Nueces Delta Salinity Effects from Pumping Freshwater into the Rincon Bayou: 2009 to 2013

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Nueces Delta Salinity Effects from Pumping Freshwater into the Rincon Bayou: 2009 to 2013

INTRODUCTION

This project's focus is monitoring the hydrological effects sourced from the Rincon Bayou Pipeline (RBP) in the Nueces Delta near Corpus Christi, Texas (Figure 1). This report will highlight some of the trends in salinity changes throughout all the pumping events since 2009, and have a more detailed look at the effects seen during fiscal year 2013 (September 1, 2012 to August 31, 2013). The results of this study are being used in the development of a water management plan that will help water managers make important decisions on quantity, timing, and duration of pipeline inflows that are most productive and important to the ecology of the Nueces Delta.

The Nueces Delta has been a scientific research concentration 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 Nueces River Overflow channel that was permanently opened in 2001. Because of these factors, the majority of freshwater flow is diverted from the river directly to the bay, bypassing the delta. The only way freshwater flows through the Nueces Delta is during severe flooding events or local heavy rainfall causing the flow to over bank into the delta (BOR 2000; Pulich et al. 2002; Hill et al. 2011). These decreased inflows into the delta and the prolonged Texas droughts cause the hypersaline conditions we see currently. Freshwater inundation within the Nueces Delta over the past 30 years has been insufficient in volume and distribution to maintain a healthy marsh, the lack of sediment loading in the system is leading to the delta front eroding into Nueces Bay, the marsh plants are under stress, and the connectivity of aquatic habitat is threatened (Hodges et al. 2012).

In 1990, studies of this hypersaline environment found to pose harm to ecological and biological processes and overall health degradation of the Nueces 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 Agreed 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 instream flow into the Choke Canyon Reservoir/Lake Corpus Christi Reservoir System up to a target amount (TCEQ 1995). The target amount varies by month and is calculated based on the combined storage 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).

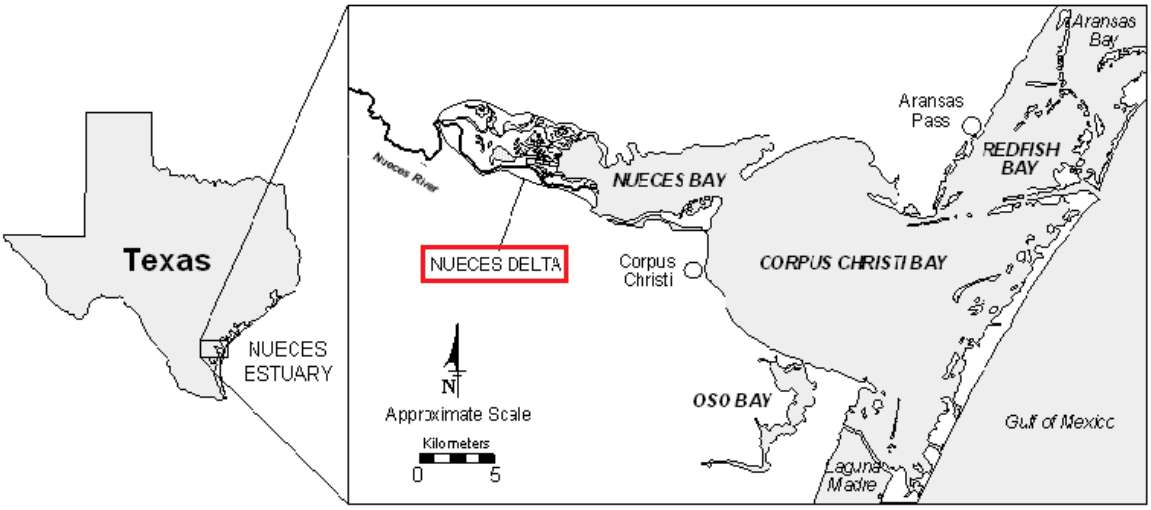


Figure 1. Location of the Nueces Delta within Texas and the Nueces Watershed.

To efficiently deliver freshwater to the Nueces Delta, the City built the Rincon Bayou pump station and pipeline (RBP) to divert up to 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 350 horsepower mixed flow submersible pumps capable of moving up to 60,000 gallons per minute with all three pumps operating (Table 1; Figure 2). 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 RBP as it releases freshwater into the Nueces Delta system with Conrad Blucher Institute stations to measure the salinity downstream and in adjacent areas to the main channel. The results of this study will be used in the development of a Rincon Bayou Pipeline Management Plan that will help water managers make important decisions on quantity, timing, and duration of pipeline inflow events that are most productive and

A)

B)

Figure 2. View of RBP pumping facilities depicting A) the intake pumps located on the Nueces River above the Calallen Dam and B) the pipeline outfall in the Rincon Bayou.

important to the ecology of the Nueces Delta. This report will focus on describing the distribution of RBP freshwater inflows in the Nueces Delta and provide a descriptive analysis for the four (4) RBP inflow events that occurred in the months of October 2012, June 2013, and July 2013. This project represents the fifth year of monitoring the RBP in the Nueces Estuary.

METHODS

The Coastal Bend Bays & Estuaries Program (CBBEP) contracts this salinity-monitoring project to the Conrad Blucher Institute for Surveying and Science (CBI) at Texas A&M University - Corpus Christi (TAMU-CC). CBI installed and maintains a network of three salinity-monitoring stations located downstream in the Nueces Delta and Bay recording data in correspondence with the RBP freshwater releases (Figure 3).

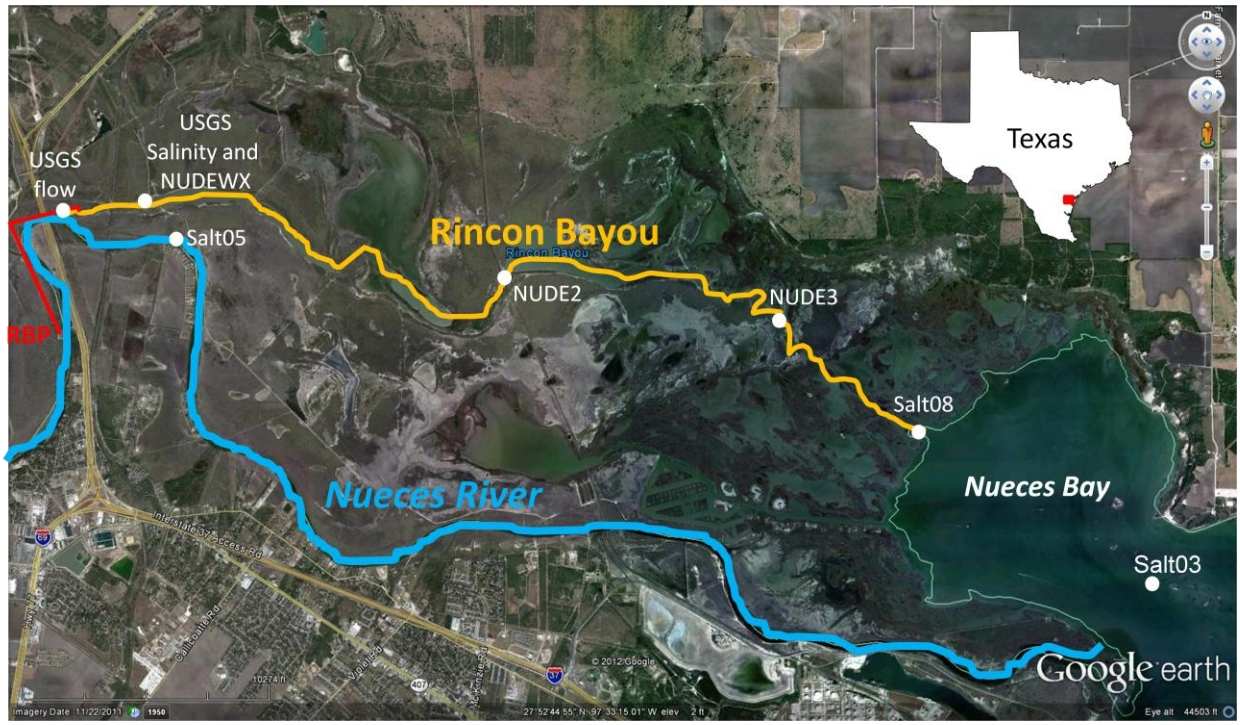


Figure 3. Map showing the RBP (Rincon Bayou Pipeline [red line]) and the three salinity monitoring stations for this project (NUDE2, NUDE3, and SALT08).

Each NUDE station is jetted approximately five feet down into the sediment near the water's edge and the sonde is extended into the deepest parts of 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 tidally influenced reach of Rincon Bayou (27.883774°N, 97.533188°W). 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 RBP freshwater has reached the interface to 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 stations are used as references in the report to compare bay and river salinity, respectively, to Rincon Bayou.

A tide gauge (NUDEBAY 185) is located in Nueces Bay and measures primary water level (m), water temperature (°C), wind speed (m/s), wind gusts (m/s), wind direction (°), and barometric pressure (mbar). The weather station, NUDEWX is located on Rincon Bayou downstream from the RBP outfall. 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. NUDEBAY 185 is serviced every 6 months.

The CBI salinity monitoring stations involve Hydrolab® MS5 and H20 water quality datasondes interfaced with line of sight spread spectrum radios aimed back to TAMU-CC (Figure 4). Stations are radio polled by an automated computer program designed and implemented by the Information Technology staff at CBI. Data is stored in the CBI project webpage that includes a map showing station locations, Quality Assurance Project Plan, Scope of Work, Data Management Documentation, Datasonde Standard Operating Procedures, Quality Assurance Quality Control documents, datasonde calibration records, and graphs of the previous seven days of data collected from each station. Each Hydrolab measures water quality parameters. Hydrolab MS5 datasondes at SALT01, SALT03, & SALT05 measure: water temperature (°C), conductivity (µS), salinity (ppt), pH, dissolved oxygen (% saturation & mg/L), and depth (m). Stations Hydrolab H20 datasondes at SALT08, NUDE2, and NUDE3 measure: water temperature (°C), conductivity (µS), salinity (ppt). Instruments are exchanged monthly with replacement calibrated datasondes (Figure 5). Calibration and post-calibration of datasondes are performed at the CBI wet lab with all quality control forms retained in the laboratory record book and stored online in the publically accessible CBI Environmental Database http://lighthouse.tamucc.edu/RinconSalinity.

Figure 4. Dominic Burch uses a radio and computer to call NUDE3 and SALT08 before and after exchanging the sondes to ensure the devices are measuring salinity accurately.

Figure 5. Dominic Burch exchanges the sondes (NUDE3 on top; SALT08 on bottom) with a newly calibrated device, which will last approximately 4 weeks until another sonde will be exchanged again.

RESULTS AND DISCUSSION

Thirteen pumping events have occurred since the RBP became operational in late 2007. No pumping events occurred during the first year due to a persistent drought limiting freshwater supply. Three pumping events occurred during year two totaling 6,017 acre-feet (7,421,860 m^3) of freshwater pumped to the Rincon Bayou. Three pumping events in year three totaling 2,997 acre-feet (3,696,745 m^3) of freshwater were pumped to the Rincon Bayou. Four pumping events occurred during year four during which 5,695 acre-feet (7,024,679 m^3) of freshwater were delivered to the Rincon Bayou. So far, 3,991 acre-feet (4,921,592 m^3) of freshwater have been pumped to the Rincon Bayou during year five as of July 21, 2013 (Table 2).

Local rainfall varied spatially between the National Weather Service 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 regularly occurring at CRP (Table 3). NUDEWX is approximately 11 miles northwest of CRP and is located directly 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.

Rainfall data varied greatly between years with the first year in 2008-2009 starting in a persistent drought and representing the driest year to date. The following 2009-2010 year was 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 current 2012-2013 year is the driest to date since the project beginning in the 2008-2009 year. As of July 21, 2013, only 14.16 in (35.97 cm) of rainfall has been recorded at CRP and 7.13 in (18.11 cm) at NUDEWX for the 2012-2013 sampling year. Drought conditions have persisted across the Texas watershed leading into the Choke Canyon and Lake Corpus Christi reservoirs causing historically low reservoir capacities (Figure 6). Capacities at Lake Corpus Christi varied between 15.1% and 29.9% throughout the 2012-2013 sampling year, the lowest levels seen in over 16 years (Nueces River Authority 2013). The Choke Canyon reservoir levels varied between 38.6% and 52.5% during the 2012-2013 year (Nueces River Authority 2013).

Difference in rainfall from year to year gives an opportunity to study the pumping events during wet versus dry conditions to better understand their delivery efficiency. Pumping events are typically activated when salinities in the Nueces Delta reach a certain threshold, typically above 30 ppt, and when reservoir levels and rainfall events allow for "pass-throughs". During wet years, salinities are likely below the 30 ppt threshold due to rainfall events introducing freshwater directly to the Nueces Bay and Delta while at the same time reservoir capacities are higher due to increased inflow. During wet years, water can be "banked" until a dry time when salinity levels reach the threshold. This was seen during the 2009-2010 wet year when 3,000 acre-feet (3,700,445 m^3) of freshwater were banked during the wet month of May and allocated

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

Year	Pumping Event	Dates of Event	Duration (days)	Tide	Acre-Feet Pumped	Wet/Dry Period
1	-	No pumping occurred	-	-	-	-
2	1	September 28 to October 21, 2009	24	High	2,987	Wet
	2	January 6 to January 14, 2010	9	Low	742	
	3	May 10 to May 31, 2010	21	High	2,288	
3	4	March 21 to March 30, 2011	10	Moderate	1,001	Dry
	5	May 3 to May 12, 2011	10	High	1,002	
	6	June 13 to June 22, 2011	10	Moderate	994	
4	7	November 2 to November 22, 2011	21	Moderate	2,031	Dry
	8	March 7 to March 19, 2012	13	Moderate	1,310	
	9	June 21 to July 13, 2012	23	High	2,354	
5	10	October 5 to October 18, 2012	13	Moderate	2,017	Dry
	11	June 1 to June 10, 2013	10	High	717	
	12	June 24 to July 2, 2013	9	Moderate	731	
	13	July 17 to July 21, 2013	5	High	526	

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

	2008-2009	**2009-2010**	**2010-2011**	**2011-2012**	**2012-2013**
NUDEWX	3.0 in. (7.62 cm)	15.6 in. (39.62 cm)	7.9 in. (20.01 cm)	N/A – sensor removed	7.13 in. (18.11 cm)
CRP	8.81 in. (22.38 cm)	42.9 in.(108.97 cm)	25.3 in.(64.26 cm)	18.68 in. (47.45cm)	14.16 in. (35.97 cm)

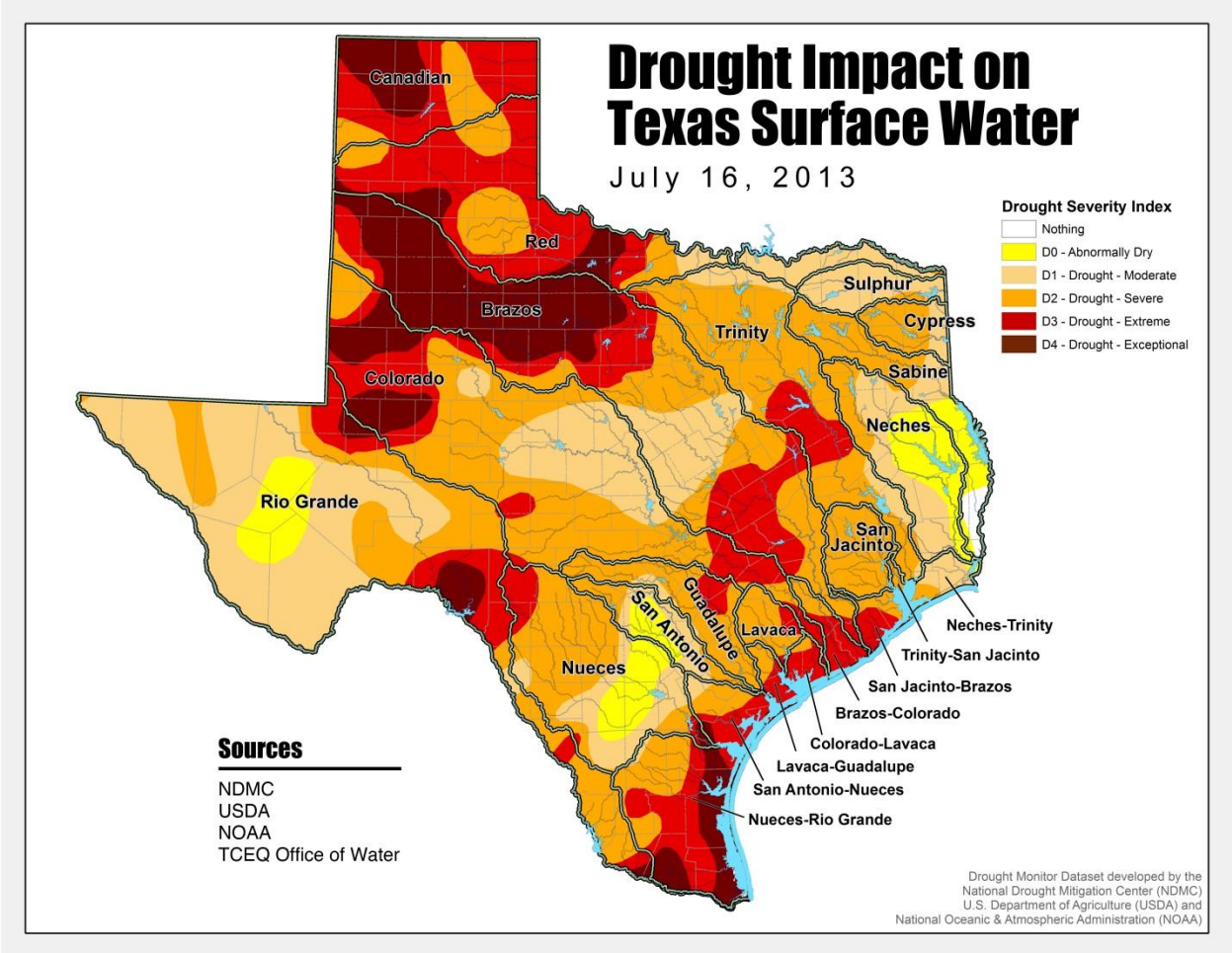


Figure 6. Drought condition throughout the state of Texas, including the Nueces river watershed.

in three 1,000 acre-feet (1,233,481 m^3) amounts during the drier months of March 2011, May 2011, and June 2011 when salinities in the Nueces Delta were higher (Tunnell and Lloyd 2011). Throughout this study period, banked water was used during the October 2012 event. This banking concept allows freshwater to be pumped during periods of high salinity when it will be most efficiently utilized in the Nueces Delta, maximizing productivity (Nueces BBEST 2011). In April 2013 the Nueces Estuary Advisory Council (NEAC) was asked by TCEQ to suspend any more water banking and to continue operating under the 2001 Agreed Order guidance until a new agreement can be formalized on how to implement the banking concept. The NEAC will be reviewing the process of how to create a pilot project using the banking concept as a water management strategy.

Regular rain events occurred between May 2013 and July 2013 allowing for regular pass-throughs to the Delta when salinities were above 30 ppt. However, low reservoir capacities and insufficient rainfall between November 2012 and May 2013 limited freshwater availability for pumping to the Rincon Bayou. During this time period only 5.35 in (13.59 cm) was recorded at CRP and 5.39 in (13.69 cm) at NUDEWX. An average salinity of 36.7 ppt with values in excess

of 60 ppt were recorded in the Rincon Bayou during this time period due to limited freshwater inflow.

Salinities during the first 2012-2013 pumping event (October 2012) at NUDE2 followed patterns typical of past pumping events with salinities dropping from 22 ppt to below 5 ppt within 4 days of pumping and gradually raising back to above 22 ppt 23 days after pumping ended (Figure 7). The following three pumping events individually represent the lowest pumping events to date in terms of acre-feet but the events also occurred within the shortest time to date with 14 days separating events 11 and 12 and 15 days separating events 12 and 13 (Figure 8).

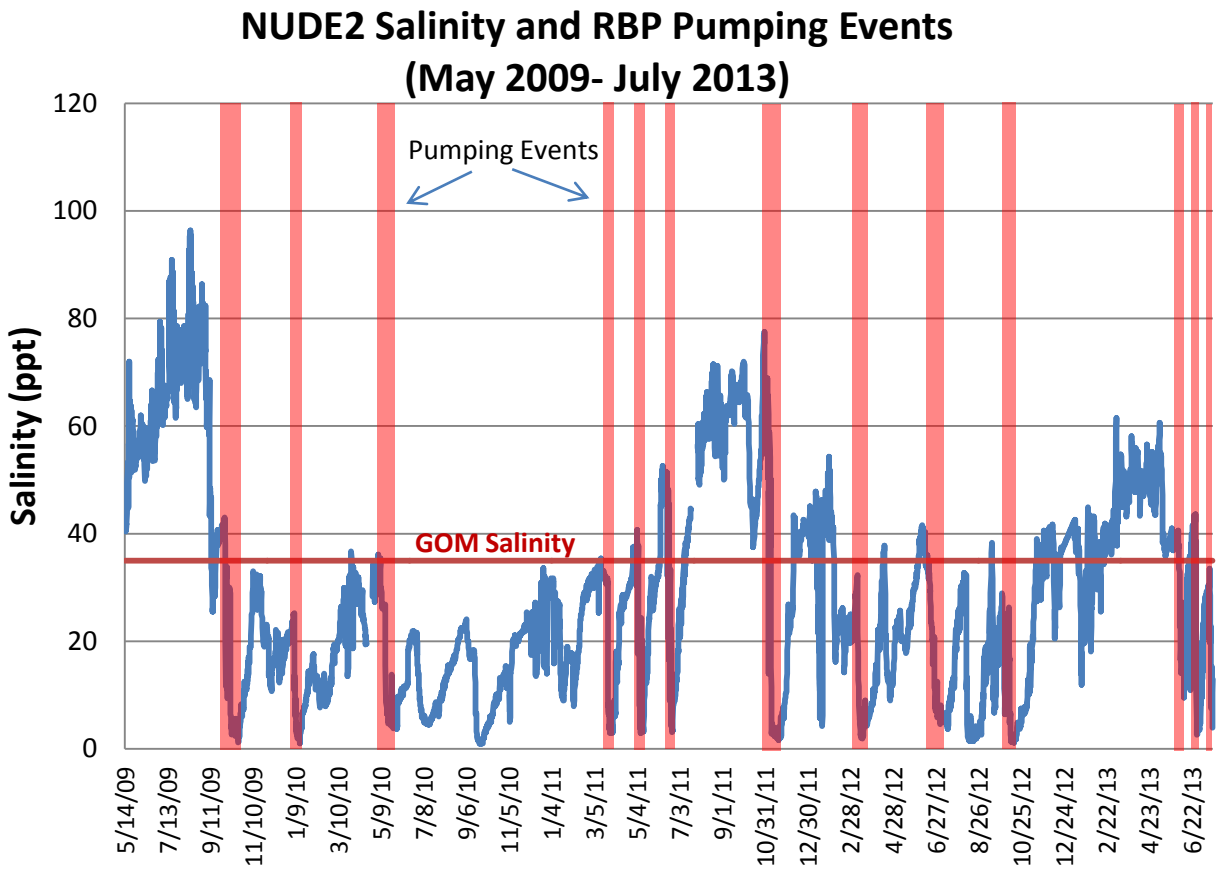


Figure 7. NUDE2 salinity during the thirteen pumping events relative to 35 ppt, which is typical Gulf of Mexico (GOM) salinity seen on the horizontal red line. Shaded areas denotes the pumping events that have occurred for the project during the period of May 2009 to July 2013. Thickness of each shaded area represents duration (days) of pumping.

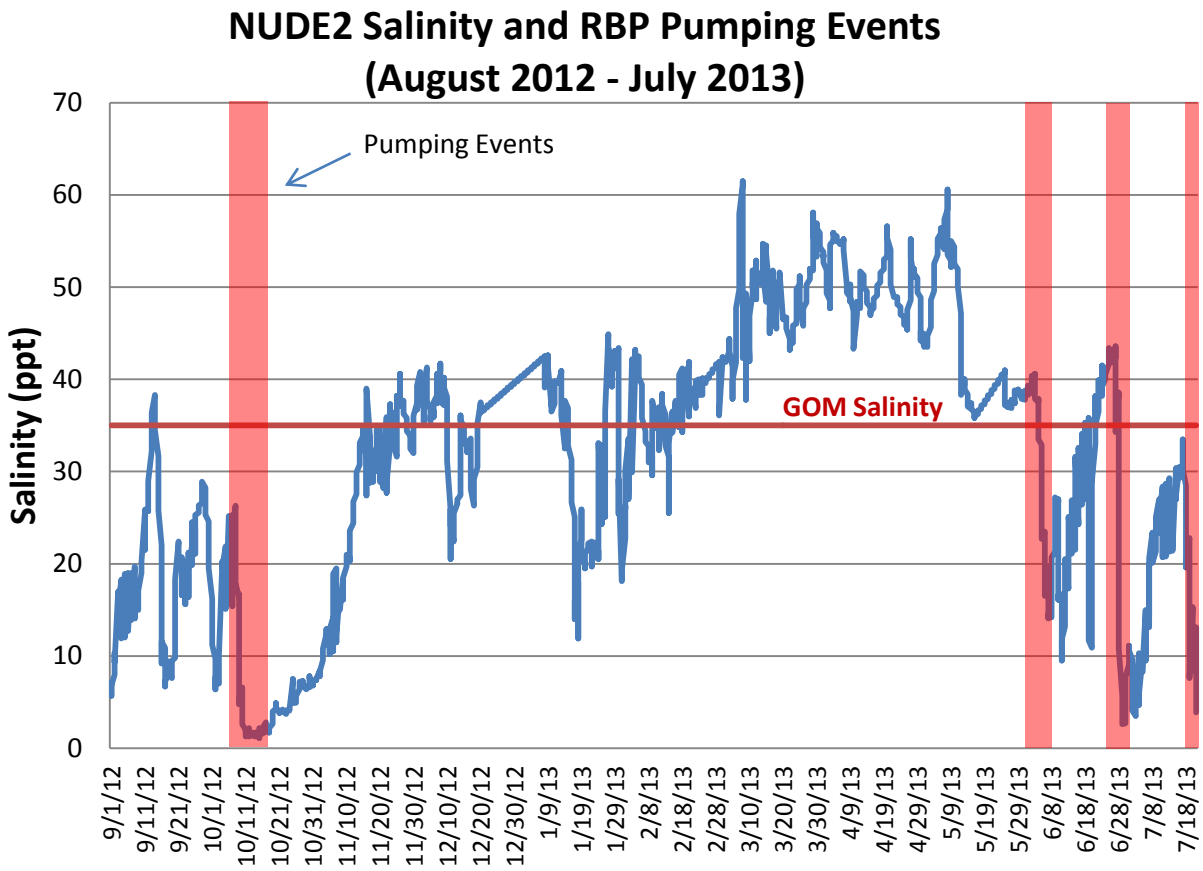


Figure 8. NUDE2 salinity during the four pumping events relative to 35 ppt, which is typical Gulf of Mexico (GOM) salinity seen on the horizontal red line. Shaded areas denotes the pumping events that have occurred for the project during the period of September 2012 to July 2013. Thickness of each shaded area represents duration (days) of pumping.

Pumping event 11 was the second lowest event at 717 acre-feet (884,406 m^3) and resulted in the lowest salinity decrease to date with values falling from 38 ppt to only 14 ppt after 7 days and raising back to 38 ppt 11 days after pumping ended. The relatively high salinity levels during this pumping event were likely due to high tides, a relatively small amount of freshwater being pumped as well as it being the first pumping event after prolonged drought. The 12 and 13 pumping events resulted in salinities levels dropping to below 5 ppt within 6 days of the pumps being turned on which were representative of past years pumping events.

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 9).

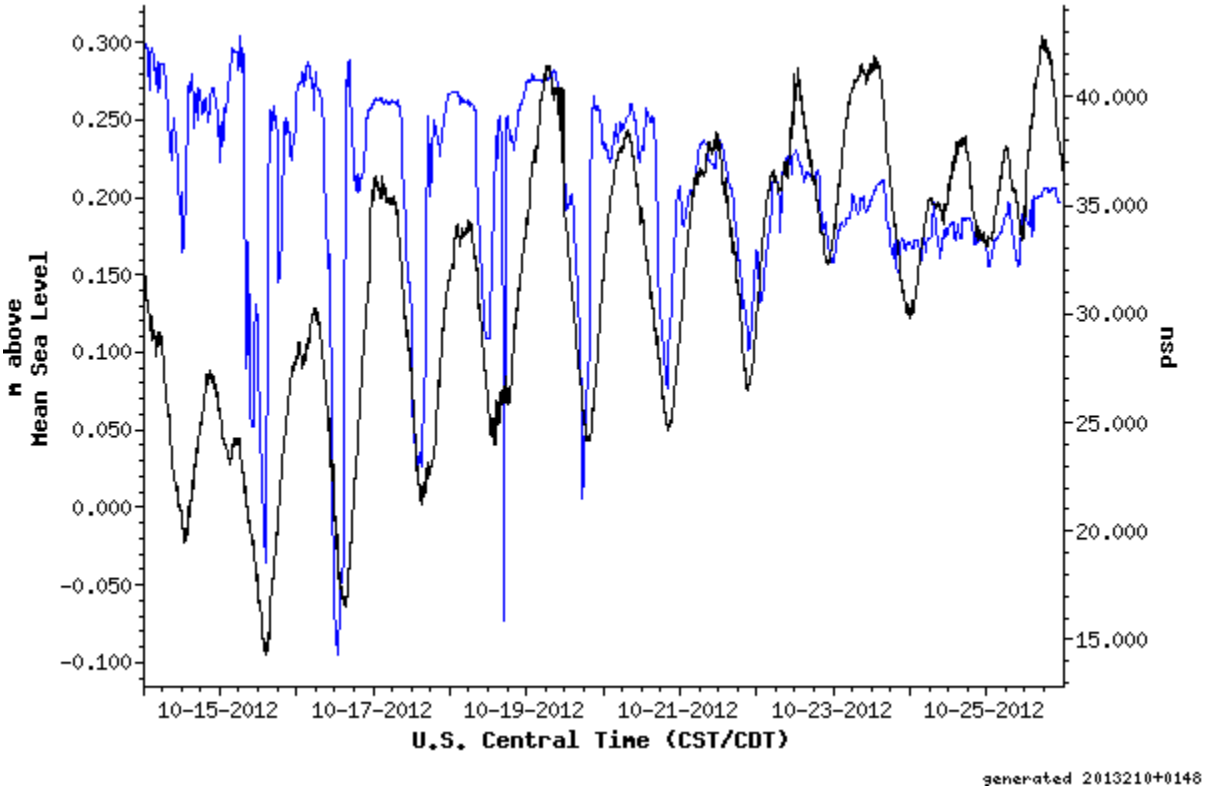
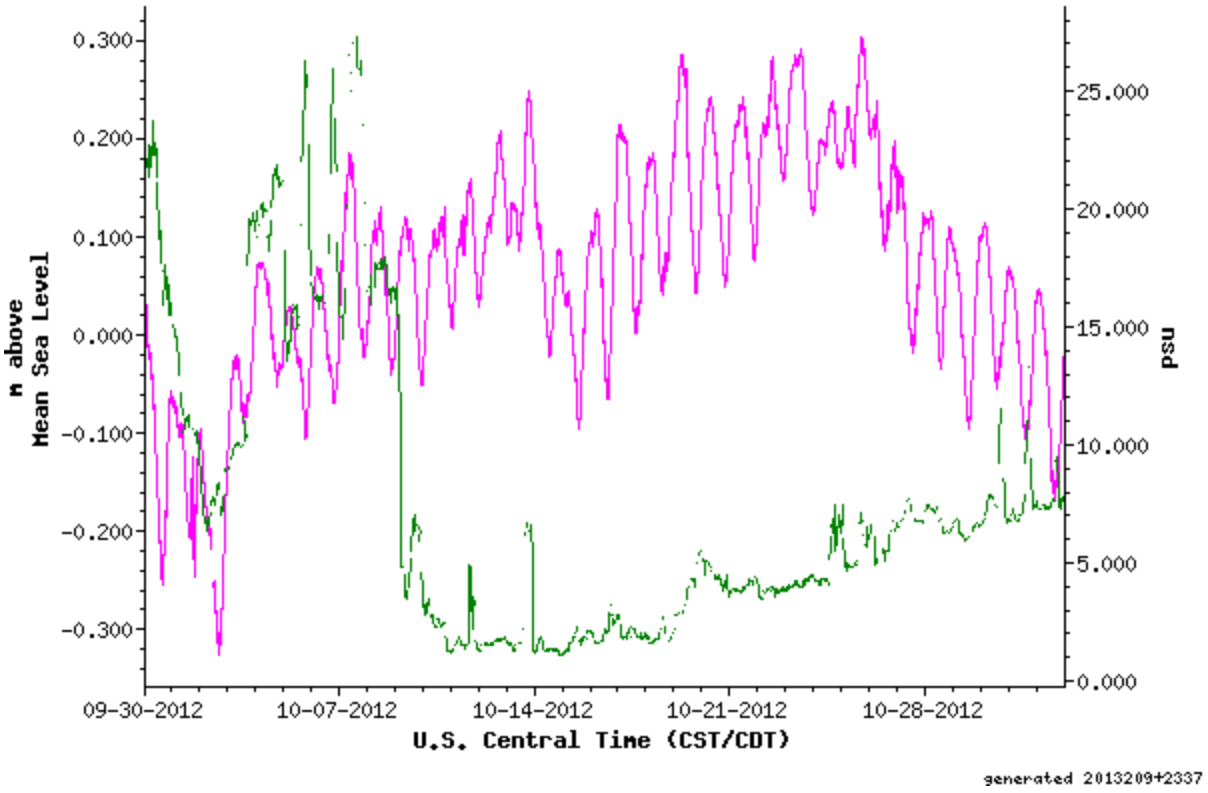


Figure 9. Salinity (blue line) and water level (black line) at SALT08 at the end of pumping event 10 (10/14/12) and 12 days after (10/26/12).

At least some tidal influence on salinity levels appeared to be present during periods of pumping events 11, 12 and 13, diurnal tidal variation appeared to have little to no affect on salinities at NUDE2 during pumping event 10 (Figure 10). It is also possible that other meteorological factors could have played a role in fresh and saltwater mixing. 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).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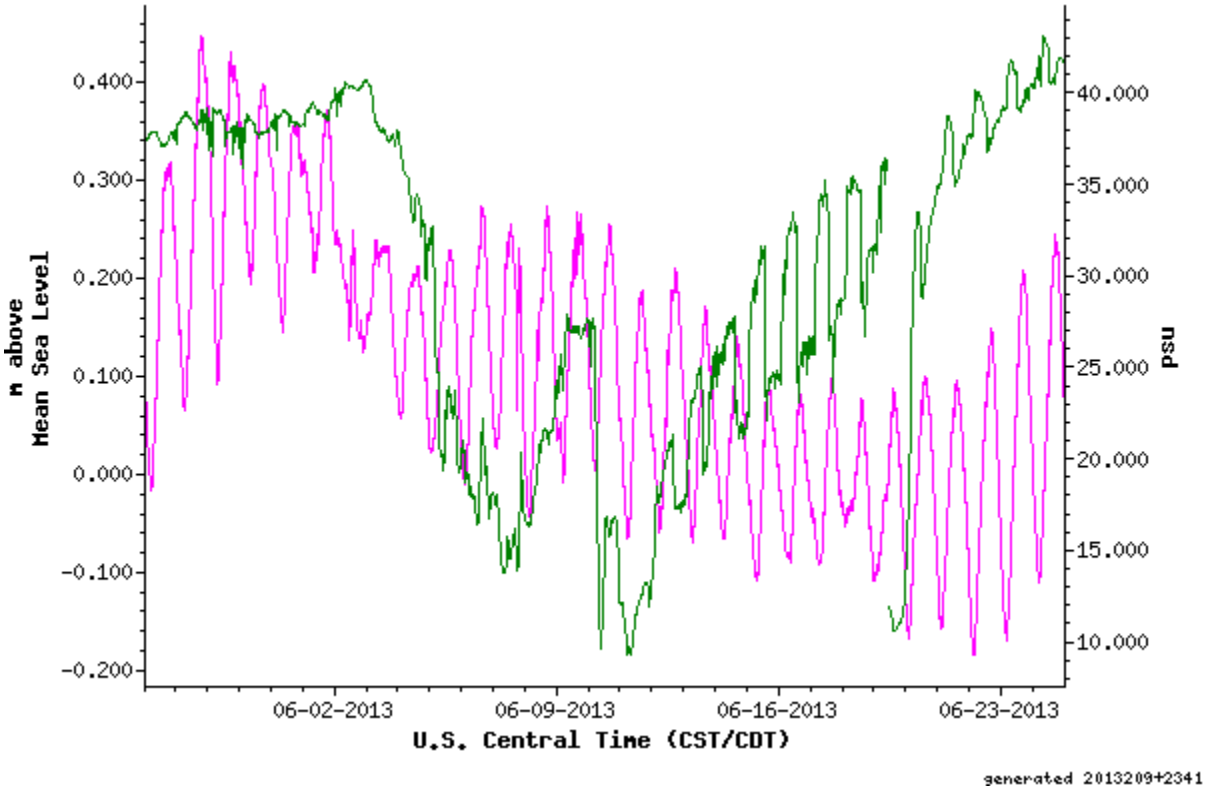
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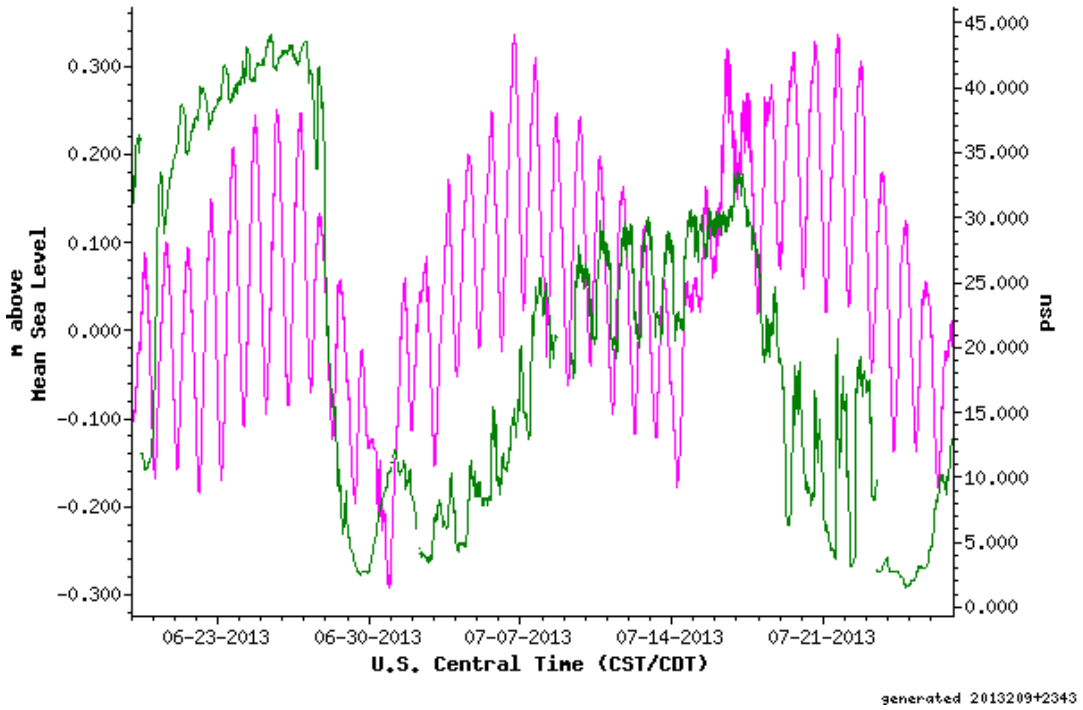

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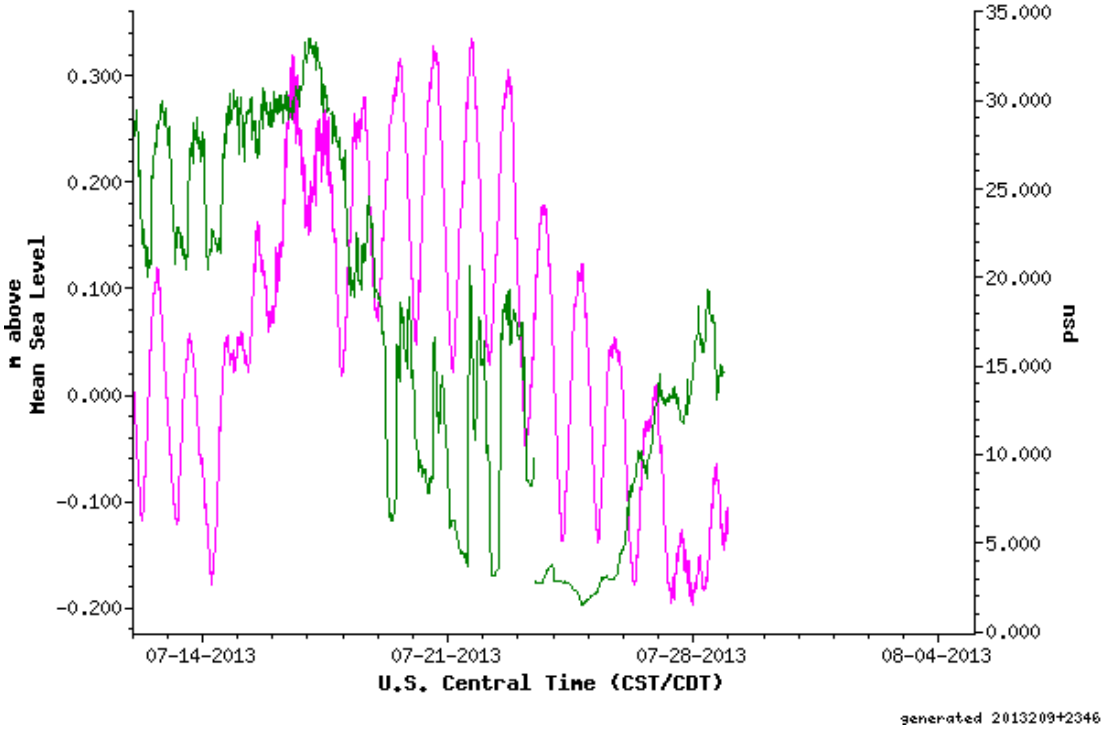

D)

Figure 10. Individual pumping events during the 2012-2013 year. Green lines represent salinity at NUDE2 and the pink line represents water level at NUDEBAY 185. Each graph represents 5 days before the pumping event and 14 days after the pumping event for A) event 10, B) event 11, C) event 12, and D) event 13.

CONCLUSIONS

The most recent sampling year gave an opportunity to study pumping events in the Nueces Delta during a drought year with prolonged limited freshwater inflow. During pumping event eleven, 717 acre-feet (884,410 m^3) were released with the resulting salinities only dropping to 14 ppt, however the following two events recorded salinities below 5 ppt with only 731 (901,675 m^3) and 526 acre-feet (648,811 m^3) of freshwater pumped to the delta, likely due to residual freshwater remaining from the most recent pumping event and due to lower water levels (see Figure 10).

The combined effects of precipitation, wind direction and velocity, tidal variations and evaporation has a significant effect on salinity levels in the Nueces Delta but the extent and the confounding nature of these factors are not fully understood. Future years of pumping should eventually take into account extraneous meteorological and tidal variations.

A review of all the pumping events since this project began in 2009 appears to indicate that banking water for future use during high salinity times is crucial for being able to manage a salinity gradient in the Nueces Delta during dry conditions. As recommended by Tunnell and Lloyd in 2011, it should be reiterated that the significant human changes within the Nueces Delta and Bay could be partially mitigated through this banking concept of saving water during wet times for release during dry times. Water management strategies such as this could be the key to reestablishing the connectivity and salinity gradient back in the Nueces Delta.

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