# Nueces Delta Salinity Effects from Pumping Freshwater into the Rincon Bayou: 2009 to 2019

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Prepared by:

James Rizzo, Principal Investigator
Conrad Blucher Institute for Surveying and Science
Texas A&M University-Corpus Christi
6300 Ocean Drive, Corpus Christi, TX 78412
James.Rizzo@tamucc.edu
Phone: (361) 825-5758

Dominic Burch, Research Engineering Associate II
Conrad Blucher Institute for Surveying and Science
Texas A&M University-Corpus Christi
6300 Ocean Drive, Corpus Christi, TX 78412
Dominic.Burch@tamucc.edu
Phone: (303) 520-2175 cell

Submitted to:
**Coastal Bend Bays & Estuaries Program**
615 N. Upper Broadway, Suite 1200
Corpus Christi, TX 78401

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James Rizzo, Principal Investigator
Conrad Blucher Institute for Surveying and Science
Texas A&M University-Corpus Christi
6300 Ocean Drive, Corpus Christi, TX 78412
James.Rizzo@tamucc.edu
Phone: (361) 825-5758

Dominic Burch, Research Engineering Associate II
Conrad Blucher Institute for Surveying and Science
Texas A&M University-Corpus Christi
6300 Ocean Drive, Corpus Christi, TX 78412
Dominic.Burch@tamucc.edu
Phone: (303) 520-2175 cell

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# Nueces Delta Salinity Effects from Pumping Freshwater into the Rincon Bayou: 2009 to 2019

## INTRODUCTION

The focus of this project is monitoring the hydrological effects related to the release of water from Rincon Bayou Pipeline (RBP) into Nueces Delta near Corpus Christi, Texas (Figure 1). This report will highlight trends in salinity changes throughout pumping events from 2009 to 2019 with a more detailed look at effects during the 2018-2019 project year (September 1, 2018 to August 31, 2019). The results of this study are used for the adaptation of the water management plan and will assist water managers in the decisions making process as it relates to quantity, timing, and duration of inflows that are most productive and important to the ecology of the Nueces Delta.

The Nueces Delta has been a scientific research area for many years due to its hypersaline condition (Matthews and Mueller 1987; Whitledge and Stockwell 1995; Montagna et al. 2002; Palmer et al. 2002; Montagna et al. 2009; Hill et al. 2011; Nueces BBEST 2011; Nueces BBASC 2012; Hodges et al. 2012). Because of watershed impoundments, riverbank modifications, and increased urbanization along the Nueces River, the Nueces Delta is no longer connected to the Nueces River except through the overflow channel that was permanently opened in 2001. The only natural freshwater inflow through the Nueces Delta is during severe flooding events or rainfall causing the flow to over bank into the delta (BOR 2000; Pulich et al. 2002; Hill et al. 2011). Decreased inflows into the delta and prolonged droughts cause hypersaline conditions in the Nueces Delta. Freshwater inundation within the Nueces Delta over the past 30 years has been insufficient in volume and distribution to maintain a healthy marsh. In addition, the lack of sediment loading in the system is leading to the delta front eroding into Nueces Bay. Marsh plants are under stress and the connectivity of aquatic habitat is threatened (Hodges et al. 2012).

In 1990, studies of this environment found a hypersaline condition that could harm the ecological and biological processes of the marsh that if left unchecked would degrade the health of the Estuary. This impact evoked the state of Texas to develop an inflow criterion for freshwater inflows (Dunton and Alexander 2000; Montagna et al. 2002; Palmer et al. 2002). The resultant 2001 Order from the Texas Commission on Environmental Quality (TCEQ) requires the City of Corpus Christi (City) to provide no less than 151,000 acre-feet (186,255,757 $m^3$) per year to the Nueces Estuary (TCEQ 1995). Each month the City is required to "pass through" inflow to the Nueces Estuary equal to the measured inflow into the Choke Canyon/Lake Corpus Christi Reservoir System up to a target amount (TCEQ 1995). The target amount varies by month with calculations based on the combined volume of the Reservoir System. The City may receive credits for excess flow from the previous month or from relief credits based on salinity measured at the SALT03 monitoring station in Nueces Bay (Montagna et al. 2009).

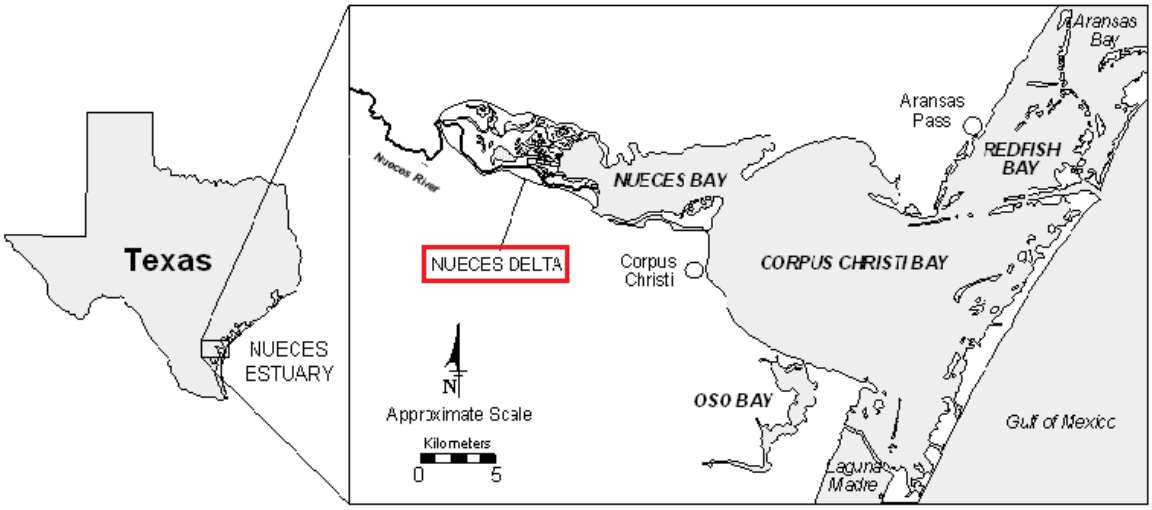



*Figure 1. Location of the Nueces Delta within Texas and the Nueces Watershed.*

To efficiently deliver freshwater to the Nueces Delta the City built the Rincon Bayou pump station and pipeline (RBP). The RBP diverts the first 3,000 acre-feet (3,700,446 $m^3$) of required "pass throughs" to the upper Rincon Bayou in the Nueces Delta. The RBP became operational in November 2007. The RBP pump station includes three (3) 350hp mixed flow submersible pumps capable of moving 60,000 gallons per minute (Table 1). The number of days to deliver a given volume of freshwater through the RBP depends on the number of pumps used.

Table 1. Capacity of the Rincon Bayou Pipeline.

| | **Number of Rincon Bayou Pumps in Operation** | | |
|---|---|---|---|
| | **1** | **2** | **3** |
| Flow, gallons/minute | 28,000 | 46,000 | 60,000 |
| Flow, cubic feet/second | 62 | 102 | 134 |
| Flow, acre-feet/day | 124 | 203 | 265 |
| Total kW | 230 | 455 | 675 |

This project's principal objective is to monitor the effects of the freshwater releases into the Nueces Delta system with monitoring stations located downstream from the RBP and adjacent to the Rincon Delta. Salinity downstream is the primary indicator measured. The results of this study will be used in the development of a Rincon Bayou Pipeline Management Plan that will help decision makers on quantity, timing, and duration of pipeline inflow events that are most productive and significant to the ecology of the Nueces Delta.

A)

B)

*Figure 2. Rincon Bayou Pumping facilities A) the intake pumps located on the Nueces River above the Calallen Dam and B) the pipeline outfall in the Rincon Bayou. Photos taken by Jace Tunnell.*

## METHODS

The Conrad Blucher Institute for Surveying and Science (CBI) at Texas A&M University - Corpus Christi (TAMU-CC), under contract with the Coastal Bend Bays & Estuaries Program (CBBEP), operates, maintains, and manages this monitoring project in the Nueces River Delta. CBI installed and has maintained a network of monitoring stations located downstream of the RBP in the Nueces Delta and Bay. The monitoring stations collect data continuously to ensure data are captured during all RBP freshwater releases (Figure 3).

Each Nueces Delta (NUDE) station is jetted approximately five feet into the sediment near the water's edge with a water quality datasonde extending into the channel, which vary in distance at each location. NUDE2 is located in the middle reach of Rincon Bayou (27.888611°N, 97.569444°W) and NUDE3 is located in the lower reach of the Rincon Bayou (27.883774°N, 97.533188°W) within the tidal zone. SALT08 is located in the lower Rincon Bayou at the confluence of Nueces Bay (27.870428°N, 97.517090°W). Salinity data from SALT08 provides verification that RBP freshwater has reached water into Nueces Bay. SALT03 (27.851561°N, 97.482028°W) is located in the middle of Nueces Bay and SALT05 (27.891601°N, 97.610684°W) is located in the Nueces River. Both of these stations are used as references in the report comparing bay and river salinity to the salinity in the Rincon Bayou. The SALT04 monitoring station was reinstalled in the mitigation channel southeast of South Lake (27.867197°N, -97.549240°W) and collects baseline salinity data for comparison to a potential flow regime change that may results from future construction of a diversion channel from the Rincon Bayou to the mitigation channel.


*Figure 3. RBP [red line]), RBP flow [orange line], Nueces River [blue line], and monitoring stations NUDE2, NUDE3, SALT04, and SALT08.*

A tide gauge (NUEBAY 185) is located in Nueces Bay (27.832149°N, -97.485056°W) and measures water level (m), water temperature (°C), wind speed (m/s), wind gusts (m/s), wind direction (°), and barometric pressure (mbar). A weather station, NUDEWX is located on Rincon Bayou downstream from the RBP outfall (27.897582°N, -97.616524°W). The NUDEWX measures wind speed (m/s), wind direction (°), barometric pressure (mbar), rainfall (mm), relative humidity (%), and solar radiation (cal/cm$^2$/min). The CBI performed monthly maintenance to NUDEWX including a rain gauge calibration check. NUEBAY 185 is serviced annually per NOAA COOPS standards for water level monitoring stations. (http://tidesandcurrents.noaa.gov/).

The salinity monitoring stations consists of Hydrolab® MS5 or H20 water quality datasondes interfaced with cellular IP modem (Figure 4). Stations are polled autonomously by systems developed by CBI. Data are stored in a secure database and disseminated via project specific web pages along with maps indicating station locations. Other project specific information such as the Quality Assurance Project Plan, Scope of Work, Data Management Documentation, Datasonde Standard Operating Procedures, Quality Assurance Quality Control documents, and datasonde calibration records are also archived within our secure database.

The Hydrolab MS5 datasondes located at SALT01, SALT03, and SALT05 measure water temperature (°C), specific conductance (µS/cm), salinity (PSU), pH, dissolved oxygen (% saturation & mg/L), and depth (m). Hydrolab H20 datasondes at SALT08, NUDE2, and NUDE3 measure: water temperature (°C), specific conductance (µS/cm), salinity (ppt). Instruments deployed are replaced with calibrated datasondes on a regular schedule. Calibration and post-calibration of datasondes are performed within CBIs lab, all quality assurance and control records archived.

Data are available at: http://cbi.tamucc.edu/cbi/data/.

## RESULTS AND DISCUSSION

Forty-five pumping events have occurred since the RBP became operational in late 2007 (Table 2). No pumping events occurred during the first year (September 2008-August 2009) due to a persistent drought limiting freshwater supply. Three pumping events occurred during year two (2009-2010) totaling 6,017 acre-feet (7,421,860 m$^3$), three pumping events in year three (2010-2011) totaling 2,997 acre-feet (3,696,745 m$^3$), four pumping events in year four (2011-2012) totaling 5,695 acre-feet (7,024,679 m$^3$), four pumping events occurred in year five (2012-2013) totaling 3,991 acre-feet (4,922,826 m$^3$), five pumping occurred in year six (2013-2014) totaling 11,694 acre-feet (14,424,337 m$^3$), and six pumping events occurred during year seven (2014-2015) totaling 14,097 acre-feet (17,388,394 m$^3$) of freshwater delivered to the Rincon Bayou. Seven pumping events have occurred during year eight (2015-2016) during which 18,616 acre-feet (22,962,464 m$^3$) were pumped. Eight pumping events occurred in year nine (2016-2017) during which 25,844 acre-feet (31,878,105 m$^3$) were pumped. Four pumping events occurred in year ten (2017-2018) during which 4,419 acre-feet (5,450,756 m$^3$) were pumped. Two pumping events occurred in year eleven (2018-2019) during which 11,950 acre-feet (14,740,108 m$^3$) were pumped (Figures 5-6).

Table 2. RBP pumping events including dates, duration, and acre-feet pumped.

| Year | Pumping Event | Dates of Event | Duration (days) | Avg. water level (m above MSL) | Acre-Feet Pumped | Wet/Dry Period |
|---|---|---|---|---|---|---|
| 1 | - | No pumping occurred | | | | |
| 2 | 1 | Sep. 28 to Oct. 21, 2009 | 24 | 0.14 | 2,987 | Wet |
| | 2 | Jan. 6 to Jan. 14, 2010 | 9 | -0.21 | 742 | |
| | 3 | May 10 to May 31, 2010 | 21 | 0.14 | 2,288 | |
| 3 | 4 | Mar. 21 to Mar. 30, 2011 | 10 | 0.03 | 1,001 | Dry |
| | 5 | May 3 to May 12, 2011 | 10 | 0.08 | 1,002 | |
| | 6 | Jun. 13 to Jun. 22, 2011 | 10 | 0.03 | 994 | |
| 4 | 7 | Nov. 2 to Nov. 22, 2011 | 21 | 0.03 | 2,031 | Dry |
| | 8 | Mar. 7 to Mar. 19, 2012 | 13 | 0.08 | 1,310 | |
| | 9 | Jun. 21 to Jul. 13, 2012 | 23 | 0.19 | 2,354 | |
| 5 | 10 | Oct. 5 to Oct. 18, 2012 | 13 | 0.07 | 2,017 | Dry |
| | 11 | Jun. 1 to Jun. 10, 2013 | 10 | 0.16 | 717 | |
| | 12 | Jun. 24 to Jul. 2, 2013 | 9 | -0.01 | 731 | |
| | 13 | Jul. 17 to Jul. 21, 2013 | 5 | 0.19 | 526 | |
| 6 | 14 | Oct. 21 to Nov. 9, 2013 | 16 | 0.24 | 2,348 | Dry |
| | 15 | Nov. 22 to Dec. 8, 2013 | 12 | 0.04 | 613 | |
| | 16 | Feb. 3 to Feb. 15, 2014 | 13 | -0.10 | 2,466 | |
| | 17 | May 9 to Jun. 3, 2014 | 24 | 0.12 | 2,736 | |
| | 18 | Jun. 23 to Jul. 15, 2014 | 23 | 0.05 | 3,531 | |
| 7 | 19 | Oct. 1 to Oct. 6, 2014 | 6 | 0.23 | 319 | Wet |
| | 20 | Jan. 18 to Jan 27, 2015 | 10 | -0.14 | 695 | |
| | 21 | Mar. 10 to Mar. 12, 2015 | 3 | -0.06 | 210 | |
| | 22 | Mar. 19 to Mar. 25, 2015 | 7 | -0.04 | 1,535 | |
| | 23 | Apr. 13 to Apr. 28, 2015 | 16 | 0.16 | 2,455 | |
| | 24 | May 12 to Jun. 15, 2015 | 35 | 0.24 | 8,883 | |
| 8 | 25 | Aug. 29 to Sep. 1, 2015 | 4 | 0.14 | 449 | Wet |
| | 26 | Sep. 21 to Oct. 1, 2015 | 11 | 0.26 | 642 | |
| | 27 | Oct. 17 to Nov. 10, 2015 | 25 | 0.33 | 3,821 | |
| | 28 | Jan. 3 to Jan. 28, 2016 | 26 | 0.06 | 2,160 | |
| | 29 | Feb. 18 to Feb. 23, 2016 | 6 | 0.05 | 672 | |
| | 30 | Mar. 16 to Mar. 23, 2016 | 8 | 0.05 | 794 | |
| | 31 | May 23 to Jul. 14, 2016 | 53 | 0.16 | 10,078 | |
| 9 | 32 | Aug. 8 to Sep. 22, 2016 | 46 | 0.20 | 7,816 | Wet |
| | 33 | Nov. 13 to Nov. 29, 2016 | 16 | 0.21 | 1,429 | |
| | 34 | Dec. 12 to Dec. 27, 2016 | 15 | 0.13 | 2,492 | |
| | 35 | Jan. 10 to Jan. 23, 2017 | 14 | 0.09 | 1,959 | |
| | 36 | Feb. 15 to Mar. 2, 2017 | 16 | 0.04 | 1,382 | |
| | 37 | Mar. 13 to Mar. 23, 2017 | 11 | 0.06 | 1,997 | |
| | 38 | Apr. 16 to Apr. 28, 2017 | 13 | 0.22 | 2,145 | |
| | 39 | May 16 to Jul. 1, 2017 | 43 | 0.22 | 6,624 | |
| 10 | 40 | Aug. 20 to Aug. 25, 2017 | 6 | 0.01 | 563 | Wet |
| | 41 | Oct. 3 to Oct. 17, 2017 | 15 | 0.01 | 1,840 | |
| | 42 | Apr. 4 to Apr. 9, 2018 | 8 | 0.11 | 740 | |
| | 43 | May 14 to May 26, 2018 | 13 | 0.02 | 1,276 | |
| 11 | 44 | Sep. 17 to Oct. 17, 2018 | 31 | 0.02 | 6,169 | Wet |
| | 45 | Jun. 19 to Jul. 23, 2019 | 34 | 0.02 | 5,781 | |

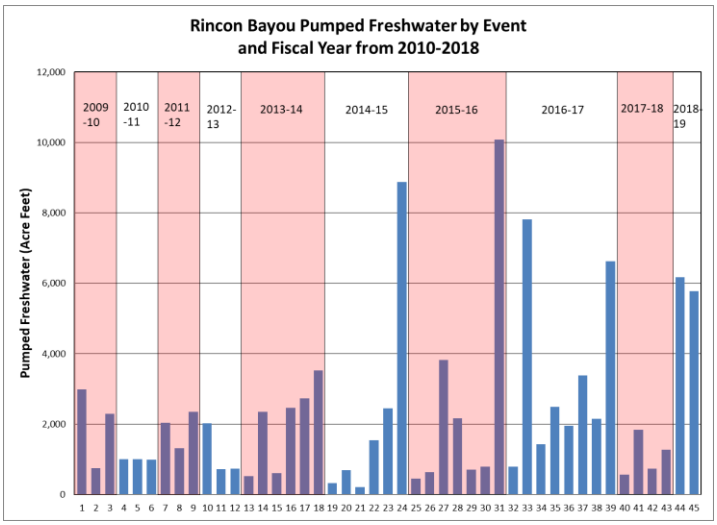



*Figure 4. Rincon Bayou pumping events by year from 2010-2019.*

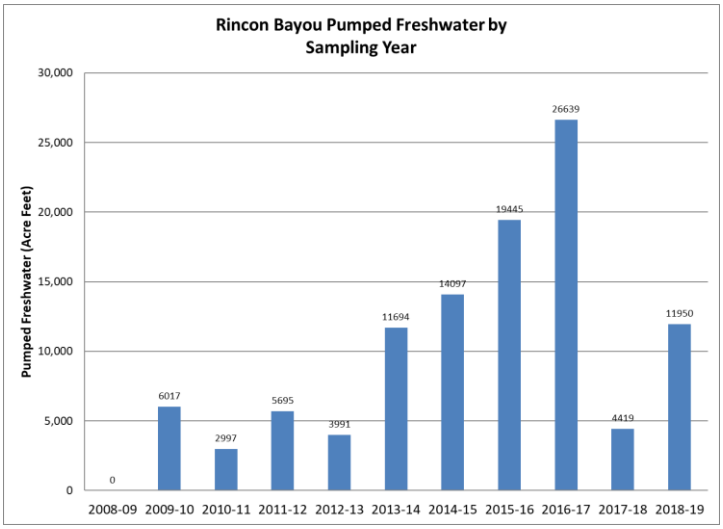



*Figure 5. Total amount of freshwater pumped for each sampling year.*

Local rainfall varied spatially between the National Weather Service (National Weather Service 2018) at Corpus Christi International Airport (CRP) at 27°46'22.43"N, 97°30'8.47"W and at NUDEWX at 27°53'50.47"N, 97°36'58.73"W with more rainfall frequently occurring at CRP (Table 3). NUDEWX is approximately 11 miles northwest of CRP and is located in the Nueces Delta. Despite the regional difference in rainfall, both locations still recorded similar rainfall trends and were representative of the general meteorological conditions in the Nueces Delta watershed.

Table 3. Total rainfall per sampling year for NUDEWX and CRP.

| | **2008-09** | **2009-10** | **2010-11** | **2011-12** | **2012-13** | **2013-14** | **2014-15** | **2015-16** | **2016-17** | **2017-18** | **2018-19** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NUDEWX | 3.0in | 15.6in | 7.9in | NA | 7.13 in | 19.29 in | 29.68 in | 18.24 in | 35.49 in | 24.75 in | 27.8 in |
| CRP | 8.81in | 42.9in | 25.3in | 18.68in | 14.16 in | 18.69 in | 48.51 in | 30.18 in | 28.03 in | 29.12 in | 31.8 in |

Rainfall data varied greatly between years with the first year in 2008-2009 starting in a persistent drought and the following 2009-2010 year being the wettest period on Texas record with 42.9 in (108.87cm) at CRP and 15.6 in (39.62 cm) at NUDEWX. The 2010-2011 and 2011-2012 years had progressively less rainfall on record with 25.3 in (64.26 cm) at CPR and 7.9 in (20.01 cm) at NUDEWX in the 2010-2011 year and 18.68 in (47.45 cm) at CRP during the 2011-2012 year. The precipitation sensor at NUDEWX was offline for repairs for approximately 3 months during 2011-2012 year and missed several rain events causing the annual rainfall total to be inaccurate. The 2012-2013 year had the least precipitation to date among sampling years with only 14.16 in (35.97 cm) of rainfall recorded at CRP and 7.13 in (18.11 cm) at NUDEWX. The precipitation during the 2013-2014 year was the fifth wettest year compared to previous sampling years with 18.69 in (47.47 cm) of rainfall at CRP and 19.29 in (49.00 cm) at NUDEWX. The 2014-2015 sampling year was the second wettest to date with 48.51 in (123.22 cm) of rainfall at CRP and 29.68 in (75.39 cm) recorded at NUDEWX. The 2015-2016 sampling year was the sixth wettest year with 30.18 in (76.66 cm) of rainfall at CRP and 18.24 in (46.33 cm) at NUDEWX. Drought conditions were absent throughout most of Texas during the 2016-2017 sampling season. The 2016-2017 sampling year was one of the wettest years to date with NUDEWX recording a sampling year record of 35.49 in (90.14 cm) and CRP reporting 28.03 in (71.20 cm). The 2017-2018 sampling year was the fourth wettest year to date (Figure 6) with NUDEWX recording a sampling year record of 24.75 in (62.87 cm) and CRP reporting 29.12 in (73.96 cm). The most recent 2018-2019 sampling year was the third wettest year to date with NUDEWX recording a sampling year record of 27.8 in (70.61 cm) and CRP reporting 31.8 in (80.77 cm).

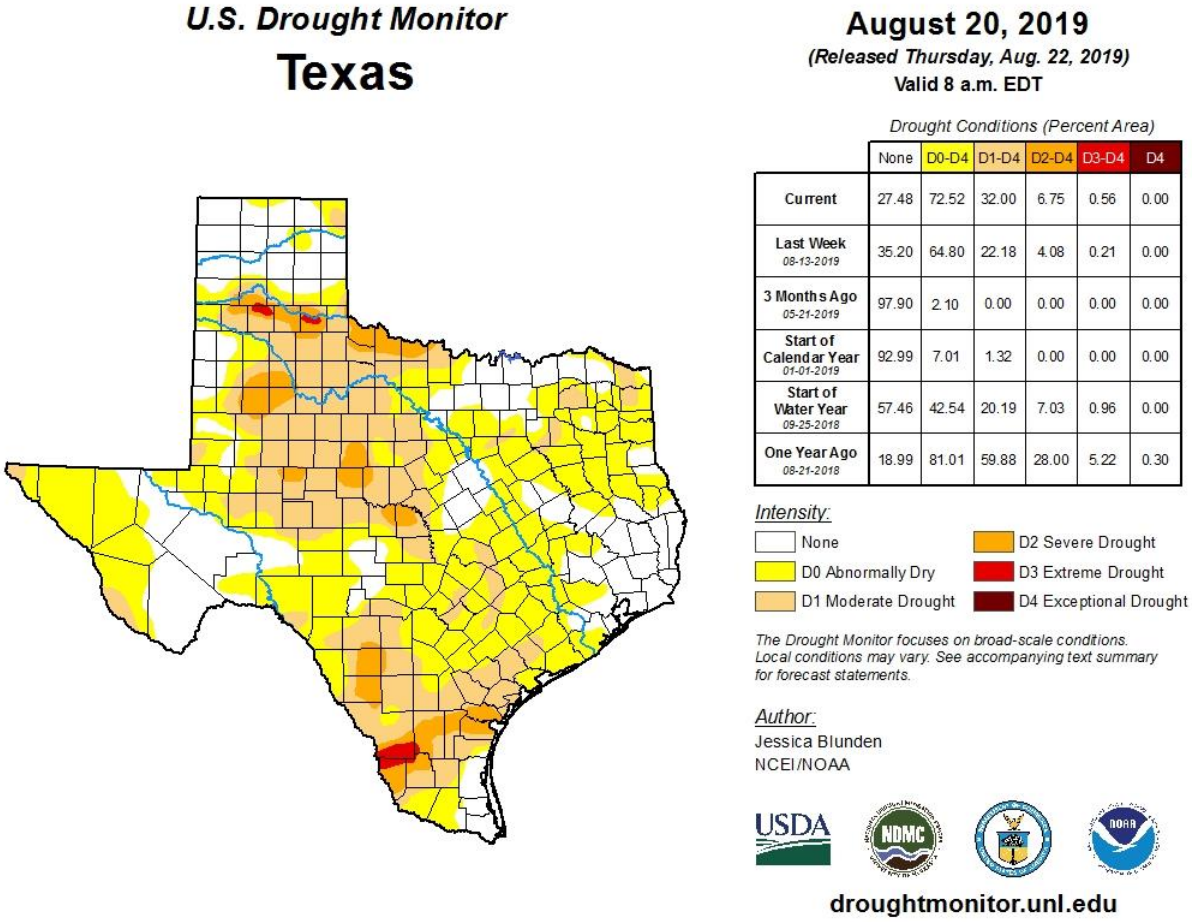



*Figure 6. Drought condition during this project year.*

Capacities at Lake Corpus Christi varied between 15.1% and 29.9% with a daily average of 17.5% throughout the 2012-2013 sampling year, the lowest levels seen in over 16 years (Nueces River Authority 2016). The Choke Canyon reservoir levels varied between 38.6% and 52.5% with an average of 45.8% during the 2012-2013 year (Nueces River Authority 2016). The following 2013-2014 sampling year were generally greater with Lake Corpus Christi ranging between 23.6% and 100.0% with a daily average of 74.5% and the Choke Canyon Reservoir ranging between 29.3% and 36.8% with a daily average of 33.5% (Nueces River Authority 2016). The 2014-2015 sampling year exhibited the highest reservoir capacities to date with Lake Corpus Christi ranging between 45.7% to 100.0% capacity with a daily average of 63.5% and Choke Canyon Reservoir ranging between 24.0% to 41.3% capacity with a daily average of 28.5%. The high amount of rainfall during the 2015-2016 sampling year resulted in generally high reservoir capacities with Lake Corpus Christi ranging between 63.0% to 89.4% capacity with a daily average of 79.3% and Choke Canyon Reservoir ranging between 32.8% to 38.4% capacity with a daily average of 35.6%. Reservoir capacities during the 2016-2017 sampling year were similar to the 2015-2016 sampling year in that both resulted in relatively high rainfall amounts and reservoir capacities. Lake Corpus Christi reservoir levels ranged between 71.8% and 96.3% with a daily average of 84.0% and Choke Canyon reservoir levels varied between 33.4% and 43.8% during the 2016-2017 sampling year with a daily average of 38.6%. Reservoir

capacities during the 2017-2018 sampling year were similar to the 2016-2017 sampling year in that both resulted in relatively high rainfall amounts and reservoir capacities. Lake Corpus Christi reservoir levels ranged between 65.9% and 100% with a daily average of 82.95% and Choke Canyon reservoir levels varied between 23.5% and 33.2% during the 2017-2018 sampling year with a daily average of 28.35%. Reservoir capacities during the 2018-2019 sampling year were similar to the 2017-2018 sampling year in that both resulted in relatively high rainfall amounts and reservoir capacities. Lake Corpus Christi reservoir levels ranged between 64.6% and 100.0% with a daily average of 82.3% and Choke Canyon reservoir levels varied between 23.3% and 55.4% during the 2018-2019 sampling year with a daily average of 39.35%.

Salinities recorded at NUDE2 generally drop shortly after a pumping event was initiated and gradually increased after the end of a pumping event (Figure 7). Pumping event 44, the salinity at NUDE2 slowly fell from approximately 25 PSU to under 5 PSU and lasted approximately 31 days after initiating the pumps. During pumping event 45, the salinity at NUDE2 slowly fell from approximately 20 PSU to under 5 PSU, and lasted approximately 34 days after initiating the pumps.

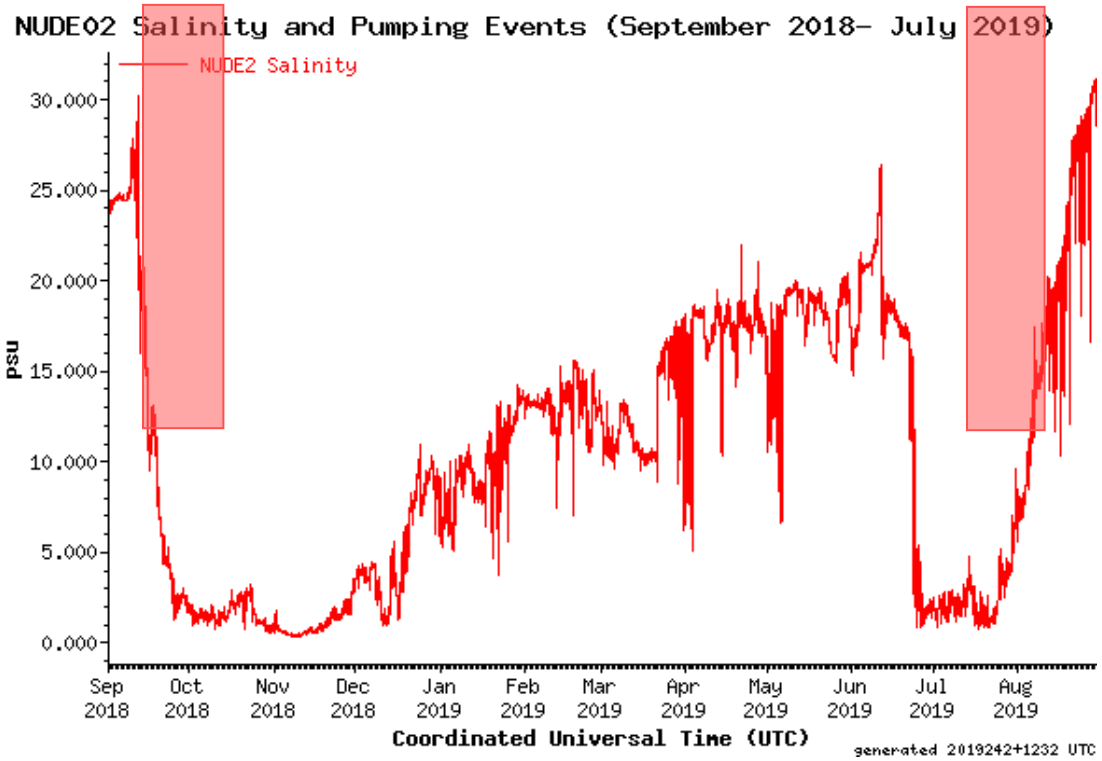
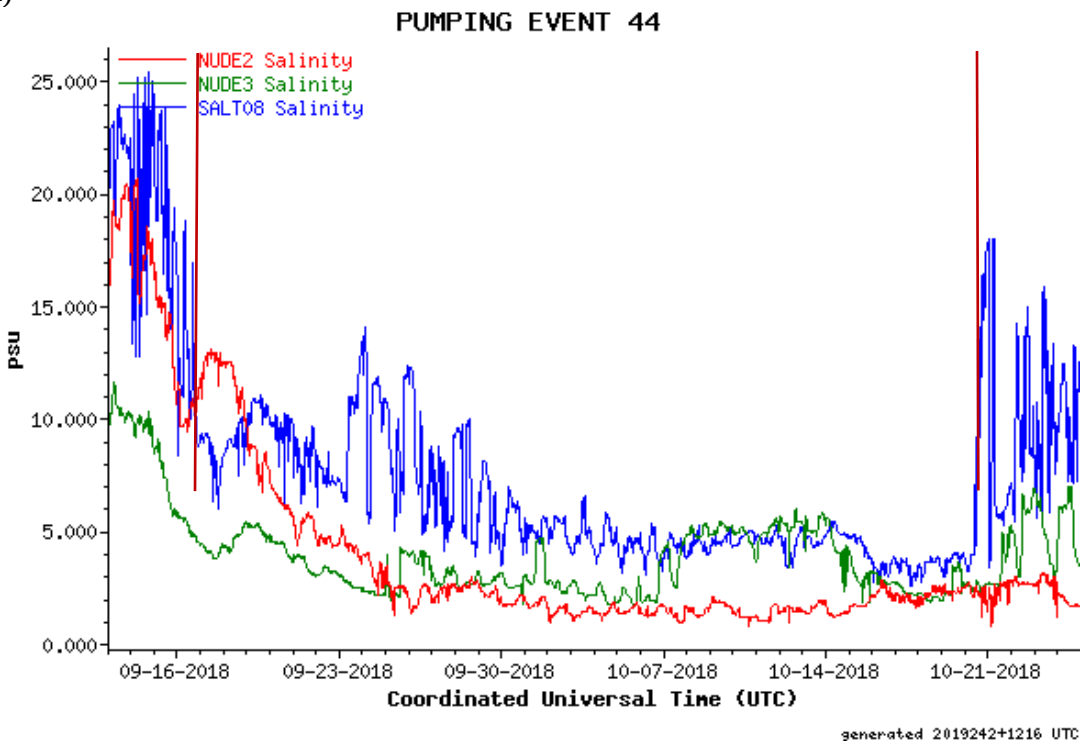



*Figure 7. NUDE2 salinity during the 2018-2019 pumping events. Shaded areas indicate pumping event duration in days.*

A)

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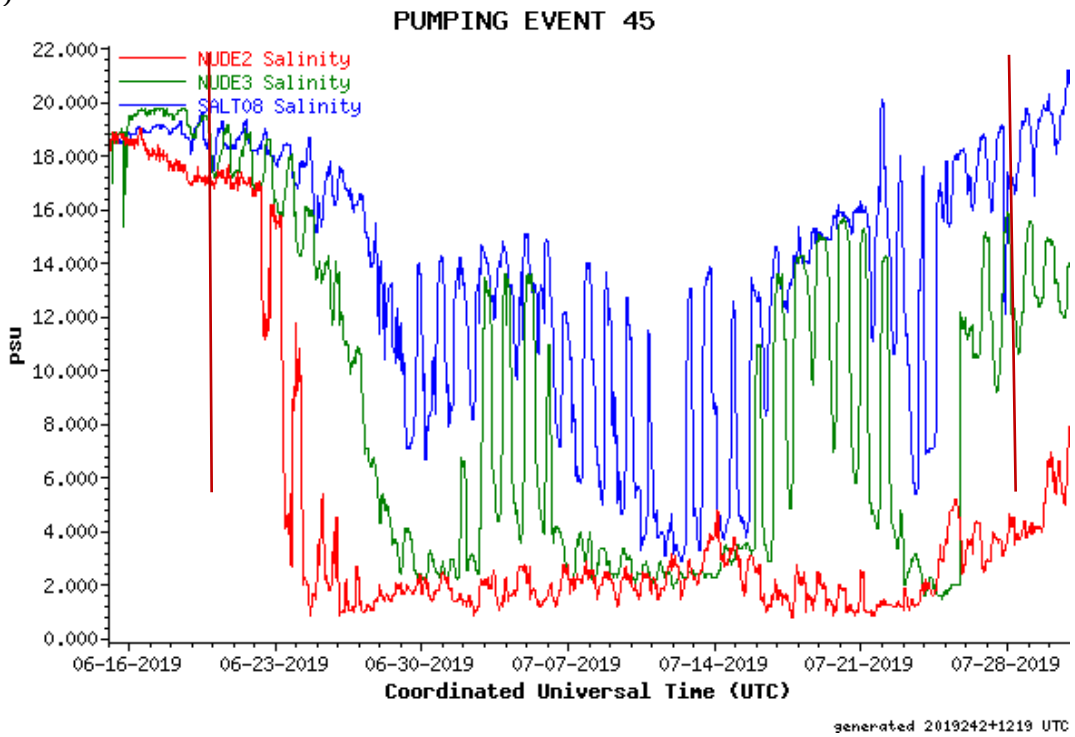


*Figure 8. Individual pumping events during the 2018-2019 year. Vertical lines within each graph indicate the pumping event with 4 days of data pre and post event. ((A) event 44 and B) event 45).*

In addition to freshwater inflows, the salinities in the Nueces Delta are also influenced by tidal variations which will cause movements of fresh and saltwater separated by a halocline (Adams and Tunnell 2010). As the tide rises, saltwater nearer to the bay is forced further back into the delta, and as the tide lowers, freshwater located further away from the bay is pulled closer to the bay. This is evident at SALT08, which will undergo rapid increases and decreases in salinity after a pumping event in correlation with rising and lowering tides (Figure 10).

At least some tidal influence on salinity levels at SALT08 appeared to be present during periods of all pumping events during the 2018-2019 sampling year. Diurnal tidal variation appeared to have little to no effect on salinities at NUDE2 during pumping events. Wind direction, wind velocity, evaporation, and rainfall during pumping events have all had an effect on hydrodynamics in the Nueces Delta (Adams and Tunnell 2010).

Pumping events did not seem to have a significant effect on salinity levels at the new SALT04 monitoring station. This is as expected as the mitigation channel currently has no direct connection to the Rincon Bayou. Salinity values at SALT04 ranged from 9.3 to 42.9 PSU with an average of 29.1 PSU during the sampling year. SALT04 will continue to monitor salinity values for the potential construction of a diversion channel that will connect the Rincon Bayou to the mitigation channel.

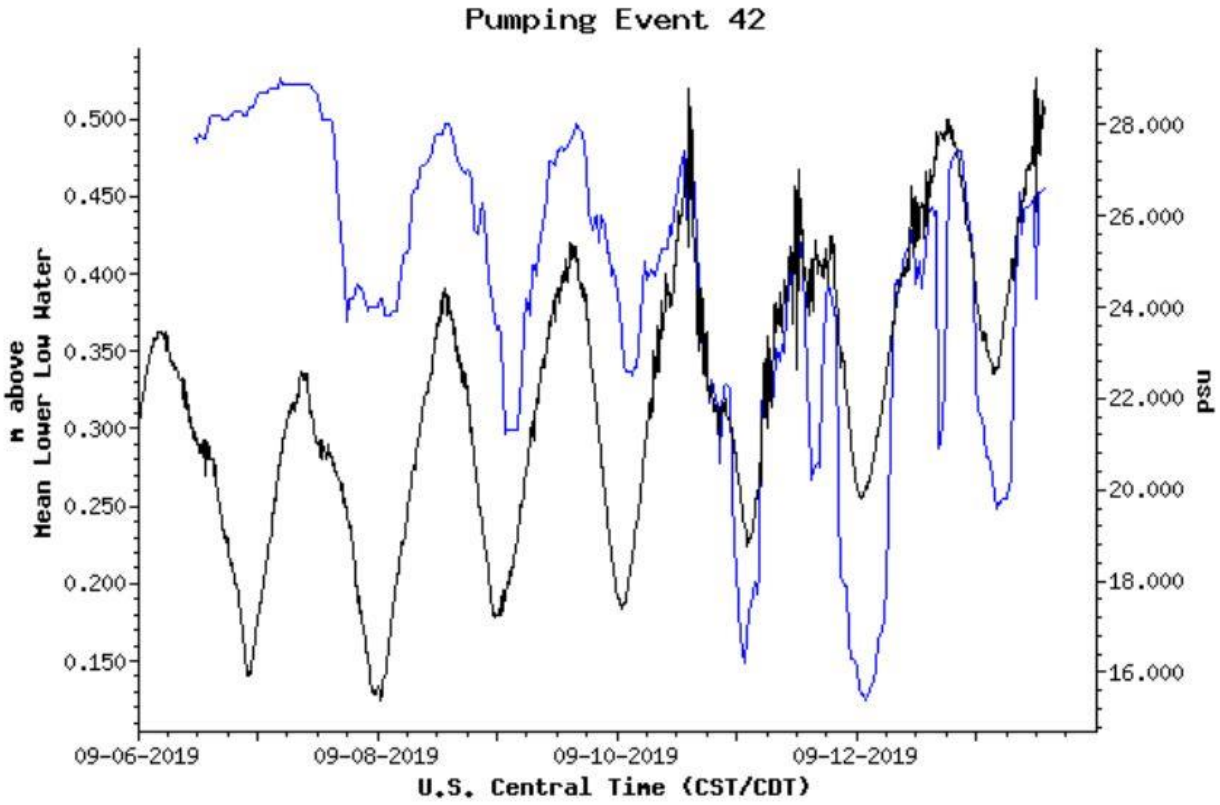


*Figure 9. Salinity and tidal variations at SALT* during pumping event.*

## CONCLUSIONS

The City of Corpus Christy, under the provisions of the 2001 Agreed Order established by the TCEQ, is required to provide freshwater inflows into Nueces Bay, Texas. Specific quantities diverted from the Nueces River vary temporally, based on historical river inflows. In an effort to potentially maximize the freshwater inflows, a strategy of introducing the supplemental inflows into the upper Nueces delta rather than directly into the Nueces River was agreed upon after a recommendation by the Nueces Estuary Advisory Committee (NEAC). A new pump station owned and operated by the City of Corpus Christi takes raw river water from the river pool above the salt barrier dam and moved it into the upper delta at the head of the Rincon Bayou. This project is designed to measure the fate of the freshwater, using salinity, tides, and meteorological data as a measuring tool.

During the 2018-2019 sampling year 11,950 acre-feet of water was pumped via the RBP. All the pumping events during the 2018-2019 sampling year were relatively large in terms of amount of water pumped with the minimum amount pumped at 5,781 acre-feet during event 45. Most of the pumping events during the 2018-2019 sampling year were typical with salinities dropping to below 5 PSU shortly after initiating the pumps.

Citation:
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