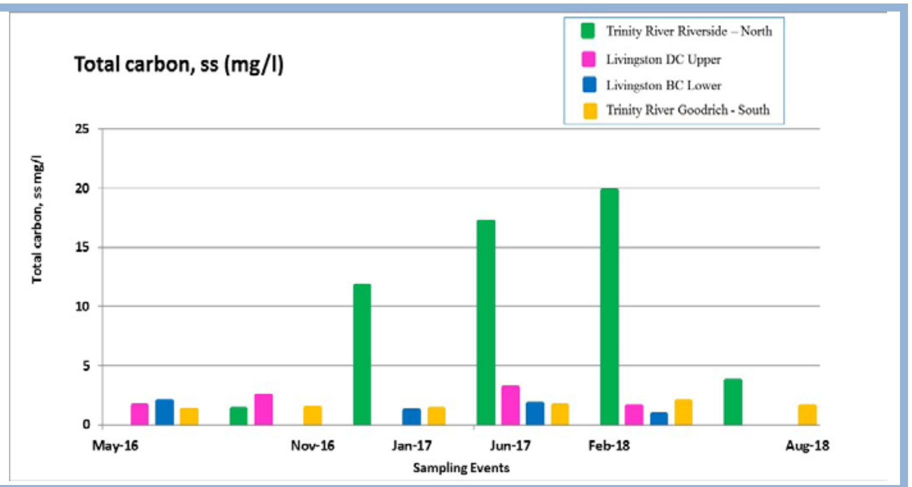
06/11/2017-06/13/2017

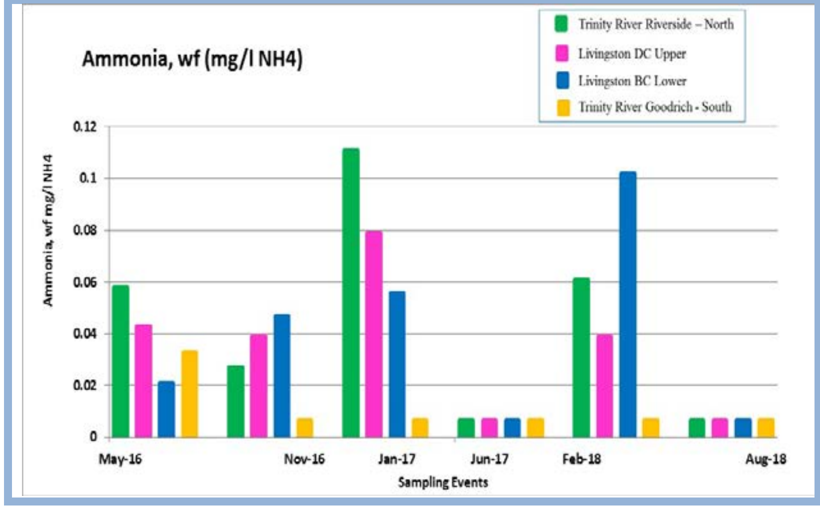


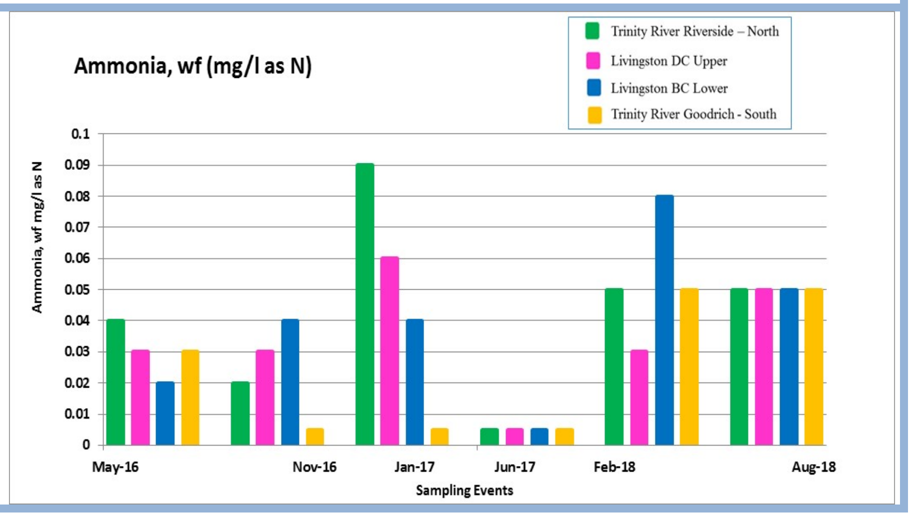
Appendix D: Water Quality Sampling Results

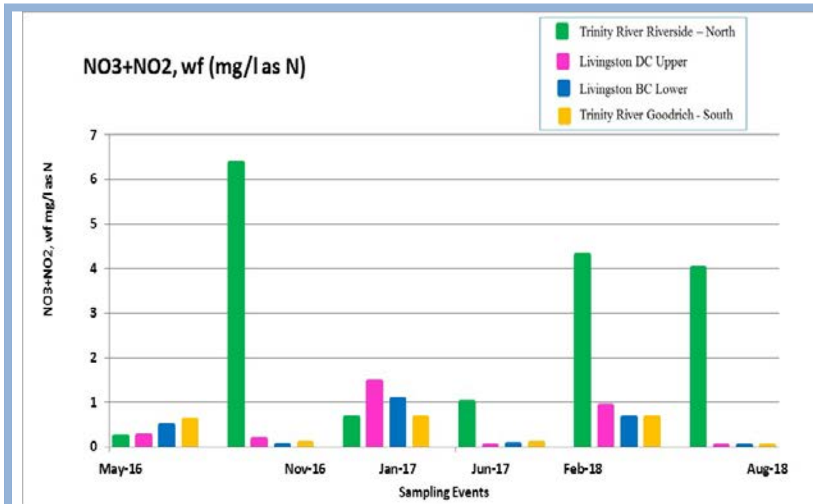
Table of graphs for selected constituents sampled in Lake Livingston during Project Period. Note: water, unfiltered (wu); water, filtered (wf); milligrams per liter (mg/L). The full table of constituent samples, as well as a complete data dictionary, are included in Appendix A and B.

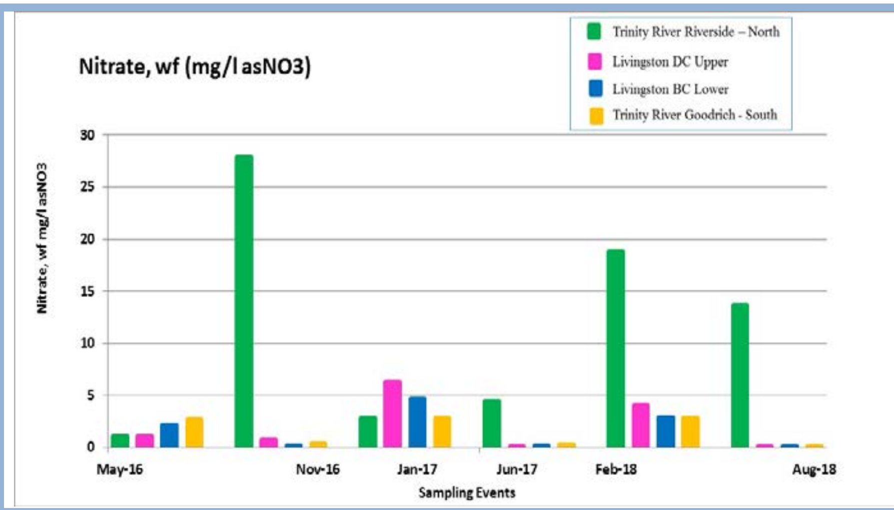

Absorbance, 254 nm (units/cm)
Trinity River Riverside – North
Livingston DC Upper
Livingston BC Lower
Trinity River Goodrich - South
Absorbance, 254 nm units/cm
0.3
0.25
0.2
0.15
0.1
0.05
0
May-16
Nov-16
Jan-17
Jun-17
Feb-18
Aug-18
Sampling Events

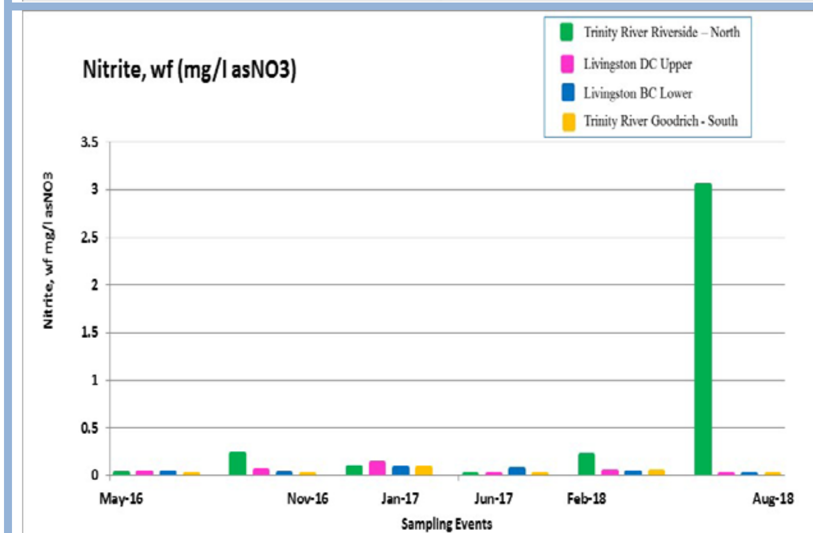

Total carbon, ss (mg/l)
Trinity River Riverside – North
Livingston DC Upper
Livingston BC Lower
Trinity River Goodrich - South
Total carbon, ss mg/l
25
20
15
10
5
0
May-16
Nov-16
Jan-17
Jun-17
Feb-18
Aug-18
Sampling Events

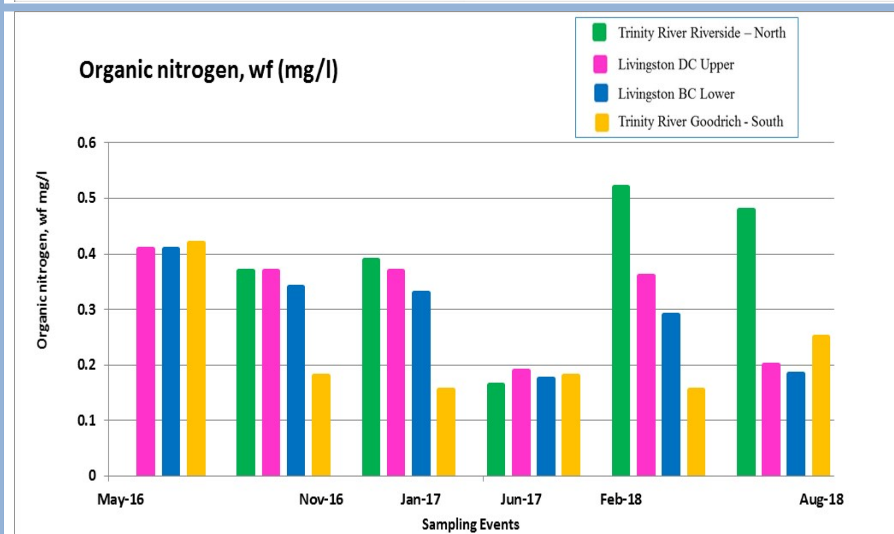

Ammonia, wf (mg/l NH4)
Trinity River Riverside – North
Livingston DC Upper
Livingston BC Lower
Trinity River Goodrich - South
Ammonia, wf mg/l NH4
0.12
0.1
0.08
0.06
0.04
0.02
0
May-16
Nov-16
Jan-17
Jun-17
Feb-18
Aug-18
Sampling Events

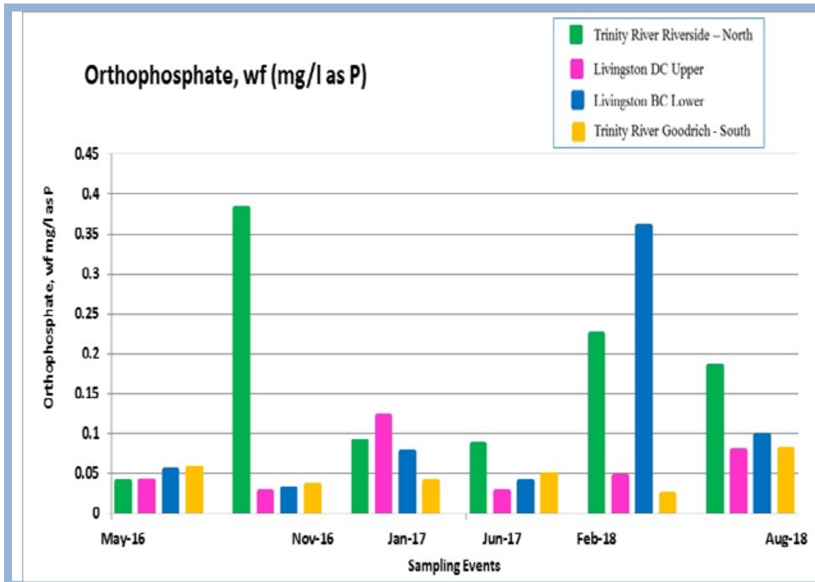

Ammonia, wf (mg/l as N)
Trinity River Riverside – North
Livingston DC Upper
Livingston BC Lower
Trinity River Goodrich - South
Ammonia, wf mg/l as N
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
May-16
Nov-16
Jan-17
Jun-17
Feb-18
Aug-18
Sampling Events

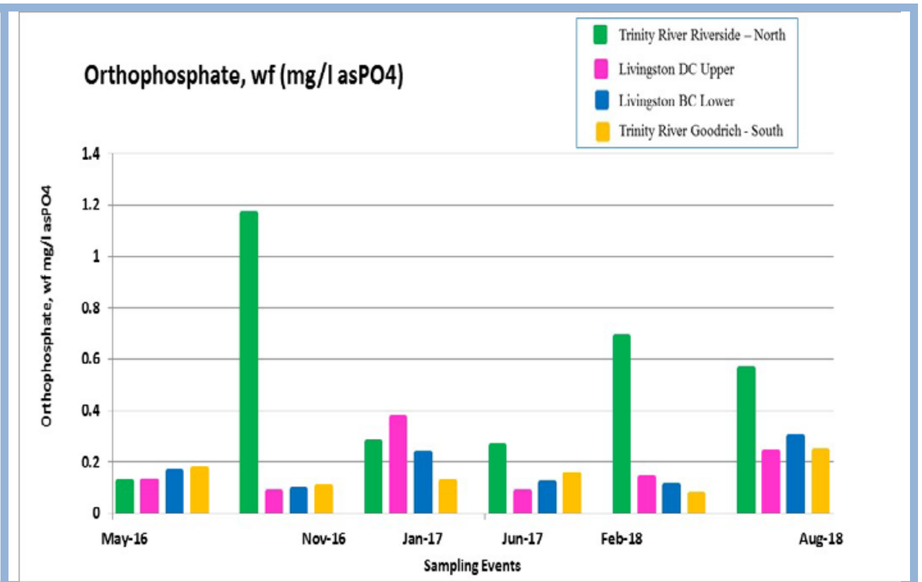

NO3+NO2, wf (mg/l as N)
Trinity River Riverside – North
Livingston DC Upper
Livingston BC Lower
Trinity River Goodrich - South
NO3+NO2, wf mg/l as N
0
1
2
3
4
5
6
7
May-16
Nov-16
Jan-17
Jun-17
Feb-18
Aug-18
Sampling Events

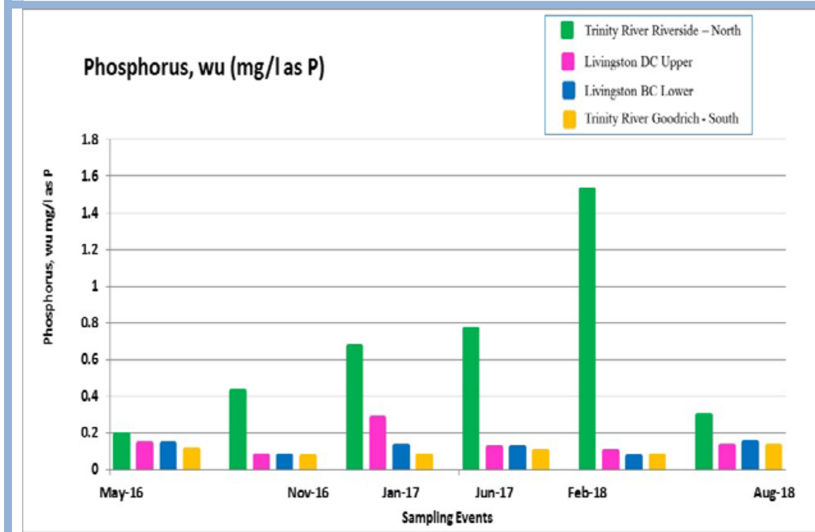

Nitrate, wf (mg/l asNO3)
Trinity River Riverside – North
Livingston DC Upper
Livingston BC Lower
Trinity River Goodrich - South
Nitrate, wf mg/l asNO3
0
5
10
15
20
25
30
May-16
Nov-16
Jan-17
Jun-17
Feb-18
Aug-18
Sampling Events

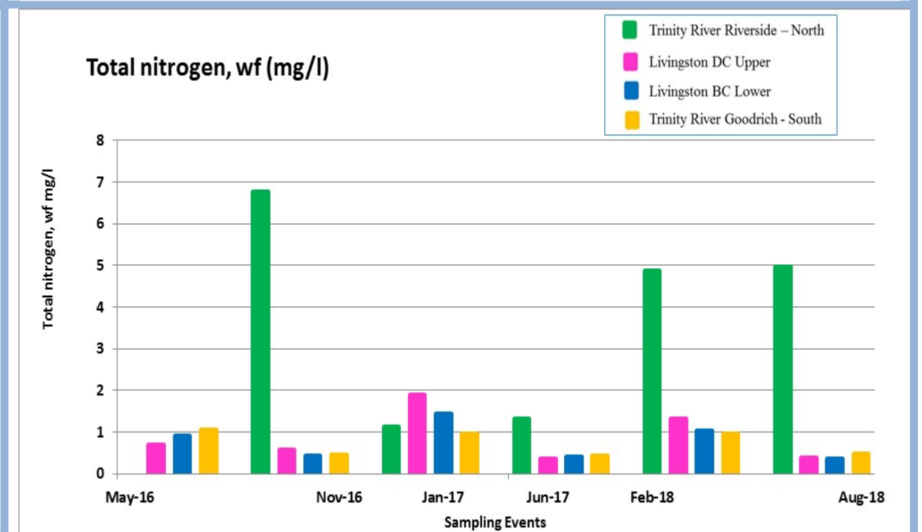

Nitrite, wf (mg/l asNO3)
Trinity River Riverside – North
Livingston DC Upper
Livingston BC Lower
Trinity River Goodrich - South
Nitrite, wf mg/l asNO3
0
0.5
1
1.5
2
2.5
3
3.5
May-16
Nov-16
Jan-17
Jun-17
Feb-18
Aug-18
Sampling Events

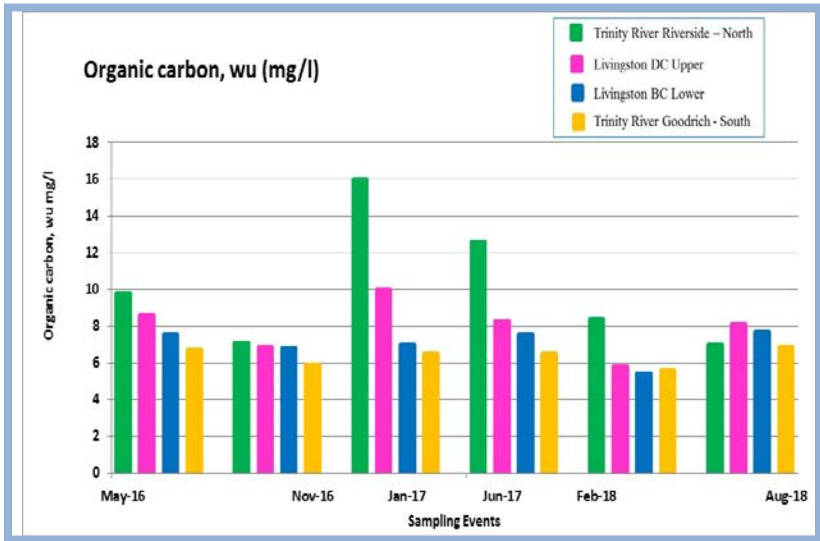

Organic nitrogen, wf (mg/l)
Trinity River Riverside – North
Livingston DC Upper
Livingston BC Lower
Trinity River Goodrich - South
Organic nitrogen, wf mg/l
0
0.1
0.2
0.3
0.4
0.5
0.6
May-16
Nov-16
Jan-17
Jun-17
Feb-18
Aug-18
Sampling Events

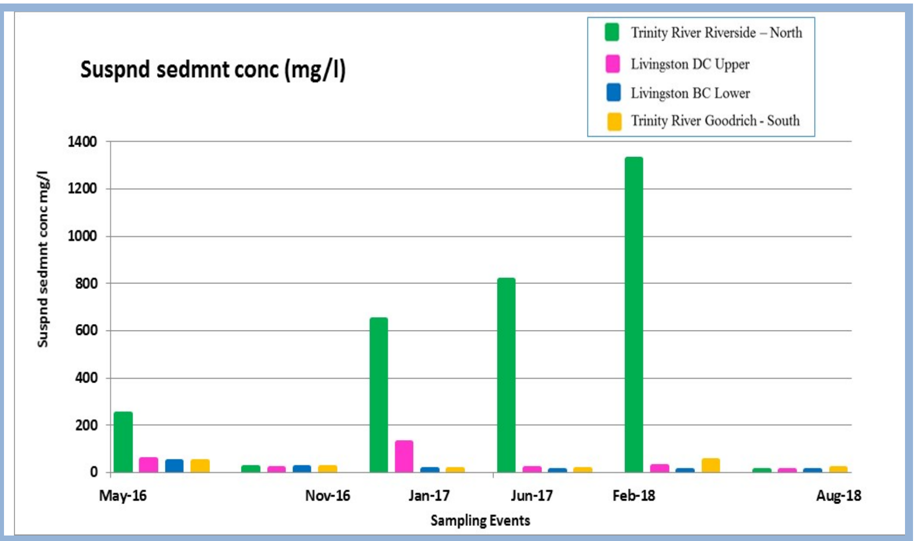

Orthophosphate, wf (mg/l as P)
Trinity River Riverside – North
Livingston DC Upper
Livingston BC Lower
Trinity River Goodrich - South
Orthophosphate, wf mg/l as P
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
May-16
Nov-16
Jan-17
Jun-17
Feb-18
Aug-18
Sampling Events

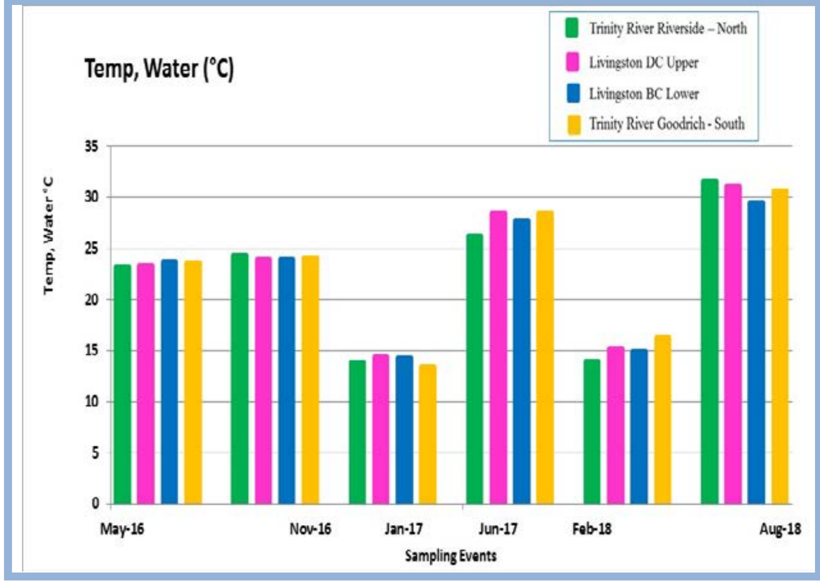

Orthophosphate, wf (mg/l asPO4)
Trinity River Riverside – North
Livingston DC Upper
Livingston BC Lower
Trinity River Goodrich - South
Orthophosphate, wf mg/l asPO4
1.4
1.2
1
0.8
0.6
0.4
0.2
0
May-16
Nov-16
Jan-17
Jun-17
Feb-18
Aug-18
Sampling Events

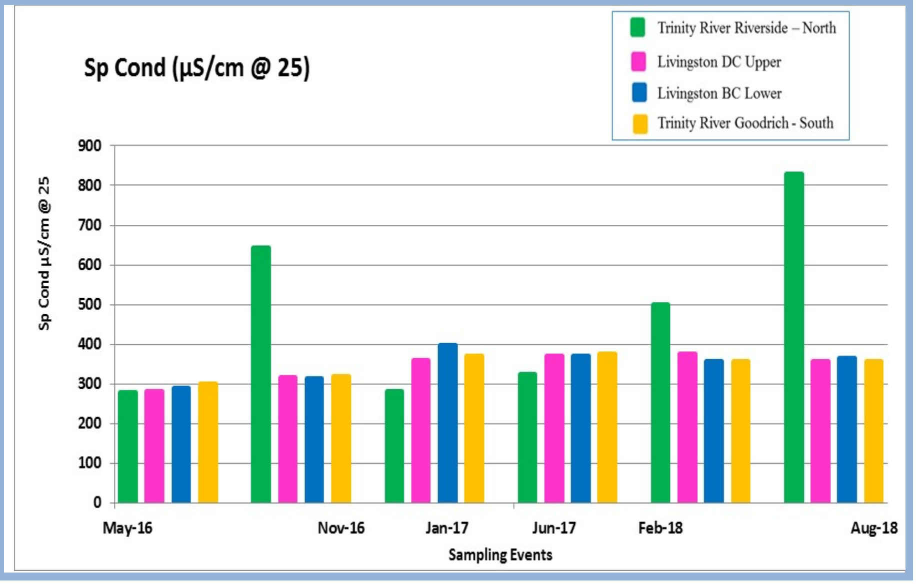

Phosphorus, wu (mg/l as P)
Trinity River Riverside – North
Livingston DC Upper
Livingston BC Lower
Trinity River Goodrich - South
Phosphorus, wu mg/l as P
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
May-16
Nov-16
Jan-17
Jun-17
Feb-18
Aug-18
Sampling Events

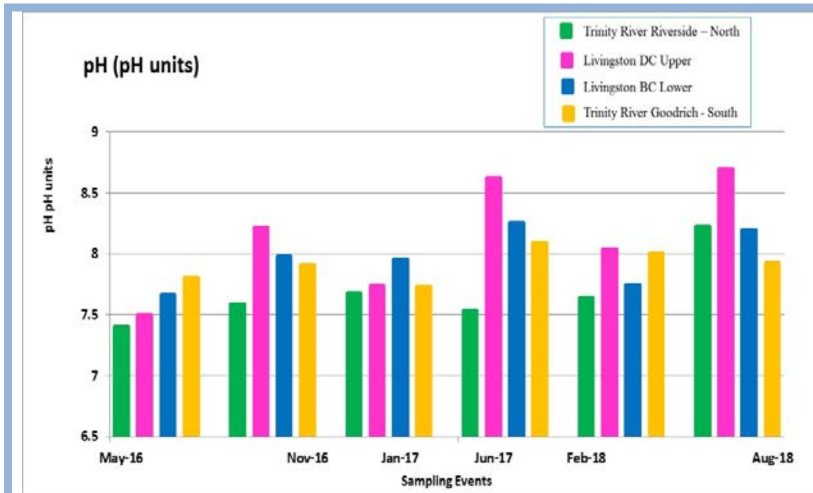

Total nitrogen, wf (mg/l)
Trinity River Riverside – North
Livingston DC Upper
Livingston BC Lower
Trinity River Goodrich - South
Total nitrogen, wf mg/l
8
7
6
5
4
3
2
1
0
May-16
Nov-16
Jan-17
Jun-17
Feb-18
Aug-18
Sampling Events

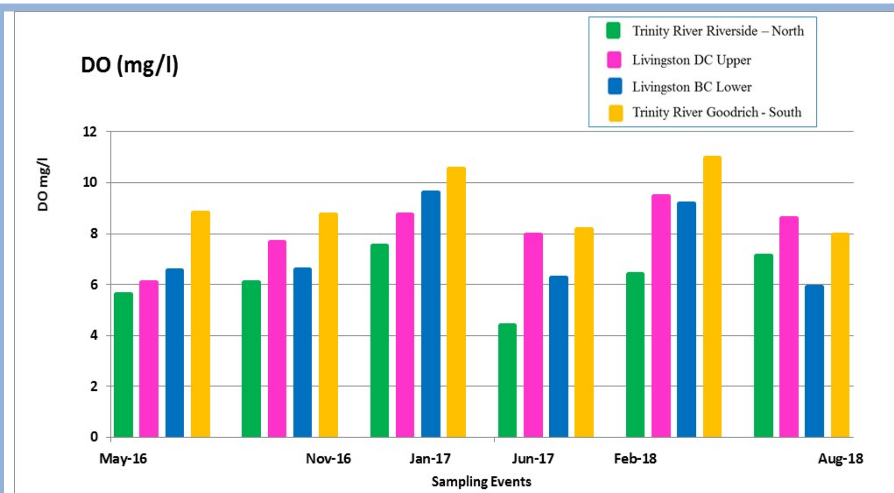

Organic carbon, wu (mg/l)
Trinity River Riverside – North
Livingston DC Upper
Livingston BC Lower
Trinity River Goodrich - South
Organic carbon, wu mg/l
0
2
4
6
8
10
12
14
16
18
May-16
Nov-16
Jan-17
Jun-17
Feb-18
Aug-18
Sampling Events

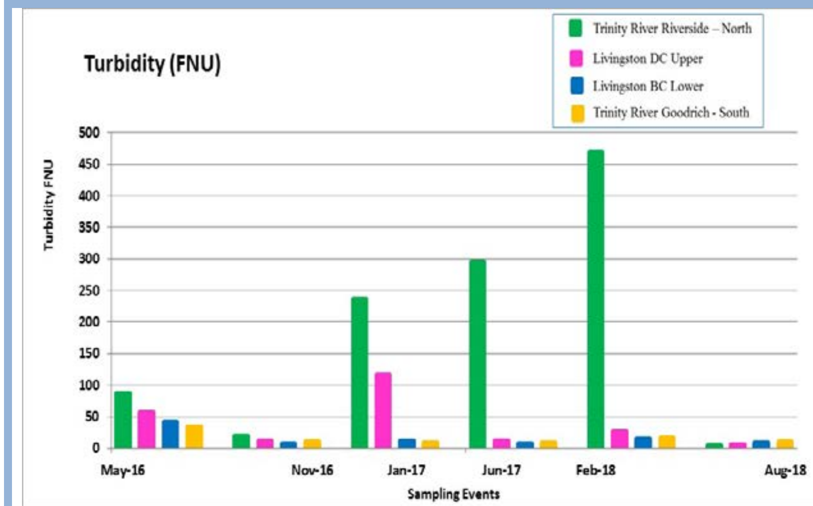

Suspnd sedmnt conc (mg/l)
Trinity River Riverside – North
Livingston DC Upper
Livingston BC Lower
Trinity River Goodrich - South
Suspnd sedmnt conc mg/l
0
200
400
600
800
1000
1200
1400
May-16
Nov-16
Jan-17
Jun-17
Feb-18
Aug-18
Sampling Events

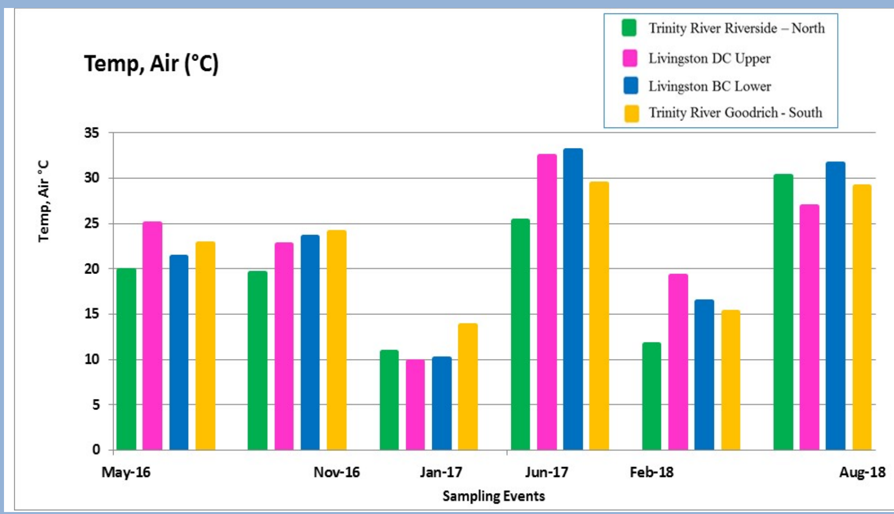

Temp, Water (°C)
Trinity River Riverside – North
Livingston DC Upper
Livingston BC Lower
Trinity River Goodrich - South
Temp, Water °C
0
5
10
15
20
25
30
35
May-16
Nov-16
Jan-17
Jun-17
Feb-18
Aug-18
Sampling Events


Sp Cond (µS/cm @ 25)
Trinity River Riverside – North
Livingston DC Upper
Livingston BC Lower
Trinity River Goodrich - South
Sp Cond µS/cm @ 25
0
100
200
300
400
500
600
700
800
900
May-16
Nov-16
Jan-17
Jun-17
Feb-18
Aug-18
Sampling Events


pH (pH units)
Trinity River Riverside – North
Livingston DC Upper
Livingston BC Lower
Trinity River Goodrich - South
pH pH units
9
8.5
8
7.5
7
6.5
May-16
Nov-16
Jan-17
Jun-17
Feb-18
Aug-18
Sampling Events


DO (mg/l)
Trinity River Riverside – North
Livingston DC Upper
Livingston BC Lower
Trinity River Goodrich - South
DO mg/l
12
10
8
6
4
2
0
May-16
Nov-16
Jan-17
Jun-17
Feb-18
Aug-18
Sampling Events


Turbidity (FNU)
Trinity River Riverside – North
Livingston DC Upper
Livingston BC Lower
Trinity River Goodrich - South
Turbidity FNU
500
450
400
350
300
250
200
150
100
50
0
May-16
Nov-16
Jan-17
Jun-17
Feb-18
Aug-18
Sampling Events


Temp, Air (°C)
Trinity River Riverside – North
Livingston DC Upper
Livingston BC Lower
Trinity River Goodrich - South
Temp, Air °C
35
30
25
20
15
10
5
0
May-16
Nov-16
Jan-17
Jun-17
Feb-18
Aug-18
Sampling Events

Appendix E: Deliverable Task Reports

Appendix E contains the final year summary and the final QPR, both of which summarize the deliverables. The amount of funds spent for the project include USGS as a subcontractor invoiced $60,000, and HARC invoiced a total of $100,000 for a total project cost of $160,000.

Geotechnology Research Institute (GTRI)
The Impacts of Assimilative Capacity of Reservoirs on Coastal Inflows
Quarterly Progress Report
GBEP Contract No. 582-16-60126

March 1, 2019 – March 31, 2019

I. Overall Progress and Results by Task

Task 1: Project Administration

Subtask 1.1 Project Oversight – The Performing Party will provide technical and fiscal oversight of the staff and/or sub grantee(s)/subcontractor(s) to ensure tasks and deliverables are acceptable and completed as scheduled and within budget. With TCEQ Project Manager authorization, the Performing Party may secure the services of sub grantee(s)/ subcontractor(s). Project oversight status will be provided to the TCEQ with the Quarterly Progress Reports (QPRs).

- *Ongoing oversight of project.*
- *GTRI signed subcontract for water quality monitoring work with USGS on October 16, 2015.*

Subtask 1.2 The Performing Party will submit electronic QPRs to the TCEQ Project Manager by the 15th of the month following each state fiscal quarter (Dec 15, Mar 15, June 15 and Sept 15). In the last quarter the contract is active reporting will change from quarterly to monthly.

- *This is the first QPR, to be submitted by December 15, 2015.*
- *December QPR submitted on December 9, 2015.*
- *March QPR to be submitted by March 15, 2016.*
- *March QPR submitted on March 4, 2016.*
- *June QPR submitted on June 13, 2016.*
- *September QPR to be submitted by September 15, 2016.*
- *September QPR submitted on September 9, 2016.*
- *December QPR to be submitted by December 15, 2016.*

- *December QPR submitted on December 14, 2016.*
- *March QPR to be submitted by March 15, 2017.*
- *March QPR submitted on March 9, 2017.*
- *June QPR to be submitted by June 15, 2017.*
- *June QPR submitted on June 5, 2017.*
- *August QPR to be submitted by September 15, 2017.*
- *August QPR submitted on September 8, 2017.*
- *November QPR to be submitted by December 15, 2017.*
- *November QPR submitted on December 11, 2017.*
- *February QPR to be submitted by March 15, 2017.*
- *February QPR submitted on March 12, 2018.*
- *May QPR submitted on June 12, 2018.*
- *August QPR submitted September 14, 2018.*
- *December QPR to be submitted by December 15, 2018.*
- *December QPR submitted December 13, 2018.*
- *December QPR to be submitted by March 15, 2019.*
- *During the last quarter of the project, which is the upcoming quarter, reporting will switch to monthly.*
- *The April MPR, which includes activities in March, was submitted April 12, 2019.*

Subtask 1.3 The Performing Party will submit reimbursement forms to the TCEQ Contract Manager 30 days after the end of each state fiscal quarter. For the final quarter of the Contract period, Reimbursement Forms are required on a monthly basis, and final billing is due 45 days after the close of the Contract.

- *September 2015 invoice sent 10/19/2015.*
- *October 2015 invoice sent 11/12/2015.*
- *November 2015 invoice sent 12/18/15.*
- *December 2015 invoice sent 1/27/16.*
- *January 2016 invoice sent 2/23/2016.*
- *February 2016 invoice sent 3/18/2016.*
- *March 2016 invoice sent 4/28/2016.*
- *April 2016 invoice sent 5/5/2016.*
- *May 2016 invoice sent 6/17/2016.*
- *June 2016 invoice sent 7/14/2016.*
- *July 2016 invoice sent 9/13/2016.*
- *August 2016 invoice sent 9/13/2016.*
- *September 2016 invoice sent 10/13/2016.*
- *October 2016 invoice sent 11/15/2016.*
- *November 2016 invoice sent 12/13/16.*

- *December 2016 invoice sent 1/27/17.*
- *January 2017 invoice sent 3/28/17.*
- *February 2017 invoice sent 4/20/17.*
- *March 2017 invoice sent 4/20/17.*
- *April 2017 invoice sent 5/23/17.*
- *May 2017 invoice sent 6/13/17.*
- *June 2017 invoice sent 7/20/17.*
- *July 2017 invoice sent 8/16/17.*
- *August invoice sent 9/19/2017.*
- *September invoice sent 10/27/2017.*
- *October invoice sent 11/17/2017.*
- *November invoice sent 12/14/2017.*
- *December invoice sent 1/12/2018.*
- *January invoice sent 02/06/2018.*
- *February invoice sent 03/16/2018.*
- *March invoice sent 04/12/2018.*
- *April invoice sent 05/15/2018.*
- *May invoice sent 06/20/2018.*
- *June invoice sent 7/6/18 (partial) / 7/18/18 (final).*
- *July invoice sent 05/10/2018.*
- *August invoice sent 10/01/18.*
- *September invoice sent 10/08/18.*
- *October invoice sent 11/14/18.*
- *November invoice sent on 12/14/18.*
- *December invoice sent on 1/14/19.*
- *January invoice sent on 3/20/19.*

Subtask 1.4 The Performing Party will participate in a post-award orientation meeting with TCEQ within 30 days of Contract execution. Meeting minutes will be due 15 days after meeting. The Performing Party will maintain regular telephone and/or email communication with the TCEQ Project Manager regarding the status and progress of the project in regard to any matters that require attention between QPRs. Matters that must be communicated to the TCEQ Project Manager include, but are not limited to:
•Notification a minimum of 14 days before the Performing Party has scheduled public meetings or events, initiation of construction, or other major task activities.
•Notification within 48 hours regarding events or circumstances that may require changes to the budget, scope of work, or schedule of deliverables.

- *GTRI and GBEP/TCEQ participated in a post-award orientation meeting on September 10, 2015. In attendance were Stephanie Glenn and Ryan Bare, GTRI and Lisa Marshall, GBEP.*
- *Minutes from September 2015 orientation meeting sent from Stephanie Glenn, GTRI to Lisa Marshall, GBEP on September 16, 2015.*

- *Ongoing communication between Stephanie Glenn, GTRI and Lisa Marshall, GBEP throughout quarter.*

Subtask 1.5 The Performing Party will provide an article for the GBEP briefing papers (one-pager format) upon request by the TCEQ. The article will include a brief summary of the project and describe the activities of the past fiscal year.

- *Fact sheet template sent to GTRI by GBEP/TCEQ on September 11, 2015.*
- *Finalized article sent by GTRI to GBEP/TCEQ on October 26, 2015.*

Task 2: Quality Assurance

Subtask 2.1: QAPP Meetings – Once the project has been approved, the Performing Party will schedule a QAPP planning meeting with the TCEQ Project Manager, QA staff and others to discuss and refine the information needed for the QAPP based on the elements of the TCEQ QAPP Shell. Meetings will be documented with information including meeting dates, meeting participants, and meeting content summary.

- *GTRI and GBEP/TCEQ participated in a QAPP planning meeting on October 7, 2015. In attendance were Stephanie Glenn and Ryan Bare, GTRI and Lisa Marshall and Michelle Krause, GBEP. QAPP outline, checklist and necessary contents were discussed.*

Subtask 2.2: QAPP – The Performing Party will create a new Quality Assurance Project Plan (QAPP), sufficient for the needs of the data quality objectives of this Scope of Work. The Performing Party shall submit a written draft QAPP within 60 days of contract execution for review and consideration of approval by the TCEQ Project Manager and in accordance with the U.S. Environmental Protection Agency's (EPA) R-5 document guidelines. The draft QAPP will be revised to address comments received from the TCEQ and/or EPA. A final QAPP without highlights or strikeout text will be submitted for approval by the TCEQ. Collection of environmental data and processes associated with the collection of environmental data shall not commence prior to approval of the QAPP. A QAPP will be submitted for approval on an annual basis for the life of this Contract.

- *GTRI began draft QAPP in conjunction with USGS.*
- *GTRI submitted draft QAPP outline to GBEP on October 7, 2015.*
- *GBEP sent reviewed draft QAPP outline with comments to GTRI on October 28, 2015.*
- *GTRI submitted revised draft QAPP to GBEP on November 3, 2015.*
- *GBEP sent reviewed draft QAPP with comments to GTRI on November 9, 2015.*

- *GTRI incorporated comments and sent final draft QAPP to GBEP on November 11, 2015.*
- *Draft QAPP submitted to TCEQ for review on November 12, 2015.*
- *Comments from TCEQ received on December 17, 2105.*
- *Updated version of QAPP addressing TCEQ comments sent to GBEP on January 8, 2016.*
- *Comments from TCEQ on updated QAPP received on January 21, 2016.*
- *Updated version of QAPP addressing TCEQ comments sent to GBEP on January 22, 2106.*
- *QAPP approved on February 24, 2016.*

Subtask 2.3: QAPP Annual Updates or Reissuances – The Performing Party will submit annual QAPP updates or reissuances no less than 90 days prior to the end of the effective period of the QAPP. The last approved version of a QAPP will remain in effect only for the specified approval period. Upon expiration of the approval period for a QAPP, all the work covered by the expired QAPP will cease until such time as a revised QAPP has been fully approved by TCEQ and, if necessary, EPA.

- *The QAPP was submitted for annual update on January 9, 2017.*
- *Revised QAPP was reviewed and accepted on February 8, 2017. Signature pages were routed for signatures.*
- *Final QAPP revision with signatures was sent out to partners on February 27, 2017.*
- *In accordance with the annual review, the QAPP was updated on February 1, 2018 and submitted for review. The revisions were approved and signature pages routed by February 13, 2018.*

Subtask 2.4: QAPP Amendments – The Performing Party will review, approve, and incorporate all changes into a revised QAPP during the annual revision process, or will submit an amendment to the QAPP 90 days prior to the scheduled initiation of changes or additions to activities listed in the current QAPP. The Performing Party will document all changes to the QAPP and the reasons for the changes. The Performing Party will ensure the approved QAPP is followed until an amended QAPP is signed/fully approved by TCEQ and, if necessary, EPA.

- *In accordance with the annual update submitted on January 9, 2017, the QAPP was amended to include two personnel changes, some minor language errors and changes to the sampling regime to better represent current sampling.*
- *In accordance with the annual update, the QAPP was reissued in Jan 2019 to reflect personnel changes.*
- *Final QAPP revision 3.0 with signatures sent to GTRI from GBEP TCEQ via email on March 22, 2019.*

Subtask 2.5: Corrective Action Reports (CARs) – The Performing Party will provide, as needed, CARs to document deviations from the activities described in the final or amended QAPP.

- *No CARs needed during this reporting period.*

Subtask 2.6: QA Audits – The Performing Party will participate in and conduct quality assurance-related auditing activities.

- *No QA Audits occurred during this reporting period.*
- *During this reporting period, dates were selected for QA Audits to occur during the next period. GTRI, GBEP and USGS worked to find accommodating schedules; Wednesday, October 12 was selected as the initial date with Tuesday, October 25 selected as the backup day in case of weather.*
- *A QA desk and field audit occurred during this reporting period on October 25, 2016 performed by Lisa Marshall and Michelle Krause of GBEP. Audit resulted in no negative and one positive findings as indicated in the audit report received by GTRI on November 18, 2016.*
- *A QA desk audit was held during this reporting period on November 29, 2017 at GTRI. In attendance were Lisa Marshall (GBEP), Bryan Eastham (GBEP), and Stephanie Glenn (GTRI). QAPP policies and procedures were reviewed.*
- *The -November 29, 2017 QA desk audit resulted in no negative and one positive findings, and a few comments, as indicated in the audit report received by GTRI on March 9, 2018.*
- *No QA Audits occurred during this reporting period.*
- *A QA desk audit was held during this reporting period on January 28, 2019 at GTRI. In attendance were Lisa Marshall (GBEP), Kristen McGovern (GBEP), Mustapha Beydoun (GTRI) and Stephanie Glenn (GTRI). QAPP policies and procedures were reviewed.*
- *The January 28, 2019 QA desk audit resulted in no negative and one positive findings, as indicated in the audit report received by GTRI on February 28, 2019.*

TASK 3: Water Quality Monitoring

Sub-task 3.1: Sampling portion of QAPP - USGS will assist GeoTechnology Research Institute in the creation of the QAPP defined in Task 2. USGS participation in the development of the QAPP will focus on sections involving sampling design and methodology, laboratory parameters and analytical methods, sampling QA/QC, and field and laboratory data management.

- *USGS assisted GTRI with all stages of QAPP development as outlined in Subtask 2.2, including addressing TCEQ comments and questions.*

Sub-task 3.2: Development of a Monitoring Plan - Performing Party, in conjunction with subcontractor, will develop a monitoring plan to determine a sampling methodology in conformity with the QAPP and project objectives. The monitoring plan will establish site selection criteria and identify specific sampling locations. It will also determine sampling design, including sample collection frequency, target flows, specific sampling procedures, and laboratory methods for water quality analyses.

- *Water quality constituent list developed by GTRI and USGS.*
- *Water quality sampling design and methodology established during meeting between GTRI and USGS on November 4, 2015.*
- *Draft monitoring plan will be considered final upon approval of QAPP.*
- *Monitoring plan established as outlined in QAPP February 8, 2016.*
- *USGS and GTRI finalized monitoring plan on March 1, 2016.*

Sub-task 3.3: Exploratory water quality sampling - USGS will conduct exploratory monitoring by deploying a Global Positioning System (GPS) drifter to estimate residence times in Lake Livingston and refine sampling frequency for possible future studies. Sampling will be conducted in accordance with the procedures detailed in the monitoring plan. The GPS drifter will be released at the far north end of Lake Livingston and travel to the far south end; it will be retrieved just above Lake Livingston Dam. During each GPS drifter release, four samples will be collected along the drifter's flow path: One at the far north end (Above), one in the top quarter (Above Middle), one in the bottom quarter (Below Middle) and one at a location below the dam (Below). Four samples will be collected at each site per event; three events in all will be captured (the plan is for one normal flow and two high/low flow events in order to capture variability and to account for lake residence times; however, this will be weather dependent (approximately 17 samples total with QA/QC samples such as field blanks and duplicates included). Field parameters to be measured are pH, temperature, conductivity, turbidity, and dissolved oxygen collected with a multi parameter sonde at the time of sample collection. Water quality parameters sampled are nutrients and sediment. Nutrient parameters being sampled are ammonia as N, nitrite, nitrite + nitrate, phosphorus, ortophosphate, total nitrogen (NH3 + NO2 + NO3 + Organic), dissolved organic carbon, total organic carbon, and UV-absorbing organic constituents.

- *USGS deployed a GPS drifter at the north end of Lake Livingston on 03/14/2016. Drifter data was recorded through 03/18/2016.*
- *Drifter data collected during previous deployments was analyzed to obtain baseline information for future sample collection.*
- *USGS did not collect water quality samples during (04/01/2016-04/30/2016).*
- *Water-quality samples were collected at:*
    - *The far north end (USGS station Trinity River near Riverside) on 5/3/2016*

  - *In the top quarter and bottom quarter on 5/5/2016*
  - *Below the dam (USGS station Trinity River near Goodrich) on 5/9/2016*
- *USGS did not collect water-quality samples during (6/1/2016-8/31/2016).*
- *Lab results from the May sampling event were sent from USGS to GTRI on September 9, 2016.*
- *USGS collected one base flow water-quality sample (see Table 1) at:*
  - *the far north end (USGS station 08066000 Trinity River at Riverside, Texas) on 10/25/2016*
  - *the above middle and bellow middle stations (USGS stations 304521095075501 Livingston Reservoir Site DC near Goodrich, Texas and 303935095055401 Livingston Reservoir Site BC near Goodrich, Texas) on 10/27/2016*
  - *a Location below the dam (USGS station 08066250 Trinity River near Goodrich, Texas) on 11/1/2016*
- *USGS did not collect water quality samples during the period 12/01/2016-12/31/2016.*
- *USGS collected water quality samples listed below:*
  - *01/23/2017 Trinity Rv nr Riverside, TX*
  - *01/26/2017 Lake Livingston Site DC*
  - *01/26/2017 Lake Livingston Site BC*
  - *01/31/2017 Trinity Rv nr Goodrich, TX*
  - *Note: The drifter was not deployed during this event due to previous problems. Instead, the timing of this sample was based upon: previous drifter data, velocity measurements from Riverside, and reservoir retention time calculations. While sampling, high turbidity (117.1 FNU) was observed at site DC, while a turbidity of 12.35 FNU was observed at BC.*
  - *USGS did not collect water quality samples during 2/01/2017-2/28/2017.*
- *USGS met with HARC on 2/2/2017 to discuss observations made while collecting the 1/23 – 1/31 sample. Specifically addressing strategies for tracking the flow in Lake Livingston during an event. Agreed to try using the drifter to track flow from Site DC to Site BC for future sample collections.*
- *USGS did not collect water quality samples during the 3/01/2017-5/31/2017 quarter.*
- *USGS reviewed events that were previously corrected to reassess targeting thresholds:*
  - *05/03/216 to 05/09/2016 discharge ranged from 43,590 to 36,800 cfs*
  - *10/25/2016 to 11/01/2016 low discharge, estimated at 1,500 cfs*
  - *01/23/2017 to 01/31/2017 discharge ranged from 1,7514 to*

4,460 cfs

- *USGS collected water quality samples listed below:*
  - *06/09/2017 Trinity Rv nr Riverside, Tx*
  - *06/11/2017 Drifter deployed at 190 Bridge,*
- *Observations made between bridge and site DC.*
  - *06/15/2017 Lake Livingston Site DC*
  - *06/15/2017 Lake Livingston Site BC*
  - *06/20/2017 Trinity Rv nr Goodrich, TX*
- *Reviewed events that were previously collected to reassess targeting thresholds:*
  - *05/03/216 to 05/09/2016 discharge of 43,590 cfs at Riverside.*
  - *10/25/2016 to 11/01/2016 low discharge, estimated at 1500 cfs*
  - *01/23/2017 to 01/31/2017 discharge of 17,514 cfs at Riverside.*
  - *06/09/2017 to 06/20/2017 discharge of 15954 cfs at Riverside.*
- *USGS met with HARC on 7/20/2017 to discuss observations made during June sampling, and how best to use our remaining two sampling events. Determined:*
  - *At least one sample should be collected in winter months.*
  - *One sample should be collected at low flow conditions.*
- *USGS did not collect water quality samples during the period (7/01/2017-8/31/2017).*
- *USGS did not collect water quality samples during the period (9/01/2017-11/30/2017).*
- *USGS provided GTRI a report of all project data collected to date on 10/02/2017.*
- *USGS collected water quality samples listed below during the reporting period (12/01/2017-2/28/2018):*
  - *02/25/2018 Trinity River near Riverside, TX*
  - *02/28/2018 Lake Livingston Site DC*
- *USGS deployed the drifter from the Hwy 190 bridge on 02/25/2018.*
- *USGS recovered the drifter on 02/28/2018.*
- *USGS collected water quality samples listed below during the reporting period (3/1/2018-3/31/2018):*
  - *03/01/2018 Lake Livingston Site BC*
  - *03/06/2018 Trinity Rv nr Goodrich, TX*
- *USGS did not collect water quality samples during the period (06/01/2018-07/31/2018).*
- *USGS collected water quality samples listed below during the reporting period (8/1/2018-8/31/2018):*
  - *08/08/2018 Trinity Rv at Riverside, TX*
  - *08/14/2018 Lk Livingston DC nr Goodrich, TX*
  - *08/14/2018 Lk Livingston BC nr Goodrich, TX*
  - *08/21/2018 Trinity Rv nr Goodrich, TX*

- *USGS has completed the sampling program on 08/21/2018 and did not collect water quality samples during the period (09/01/2018-2/28/2019).*
- *USGS has completed the sampling program on 08/21/2018 and did not collect water quality samples during the period (March 2019).*
-

TASK 4: Year-end/Final Reports

Subtask 4.1: Summary Report – The Performing Party will provide a year-end report summarizing first year sampling efforts, initial results and preliminary data analysis.

- *The first year-end summary report was submitted by GTRI to GBEP on October 12, 2016.*
- *Preliminary TCEQ Clean River Program (SWIQMS) data gathering analysis initiated along with QA procedures for Lake Livingston and its surrounding watershed.*
- *Initiated development of second year-end summary report - will be completed and submitted next quarter.*
- *The second year-end summary report was submitted by GTRI to GBEP on September 28, 2017.*
- *Data analysis was begun on data received thus far in the project. Discussion focused on best summarization, visualization and results for the data analysis.*
- *Data analysis continued for data received thus far in the project.*
- *The development of a data visual application to showcase project results was initiated.*
    - *Initial GPS drifter results digitized, analyzed and the process to develop them into short video clips was begun.*
    - *Initial water quality monitoring results assessed; nutrients, dissolved oxygen and water temperature results prepared for visualization by date and by constituent.*
    - *Depth profiles for data points received thus far were analyzed and assessed for presentation method.*
    - *Initial frame of story map developed for tabular presentation of spatial results*
    - *Initial frame of spatial results developed constituents by date*
- *Initiated development of third year-end summary report - will be completed and submitted next quarter.*
- *The third year-end summary report was completed and submitted by GBEP on 10/01/2018.*

- *GTRI received a final project data set containing all sampling results from USGS on 11/06/2018.*
- *The final data set was processed by GTRI to begin final data analysis and allow for integration with story map and data visual application.*
- *Multi-media content continued to be developed for the story map application along with finalizing graph figures including sampling results by depth, by date and by constituent.*
- *Continued development and refinement of story map application and web maps including the modification and refinement of the drifter and USGS stream gage at Goodrich time aware data.*

Subtask 4.2: Draft Final Report – The Performing Party will provide a draft report summarizing all project activities, findings, and the contents of all previous deliverables, referencing and/or attaching them as web links or appendices. This comprehensive, technical report will provide analysis of all activities and deliverables under this scope of work. The report should be structured per the following outline:

- Title;
- Table of Contents;
- Executive Summary;
- Introduction;
- Project Significance and Background;
- Methods;
- Results and Observations;
- Discussion and Data Summary;
- Summary;
- References; and
- Appendices.

- *Began work on Draft Final Report - Development of data analysis, figures, and content for final report.*
  - *Performed data analysis on results*
  - *Developed content for all sections to communicate efforts completed under this project*
  - *Developed figures to communicate results of data analysis*
  - *Develop maps to communicate results of spatial analysis*
- *Completed work on Draft Final Report.*
  - *Completed data analysis and developed maps and figures to use in the Draft Final Report*
  - *Developed content for all sections as outlined in guidance structure above.*
- *GTRI submitted Draft Final Report to GBEP/TCEQ on March 8, 2019.*

Subtask 4.3: Final Report – The Performing Party will revise the draft final report to address comments provided by the TCEQ Project Manager and the EPA. The Performing Party will submit the final report to the TCEQ Project Manager, who will subsequently submit it to EPA.

- GTRI received comments back on the Draft Final Report from the GBEP/TCEQ manager via email on March 20, 2019.
- GTRI began revising the Draft Final Report to address the comments provided.

II. Related Issues/Current Problems and Favorable or Unusual Developments

III. Projected Work for Next Quarter

- *GTRI to continue revision of draft final report to address comments received.*
- *GTRI to submit final report*

Geotechnology Research Institute (GTRI)
The Impacts of Assimilative Capacity of Reservoirs on Coastal Inflows
Year-End Summary Report
GBEP Contract No. 582-16-60126

September 1, 2017 – August 31, 2018

IV. Overall Progress and Results by Task

Task 1: Project Administration

Subtask 1.1 Project Oversight – The Performing Party will provide technical and fiscal oversight of the staff and/or sub grantee(s)/subcontractor(s) to ensure tasks and deliverables are acceptable and completed as scheduled and within budget. With TCEQ Project Manager authorization, the Performing Party may secure the services of sub grantee(s)/ subcontractor(s). Project oversight status will be provided to the TCEQ with the Quarterly Progress Reports (QPRs).

This year-end summary report summarizes work completed between September 1, 2017 and August 31, 2018. During the project's first fiscal year GTRI signed a subcontract for water quality monitoring work with USGS on October 16, 2015 and has had ongoing oversight of the project.

Subtask 1.2 The Performing Party will submit electronic QPRs to the TCEQ Project Manager by the 15th of the month following each state fiscal quarter (Dec 15, Mar 15, June 15 and Sept 15). In the last quarter the contract is active reporting will change from quarterly to monthly.

The performing party submitted QPRs on time starting with the December 15, 2017 QPR through the September 15, 2018 QPR.

Subtask 1.3 The Performing Party will submit reimbursement forms to the TCEQ Contract Manager 30 days after the end of each state fiscal quarter. For the final quarter of the Contract period, Reimbursement Forms are required on a monthly basis, and final billing is due 45 days after the close of the Contract.

The Performing Party submitted reimbursement forms to the TCEQ Contract Manager 30 days after the end of each state fiscal quarter starting with the August 2017 invoice through the July 2018 invoice.

Subtask 1.4 The Performing Party will participate in a post-award orientation meeting with TCEQ within 30 days of Contract execution. Meeting minutes will be due 15 days after meeting. The Performing Party will maintain regular telephone and/or email communication with the TCEQ Project Manager regarding the status and progress of the project in regard to any matters that require attention between QPRs. Matters that must be communicated to the TCEQ Project Manager include, but are not limited to:
•Notification a minimum of 14 days before the Performing Party has scheduled public meetings or events, initiation of construction, or other major task activities.
•Notification within 48 hours regarding events or circumstances that may require changes to the budget, scope of work, or schedule of deliverables.

- *GTRI and GBEP/TCEQ participated in a post-award orientation meeting on September 10, 2015. In attendance were Stephanie Glenn and Ryan Bare, GTRI and Lisa Marshall, GBEP.*
- *Ongoing communication between Stephanie Glenn, GTRI, and Lisa Marshall, GBEP, throughout reporting year.*

Subtask 1.5 The Performing Party will provide an article for the GBEP briefing papers (one-pager format) upon request by the TCEQ. The article will include a brief summary of the project and describe the activities of the past fiscal year.

The finalized article was sent by GTRI to GBEP/TCEQ on October 26, 2015.

Task 2: Quality Assurance

Subtask 2.1: QAPP Meetings – Once the project has been approved, the Performing Party will schedule a QAPP planning meeting with the TCEQ Project Manager, QA staff and others to discuss and refine the information needed for the QAPP based on the elements of the TCEQ QAPP Shell. Meetings will be documented with information including meeting dates, meeting participants, and meeting content summary.

GTRI and GBEP/TCEQ participated in a QAPP planning meeting on October 7, 2015. In attendance were Stephanie Glenn and Ryan Bare, GTRI and Lisa Marshall and Michelle Krause, GBEP. QAPP outline, checklist and necessary contents were discussed.

Subtask 2.2: QAPP – The Performing Party will create a new Quality Assurance Project Plan (QAPP), sufficient for the needs of the data quality objectives of this Scope of Work. The Performing Party shall submit a written draft QAPP within 60 days of contract execution for review and consideration of approval by the TCEQ Project Manager and in accordance with the U.S. Environmental Protection Agency's (EPA) R-5 document guidelines. The draft QAPP will be revised to address comments received from the TCEQ and/or EPA. A final QAPP without highlights or strikeout text will be submitted for approval by the TCEQ. Collection of environmental data and processes associated with the collection of environmental data shall not commence prior to approval of the QAPP. A QAPP will be submitted for approval on an annual basis for the life of this Contract.

The Performing Party created a new QAPP, incorporated comments and sent draft QAPP to GBEP on November 11, 2015. The draft QAPP was then submitted to TCEQ for review on November 12, 2015. After all revisions were incorporated the final QAPP was approved on February 24, 2016.

Subtask 2.3: QAPP Annual Updates or Reissuances – The Performing Party will submit annual QAPP updates or reissuances no less than 90 days prior to the end of the effective period of the QAPP. The last approved version of a QAPP will remain in effect only for the specified approval period. Upon expiration of the approval period for a QAPP, all the work covered by the expired QAPP will cease until such time as a revised QAPP has been fully approved by TCEQ and, if necessary, EPA.

- *An annual update was performed and submitted by GTRI to GBEP on January 9th, 2017. The final version of the updated QAPP was approved on February 27, 2017.*
- *In accordance with the annual review, the QAPP was updated on February 1, 2018 and submitted for review. The revisions were approved and signature pages routed by February 13, 2018.*

Subtask 2.4: QAPP Amendments – The Performing Party will review, approve, and incorporate all changes into a revised QAPP during the annual revision process, or will submit an amendment to the QAPP 90 days prior to the scheduled initiation of changes or additions to activities listed in the current QAPP. The Performing Party will document all changes to the QAPP and the reasons for the changes. The Performing Party will ensure the approved QAPP is followed until an amended QAPP is signed/fully approved by TCEQ and, if necessary, EPA.

No QAPP amendments at this time.

Subtask 2.5: Corrective Action Reports (CARs) – The Performing Party will provide, as needed, CARs to document deviations from the activities described in the final or amended QAPP.

No CARs needed during this reporting period.

Subtask 2.6: QA Audits – The Performing Party will participate in and conduct quality assurance-related auditing activities.

- *A QA audit occurred on October 25, 2016 performed by Lisa Marshall and Michelle Krause of GBEP. Participating parties included USGS, GTRI and*

GBEP. Both field and desk procedures were audited. Audit resulted in no negative and one positive findings as indicated in the audit report received by GTRI on November 18, 2016.

- *A QA desk audit was held during this reporting period on November 29, 2017 at GTRI. In attendance were Lisa Marshall (GBEP), Bryan Eastham (GBEP), and Stephanie Glenn (GTRI). QAPP policies and procedures were reviewed. The QA desk audit resulted in no negative and one positive findings.*

TASK 3: Water Quality Monitoring

Sub-task 3.1: Sampling portion of QAPP - USGS will assist GeoTechnology Research Institute in the creation of the QAPP defined in Task 2. USGS participation in the development of the QAPP will focus on sections involving sampling design and methodology, laboratory parameters and analytical methods, sampling QA/QC, and field and laboratory data management.

USGS assisted GTRI with all stages of QAPP development as outlined in Subtask 2.2, including addressing TCEQ comments and questions.

Sub-task 3.2: Development of a Monitoring Plan - Performing Party, in conjunction with subcontractor, will develop a monitoring plan to determine a sampling methodology in conformity with the QAPP and project objectives. The monitoring plan will establish site selection criteria and identify specific sampling locations. It will also determine sampling design, including sample collection frequency, target flows, specific sampling procedures, and laboratory methods for water quality analyses.

GTRI in partnership with USGS developed a monitoring plan detailing a water quality constituent list and sampling design and methodology. USGS and GTRI finalized the monitoring plan on March 1, 2016.

Sub-task 3.3: Exploratory water quality sampling - USGS will conduct exploratory monitoring by deploying a Global Positioning System (GPS) drifter to estimate residence times in Lake Livingston and refine sampling frequency for possible future studies. Sampling will be conducted in accordance with the procedures detailed in the monitoring plan. The GPS drifter will be released at the far north end of Lake Livingston and travel to the far south end; it will be retrieved just above Lake Livingston Dam. During each GPS drifter release, four samples will be collected along the drifter’s flow path: One at the far north end (Above), one in the top quarter (Above Middle), one in the bottom quarter (Below Middle) and one at a location below the dam (Below). Four samples will be collected at each site per event; three events in all will be captured (the plan is for one normal flow and two high/low flow events in order to capture variability and to account for lake residence times; however, this will be weather dependent (approximately 17 samples total with QA/QC samples such as field blanks and duplicates included). Field parameters to be measured are pH, temperature, conductivity, turbidity, and dissolved oxygen collected with a multi parameter sonde at the time of sample collection. Water quality parameters sampled are nutrients and sediment. Nutrient parameters being sampled are ammonia as N, nitrite, nitrite + nitrate, phosphorus, orthophosphate, total nitrogen (NH3 + NO2 + NO3 + Organic), dissolved organic carbon, total organic carbon, and UV-absorbing organic constituents.

- *USGS deployed the drifter on 11-04-15, 12-22-15 and 4-26-16. Problems with shallow depth, high density of vegetative material and slow drift were encountered. In addition, USGS collected water quality samples at the far north end (USGS station Trinity River near Riverside) on 5/3/2016, in the top quarter and bottom quarter on 5/5/2016 and below the dam (USGS station Trinity River near Goodrich) on 5/9/2016. One sampling event has been performed at each of four water quality stations. The field parameters measured were pH, temperature, conductivity, turbidity, and dissolved oxygen. Water quality parameters sampled were nutrients and sediment. Nutrient parameters sampled were ammonia as N, nitrite, nitrite + nitrate, phosphorus, orthophosphate, total nitrogen (NH3 + NO2 + NO3 + Organic), dissolved organic carbon, total organic carbon, and UV- absorbing organic constituents. Lab results from the May sampling event were sent from USGS to GTRI on September 9, 2016. See Table 1 for sampling data results. USGS collected one base flow water-quality sample at:*
- *the far north end (USGS station 08066000 Trinity River at Riverside, Texas) on 10/25/2016*
- *the above middle and bellow middle stations (USGS stations 304521095075501 Livingston Reservoir Site DC near Goodrich, Texas and 303935095055401 Livingston Reservoir Site BC near Goodrich, Texas) on 10/27/2016*
- *a Location below the dam (USGS station 08066250 Trinity River near Goodrich, Texas) on 11/1/2016*
- *One sampling event has been performed at each of four water quality stations. The field parameters measured were pH, temperature, conductivity, turbidity, and dissolved oxygen. Water quality parameters sampled were nutrients and sediment. Nutrient parameters sampled were ammonia as N, nitrite, nitrite + nitrate, phosphorus, orthophosphate, total nitrogen (NH3 + NO2 + NO3 + Organic), dissolved organic carbon, total organic carbon, and UV- absorbing organic constituents.*
- *USGS collected water quality samples listed below:*
    - *01/23/2017 Trinity Rv nr Riverside, Tx*
    - *01/26/2017 Lake Livingston Site DC*
    - *01/26/2017 Lake Livingston Site BC*
    - *01/31/2017 Trinity Rv nr Goodrich, TX*
    - *Note: The drifter was not deployed during this event due to previous problems. Instead, the timing of this sample was based upon: previous drifter data, velocity measurements from Riverside, and reservoir retention time calculations. While*

sampling, high turbidity (117.1 FNU) was observed at site DC, while a turbidity of 12.35 FNU was observed at BC.

- *USGS met with HARC on 2/2/2017 to discuss observations made while collecting the 1/23 – 1/31 sample. Specifically addressing strategies for tracking the flow in Lake Livingston during an event. Agreed to try using the drifter to track flow from Site DC to Site BC for future sample collections.*
  - *USGS collected water quality samples listed below:*
    - *06/09/2017 Trinity Rv nr Riverside, Tx*
    - *06/11/2017 Drifter deployed at 190 Bridge,*
  - *Observations made between bridge and site DC.*
    - *06/15/2017 Lake Livingston Site DC*
    - *06/15/2017 Lake Livingston Site BC*
    - *06/20/2017 Trinity Rv nr Goodrich, TX*
  - *Reviewed events that were previously collected to reassess targeting thresholds:*
    - *05/03/216 to 05/09/2016 discharge of 43,590 cfs at Riverside.*
    - *10/25/2016 to 11/01/2016 low discharge, estimated at 1500 cfs*
    - *01/23/2017 to 01/31/2017 discharge of 17,514 cfs at Riverside.*
    - *06/09/2017 to 06/20/2017 discharge of 15954 cfs at Riverside.*
  - *USGS met with HARC on 7/20/2017 to discuss observations made during June sampling, and how best to use our remaining two sampling events. Determined:*
    - *At least one sample should be collected in winter months.*
    - *One sample should be collected at low flow conditions.*
  - *USGS did not collect water quality samples during the period (9/01/2017-11/30/2017).*
  - *USGS provided GTRI a report of all project data collected to date on 10/02/2017.*
  - *USGS collected water quality samples listed below during the reporting period (12/01/2017-2/28/2018):*
    - *02/25/2018 Trinity River near Riverside, TX*
    - *02/28/2018 Lake Livingston Site DC*
  - *USGS deployed the drifter from the Hwy 190 bridge on 02/25/2018 recovered on 02/28/2018.*
  - *USGS collected water quality samples listed below during the reporting period (3/1/2018-3/31/2018):*
    - *03/01/2018 Lake Livingston Site BC*
    - *03/06/2018 Trinity Rv nr Goodrich, TX*
  - *USGS did not collect water quality samples during the period (06/01/2018-07/31/2018).*
  - *USGS collected water quality samples listed below during the reporting period (8/1/2018-8/31/2018):*
    - *08/08/2018 Trinity Rv at Riverside, TX*
    - *08/14/2018 Lk Livingston DC nr Goodrich, TX*
    - *08/14/2018 Lk Livingston BC nr Goodrich, TX*

- *08/21/2018 Trinity Rv nr Goodrich, TX*

TASK 4: Year-end/Final Reports

Subtask 4.1: Summary Report – The Performing Party will provide a year-end report summarizing first year sampling efforts, initial results and preliminary data analysis.

- *This report completes the third year-end Summary Report.*
- *Data analysis was begun on data received thus far in the project. Discussion focused on best summarization, visualization and results for the data analysis.*
- *The development of a data visual application to showcase project results was initiated.*
  - *Initial GPS drifter results digitized, analyzed and the process to develop them into short video clips was begun.*
  - *Initial water quality monitoring results assessed; nutrients, dissolved oxygen and water temperature results prepared for visualization by date and by constituent.*
  - *Depth profiles for data points received thus far were analyzed and assessed for presentation method.*
  - *Initial frame of story map developed for tabular presentation of spatial results*
  - *Initial frame of spatial results developed constituents by date*

Subtask 4.2: Draft Final Report – The Performing Party will provide a draft report summarizing all project activities, findings, and the contents of all previous deliverables, referencing and/or attaching them as web links or appendices. This comprehensive, technical report will provide analysis of all activities and deliverables under this scope of work. The report should be structured per the following outline:

- Title;
- Table of Contents;
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- Methods;
- Results and Observations;
- Discussion and Data Summary;
- Summary;
- References; and
- Appendices.

No activity to report at this time.

Subtask 4.3: Final Report – The Performing Party will revise the draft final report to address comments provided by the TCEQ Project Manager and the EPA. The Performing Party will submit the final report to the TCEQ Project Manager, who will subsequently submit it to EPA.

No activity to report at this time.

V. Related Issues/Current Problems and Favorable or Unusual Developments

VI. Projected Work for Next Year

- *USGS to continue to deliver lab data results to GTRI as they are available.*
- *GTRI to continue data analysis, as appropriate.*
- *GTRI to continue communications with GBEP.*
- *GTRI to complete all tasks by end of project in April 2019.*