Nueces Delta Salinity Effects from Pumping Freshwater into the Rincon Bayou: 2009 to 2015

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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 trends in salinity changes throughout pumping events from 2009 to 2015 and have a more detailed look at the effects seen during the 2014-2015 sampling year (September 1, 2014 to August 31, 2015). The results of this study are used for the continual adaptation of a water management plan that will help water managers make 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 focus 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 natural means of freshwater flow 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). Decreased inflows into the delta and prolonged Texas droughts have caused frequent 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, 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).

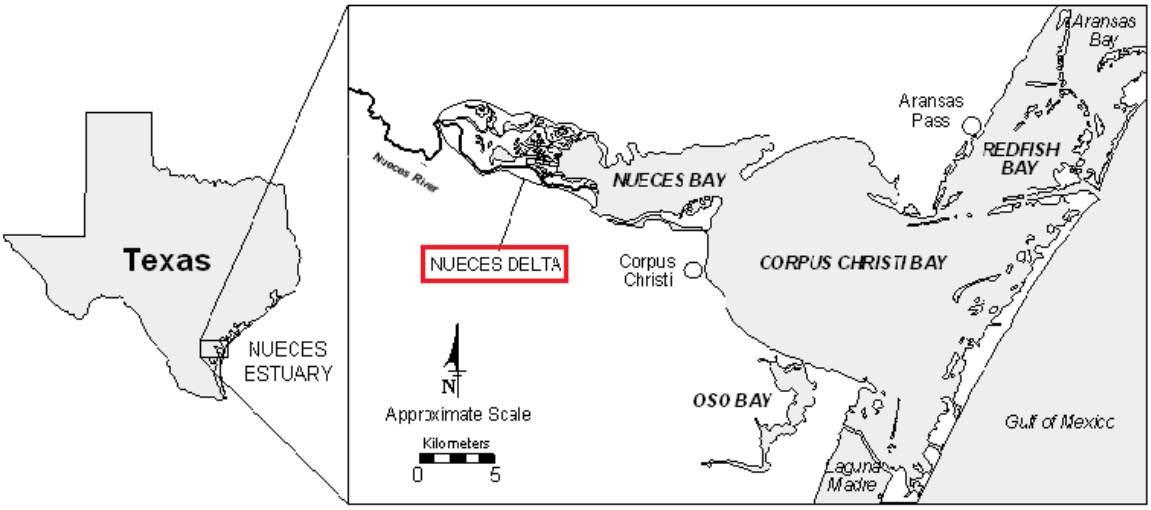


Figure 1. Location of the Nueces Delta within Texas and the Nueces Watershed.

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 monitoring 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 decisions on quantity, timing, and duration of pipeline inflow events that are most productive and significant to the ecology of

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. Photos taken by Jace Tunnell.

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 six RBP pumping events that occurred between September 1st 2014 and August 31st 2015. This project represents the seventh 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). Each Nueces Delta (NUDE) station is jetted

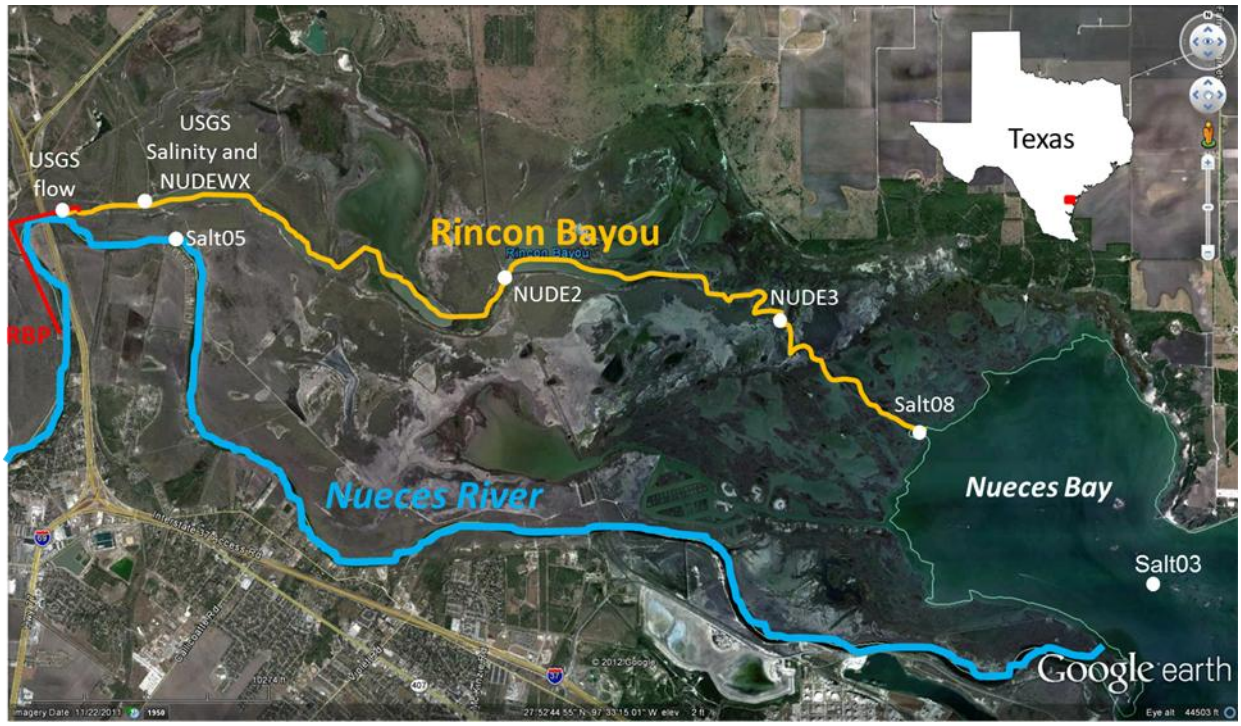


Figure 3. Map showing the RBP (Rincon Bayou Pipeline [red line]) and the three salinity monitoring stations for this project (NUDE2, NUDE3, and SALT08).

approximately five feet into the sediment near the water's edge with a water quality datasonde extending 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) 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 annually as per NOAA COOPS standards for water level monitoring stations (http://tidesandcurrents.noaa.gov/).

The CBI salinity monitoring stations involve Hydrolab® MS5 and H20 water quality datasondes interfaced with cellular IP modem (Figure 4). Stations are 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), 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 (PSU). Instruments are exchanged monthly with 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 datasondes to ensure the devices are measuring salinity accurately.

Figure 5. SALT08 (top image) and NUDE3 (bottom image) datasondes are being exchanged with a newly calibrated datasonde which will remain deployed for approximately 4 weeks after which the datasonde will be replaced in the same fashion.

RESULTS AND DISCUSSION

Twenty-four 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) and five pumping events totaling 11,694 acre-feet (14,424,337 m^3) of freshwater were delivered to the Rincon Bayou during year six. So far, six pumping events have occurred during year seven (2014-2015) totaling 14,097 acre-feet (17,388,394 m^3; Figures 6-7).

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	Sep. 28 to Oct. 21, 2009	24	High	2,987	Wet
	2	Jan. 6 to Jan. 14, 2010	9	Low	742	
	3	May 10 to May 31, 2010	21	High	2,288	
3	4	Mar. 21 to Mar. 30, 2011	10	Moderate	1,001	Dry
	5	May 3 to May 12, 2011	10	High	1,002	
	6	Jun. 13 to Jun. 22, 2011	10	Moderate	994	
4	7	Nov. 2 to Nov. 22, 2011	21	Moderate	2,031	Dry
	8	Mar. 7 to Mar. 19, 2012	13	Moderate	1,310	
	9	Jun. 21 to Jul. 13, 2012	23	High	2,354	
5	10	Oct. 5 to Oct. 18, 2012	13	Moderate	2,017	Dry
	11	Jun. 1 to Jun. 10, 2013	10	High	717	
	12	Jun. 24 to Jul. 2, 2013	9	Moderate	731	
	13	Jul. 17 to Jul. 21, 2013	5	High	526	
6	14	Oct. 21 to Nov. 9, 2013	16	High	2,348	Dry
	15	Nov. 22 to Dec. 8, 2013	12	Moderate	613	
	16	Feb. 3 to Feb. 15, 2014	13	Low	2,466	
	17	May 9 to Jun. 3, 2014	24	Moderate	2,736	
	18	Jun. 23 to Jul. 15, 2014	23	Moderate	3,531	
7	19	Oct. 1 to Oct. 6, 2014	6	High	319	Wet
	20	Jan. 18 to Jan 27, 2015	10	Low	695	
	21	Mar. 10 to Mar. 12, 2015	3	Moderate	210	
	22	Mar. 19 to Mar. 25, 2015	7	Moderate	1,535	
	23	Apr. 13 to Apr. 28, 2015	16	Moderate	2,455	
	24	May 12 to Jun. 15, 2015	35	Moderate	8,883	

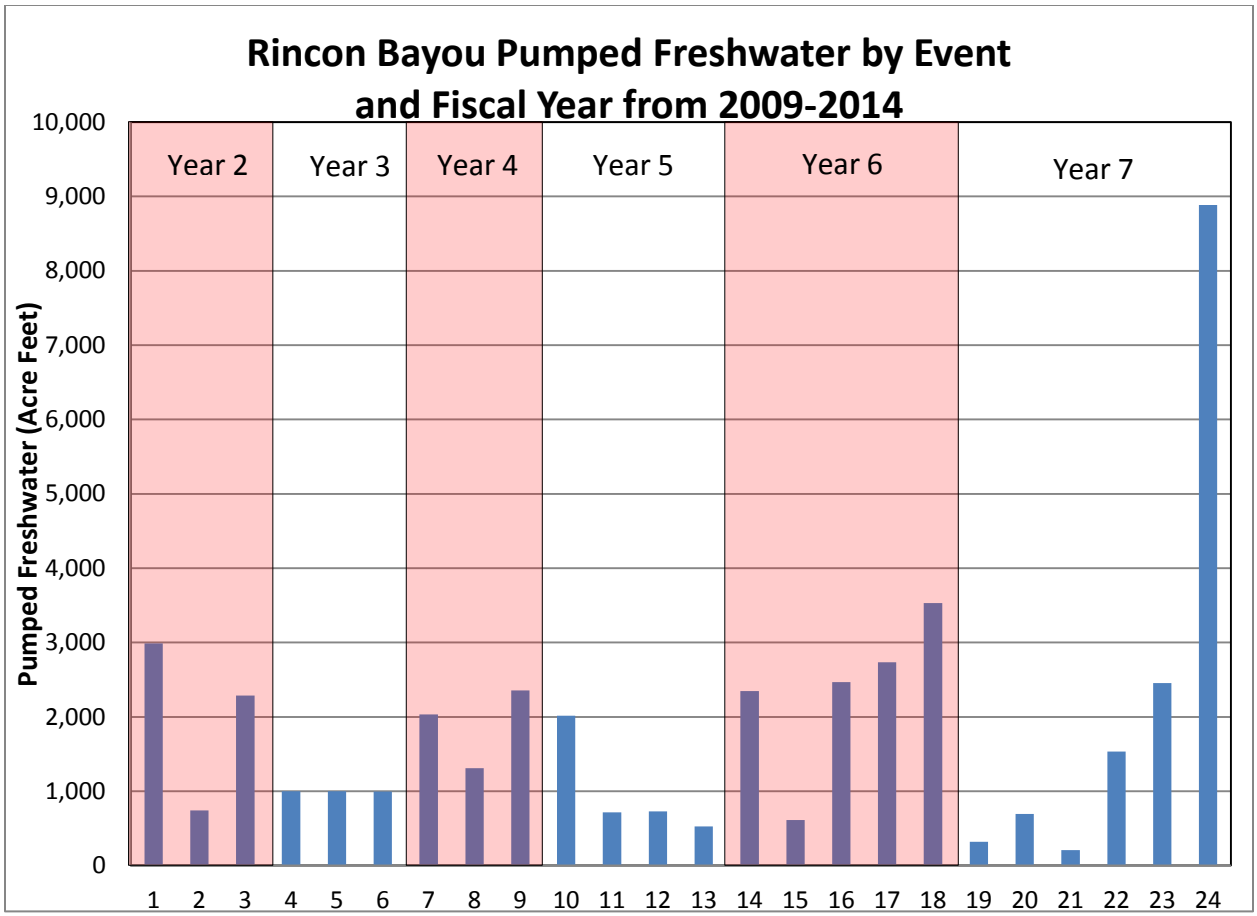


Figure 6. Rincon Bayou pumping events by fiscal year from 2009-2015.

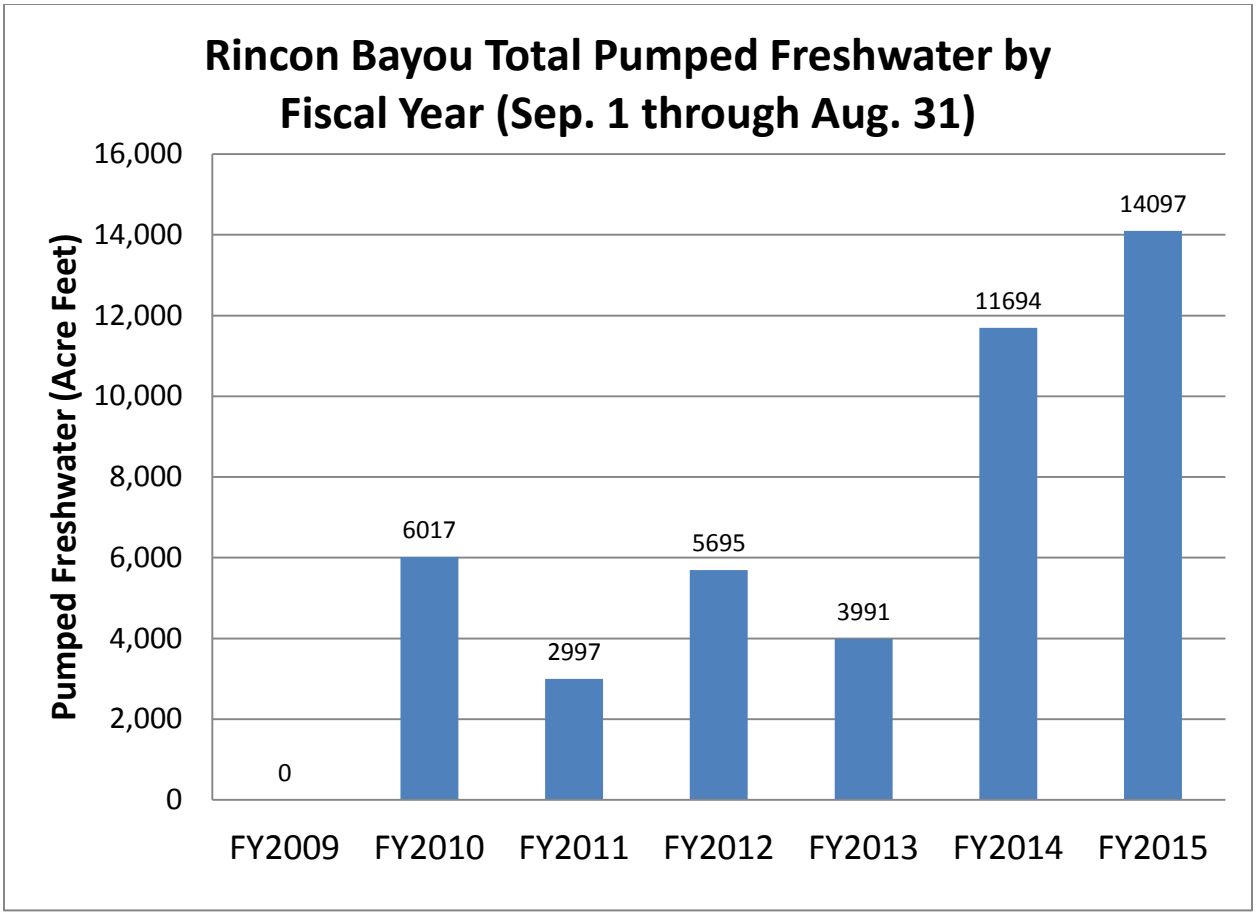


Figure 7. Total amount of freshwater pumped for each fiscal year (September 1 through August 31).

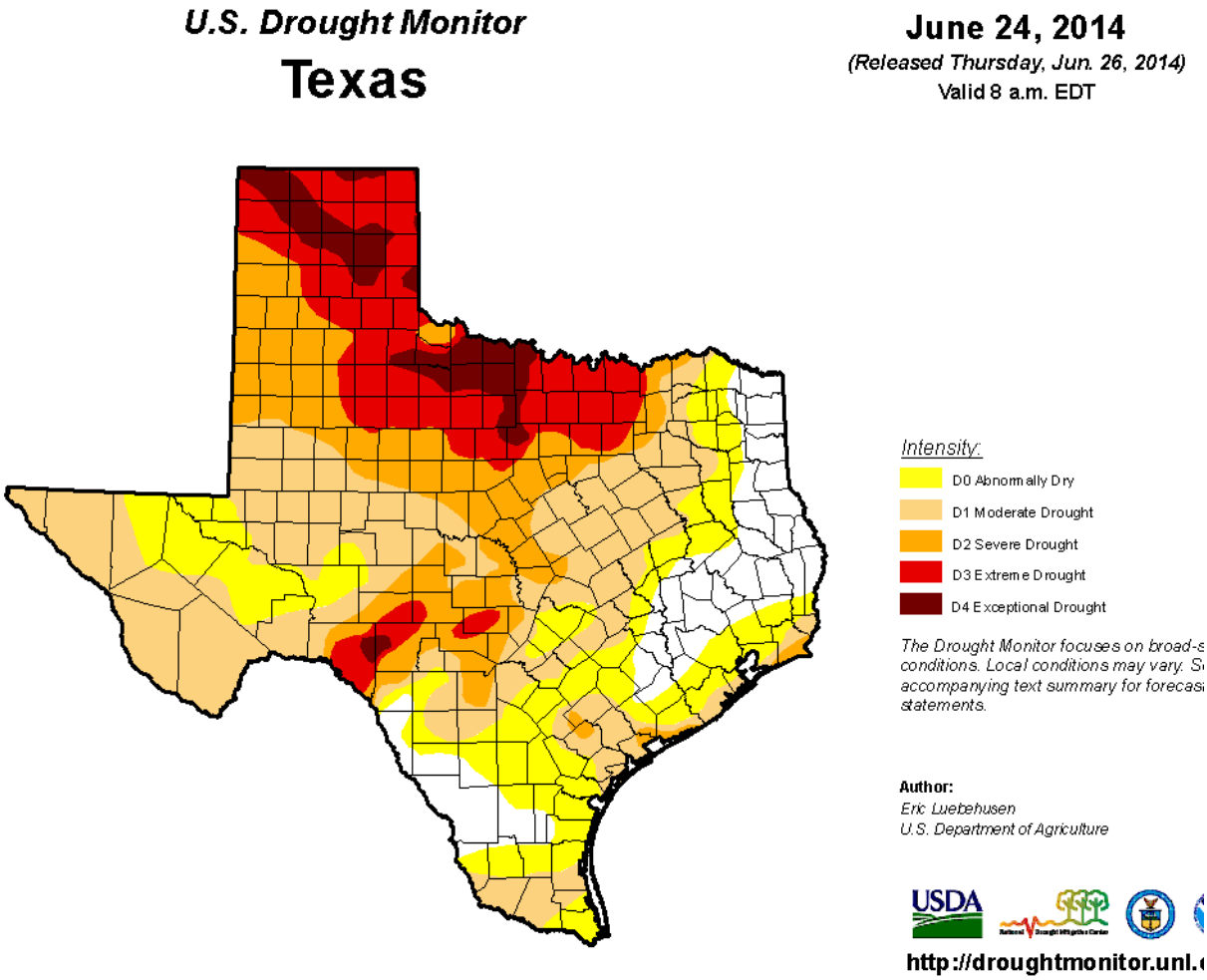
Local rainfall varied spatially between the National Weather Service at Corpus Christi International Airport (CRP) at 27°46'22.43"N, 97°30'8.47"W and at NUDEWX at 27°53'50.47"N, 97°36'58.73"W with more rainfall frequently occurring at CRP (Table 3). NUDEWX is approximately 11 miles northwest of CRP and 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.

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

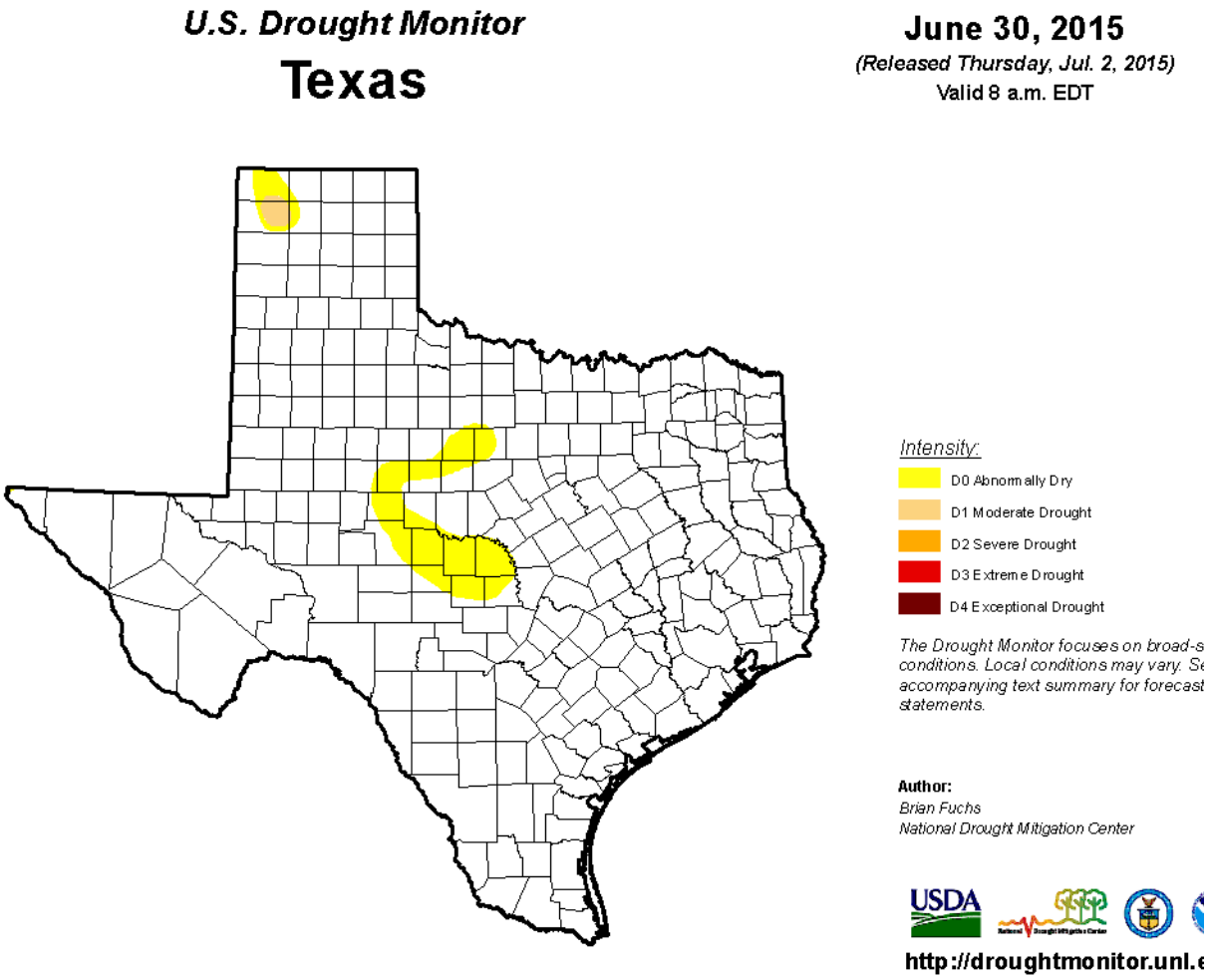
	2008-2009	**2009-2010**	**2010-2011**	**2011-2012**	**2012-2013**	**2013-2014**	**2014-2015**
NUDEWX	3.0 in.	15.6 in.	7.9 in.	NA	7.13 in.	19.29 in.	29.68 in.
CRP	8.81 in.	42.9 in.	25.3 in.	18.68 in.	14.16 in.	18.69 in.	48.51 in.

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, until 2014-2015, with 42.9 in (108.87cm) at CRP and 15.6 in (39.62 cm) at NUDEWX. 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 third 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 most recent 2014-2015 sampling year was the wettest to date with 48.51 in (123.22 cm) of rainfall at CRP and 29.68 in (75.39 cm) recorded at NUDEWX. Drought conditions were absent throughout most of Texas during the 2014-2015 sampling season compared to the previous year (U.S. Drought Monitor 2015; Figure 8).



A)



B)

Figure 8. Drought condition throughout the state of Texas on June 24, 2014 (A) and on June 30, 2015 (B).

The high amount of rainfall during the 2014-2015 sampling year, especially during the March, April and May months, led to generally high reservoir capacities compared to recent sampling years. 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. The Choke Canyon reservoir levels varied between 38.6% and 52.5% with an average of 45.8% during the 2012-2013 year. 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%. The most recent 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% (Nueces River Authority 2015).

Salinities recorded at NUDE2 generally dropped significantly shortly after a pumping event was initiated and gradually increased after the end of a pumping event (Figure 9). Pumping events 19-23 resulted in salinities at NUDE2 dropping to below 5 PSU between 1 and 5 days after the pumps were initiated and gradually rising after the end of the pumping event (Figure 10). Pumping event 24 represents the longest duration, 35 days, and the greatest amount of freshwater pumped, 8,883 acre-feet, during one single event to date.

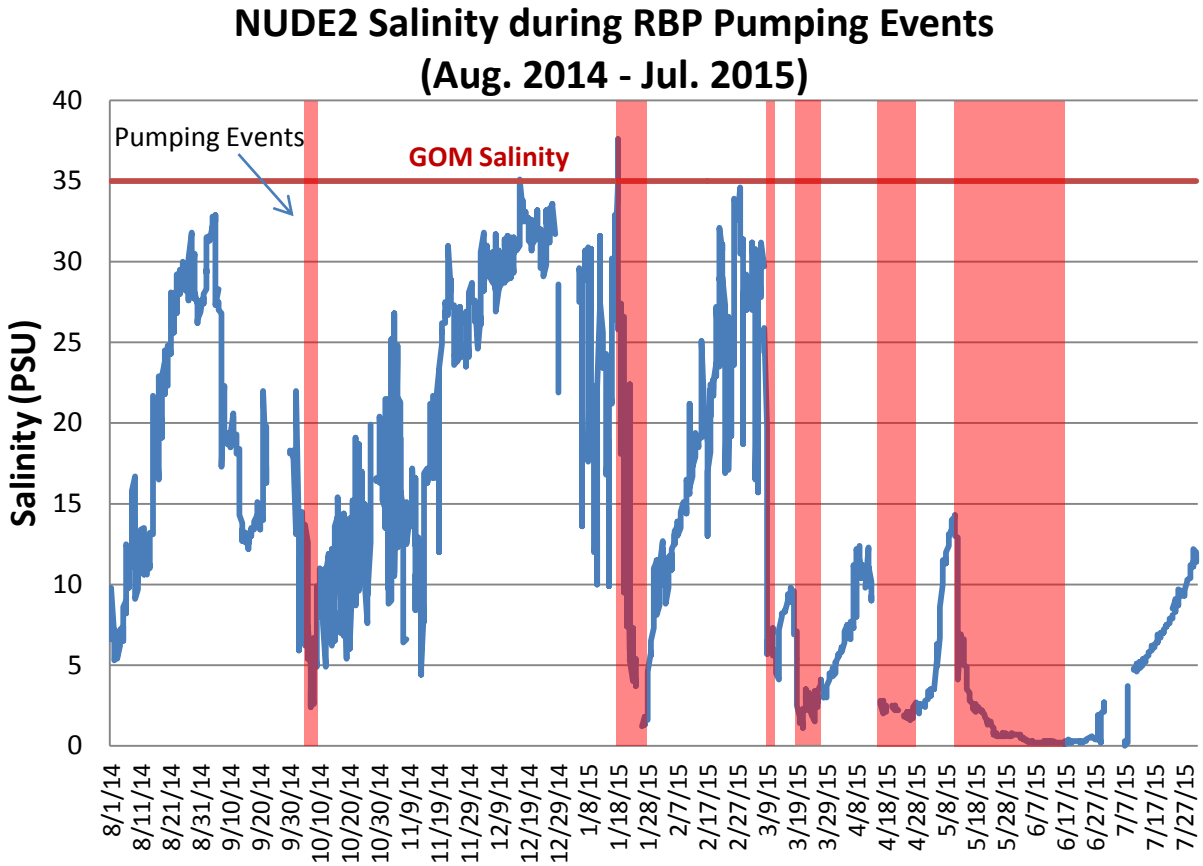
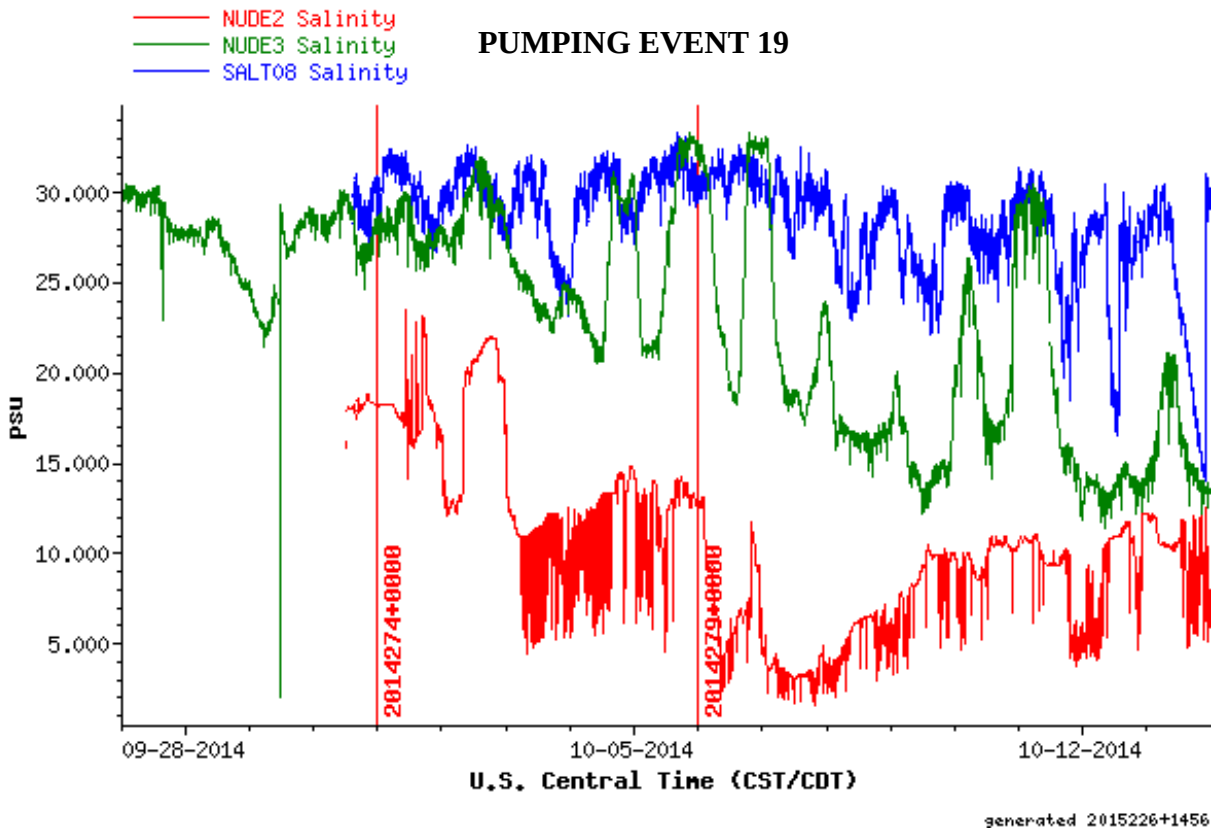
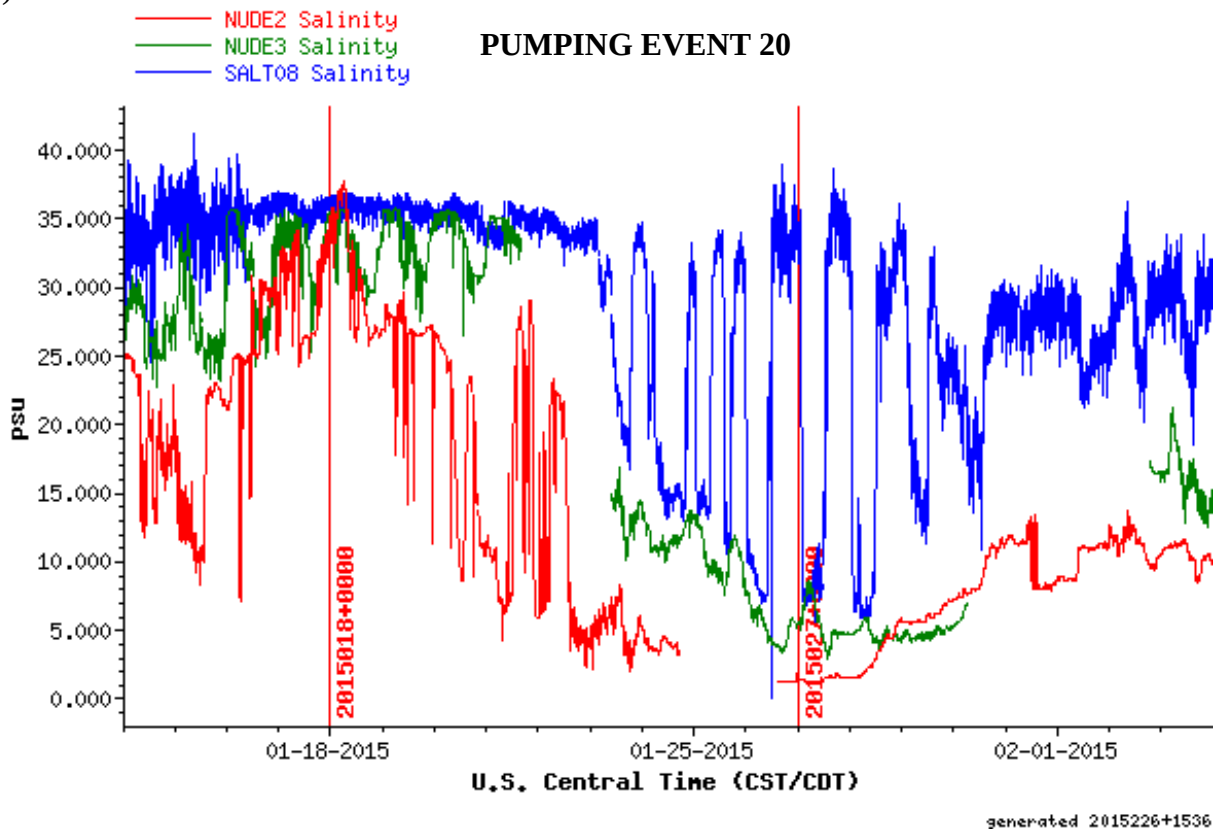


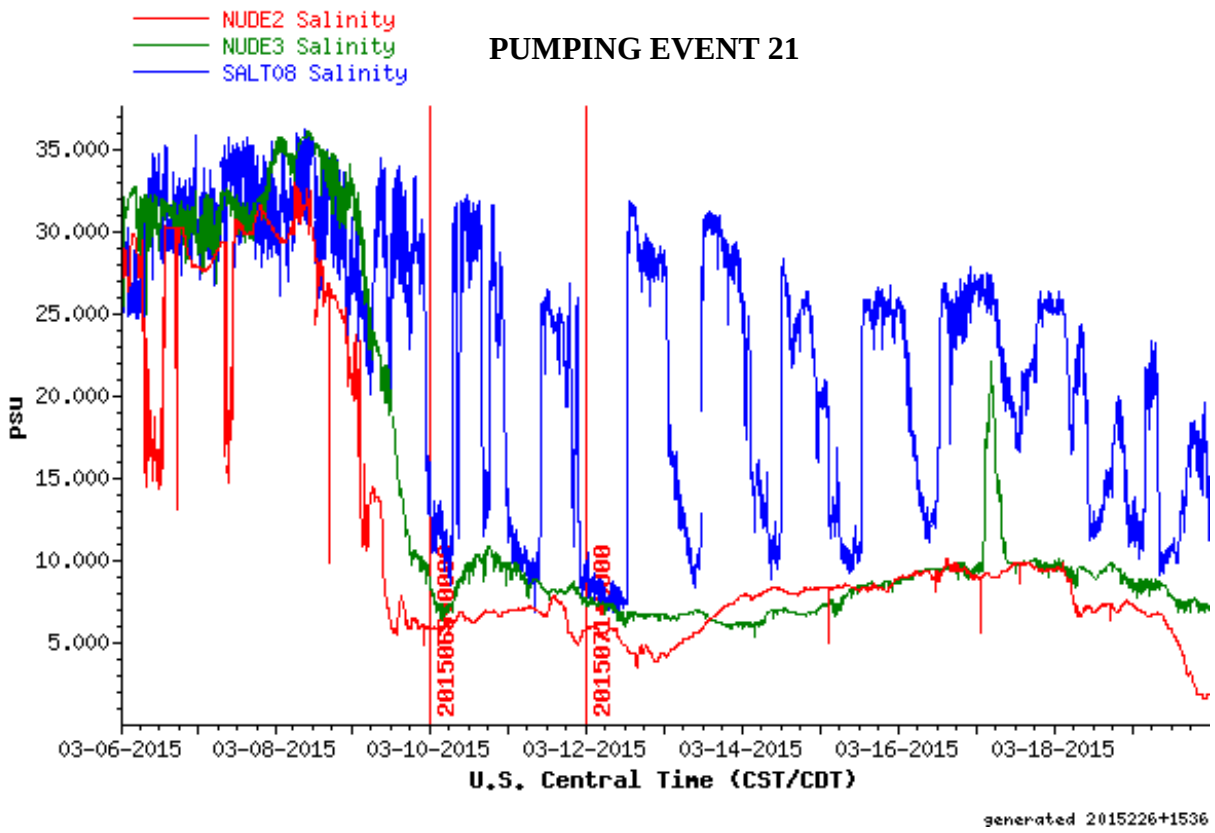
Figure 9. NUDE2 salinity during the 2014-2015 sampling year. Shaded areas denote the six pumping event, thickness of each shaded area represents duration (days) of pumping events. The horizontal red line represents 35 PSU which is typical Gulf of Mexico (GOM) salinity.


NUDE2 Salinity
NUDE3 Salinity
SALT08 Salinity
PUMPING EVENT 19
30.000
25.000
20.000
15.000
10.000
5.000
psu
20142740000
20142790000
09-28-2014
10-05-2014
10-12-2014
U.S. Central Time (CST/CDT)
generated 2015226+1456

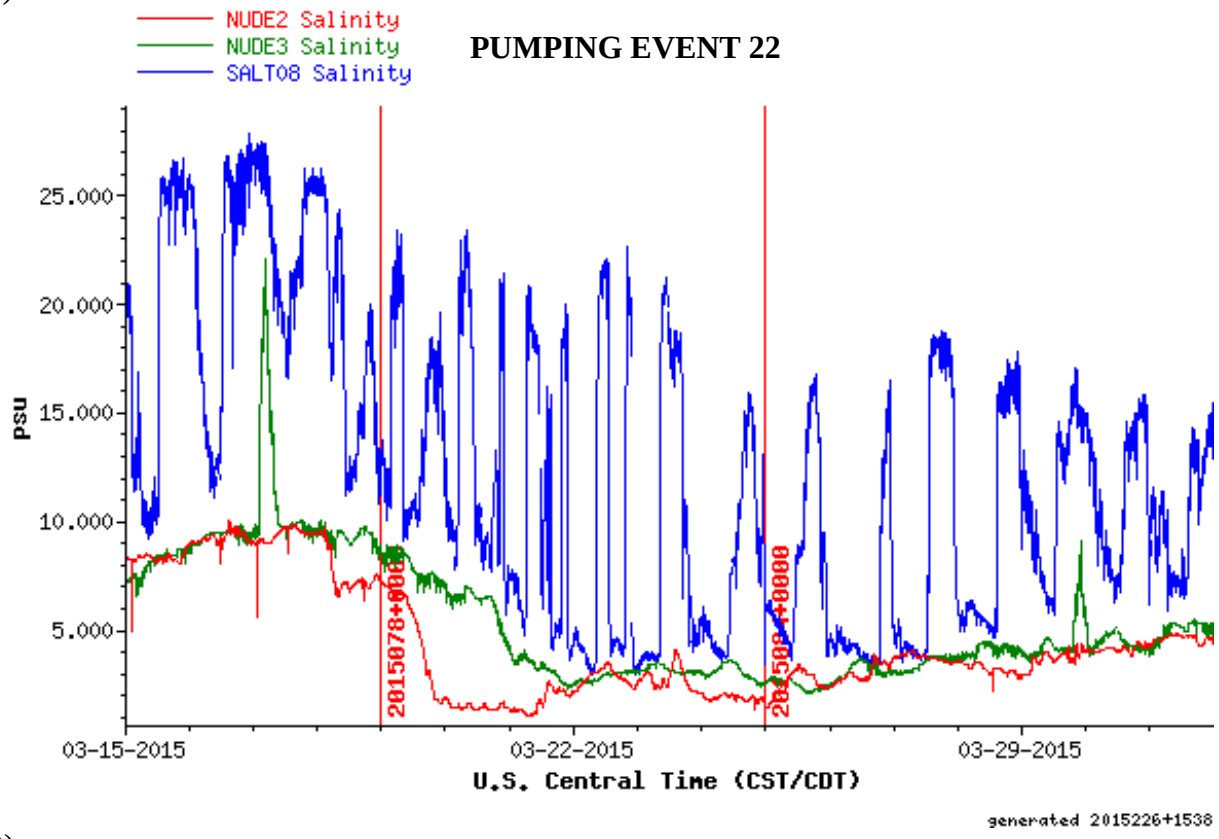
A)


NUDE2 Salinity
NUDE3 Salinity
SALT08 Salinity
PUMPING EVENT 20
40.000
35.000
30.000
25.000
20.000
15.000
10.000
5.000
0.000
psu
20150180000
01-18-2015
01-25-2015
02-01-2015
U.S. Central Time (CST/CDT)
generated 2015226+1536

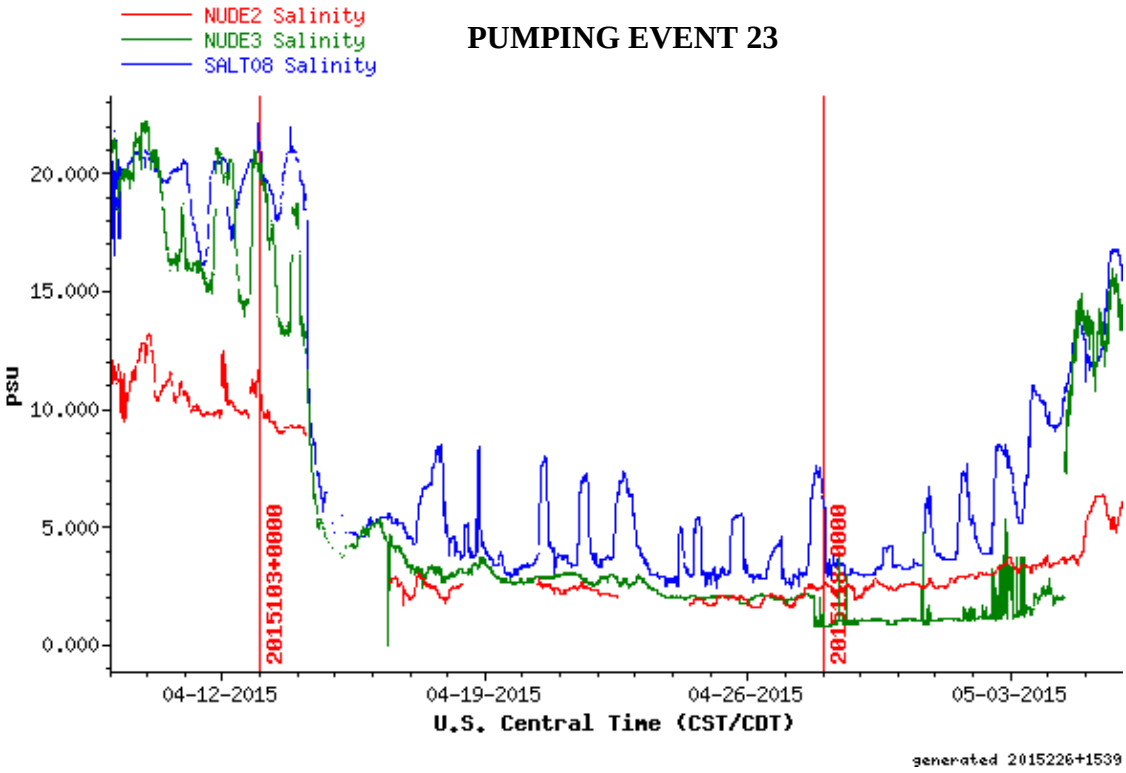
B)


NUDE2 Salinity
NUDE3 Salinity
SALT08 Salinity
PUMPING EVENT 21
35.000
30.000
25.000
20.000
15.000
10.000
5.000
PSU
03-06-2015
03-08-2015
03-10-2015
03-12-2015
03-14-2015
03-16-2015
03-18-2015
U.S. Central Time (CST/CDT)
generated 2015226+1536

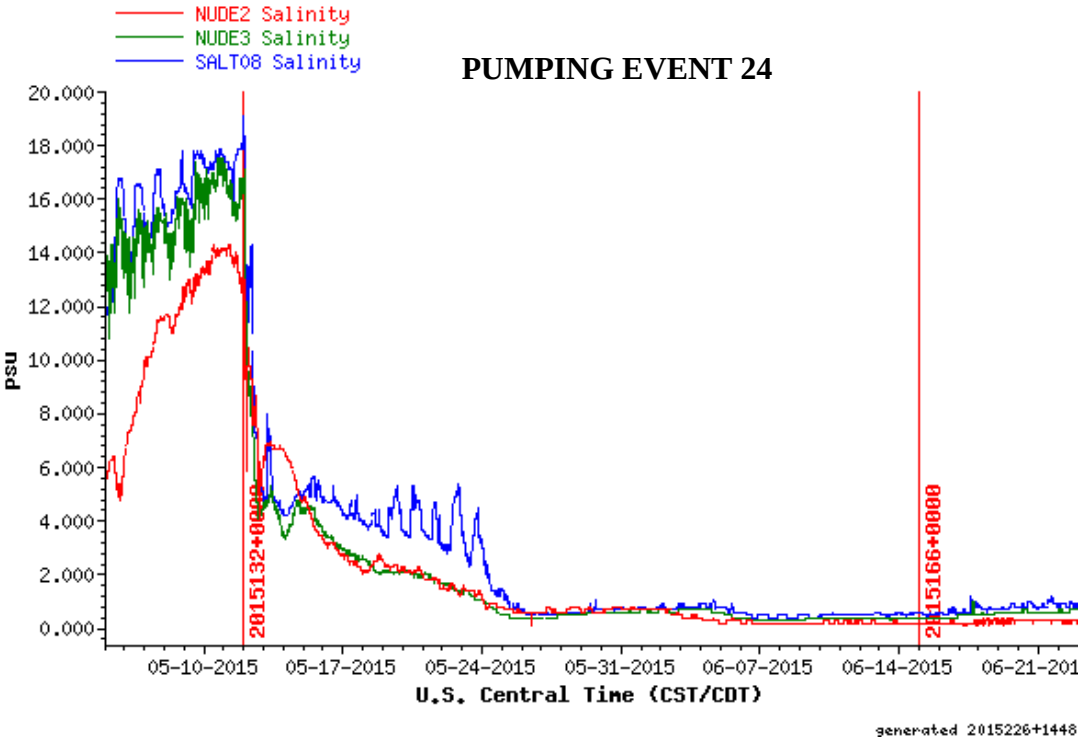
C)


NUDE2 Salinity
NUDE3 Salinity
SALT08 Salinity
PUMPING EVENT 22
25.000
20.000
15.000
10.000
5.000
PSU
03-15-2015
03-22-2015
03-29-2015
U.S. Central Time (CST/CDT)
generated 2015226+1538

D)



E)



F)

Figure 10. Individual pumping events during the 2014-2015 year. Vertical lines represent the start (left line) and end (right line) of pumping events. Each graph represents 4 days before the pumping event and 7 days after the pumping event for A) event 19, B) event 20, C) event 21, D) event 22, E) event 23, and F) event 24.

Pumping event 24 concurred during one of the highest total rain events in Texas history with the month of May setting a precipitation record of 14.23", following March and April months with above average precipitation, each exceeding 6" total precipitation (National Weather Service 2015). The high amounts of precipitation filled Lake Corpus Christi to 100.0% capacity leading to a release of freshwater from the Wesley Seale Dam during the months of May and June, which caused local flooding along the Nueces River and Nueces Delta (Figures 11-13). Freshwater from Nueces River will enter the Nueces Delta directly during times of flood (BOR 2000; Pulich et al. 2002; Hill et al. 2011). As a result, the lowered salinities during pump event 24, and to an extent, pump events 22 and 23, are likely also a function of heavy rainfalls and local flooding, although the exact amount of freshwater introduced from rainfall and flooding is unknown. Salinities below 15 PSU persisted from the end of pumping event 21 on Mar. 12, 2015 through Jul. 31, 2015.

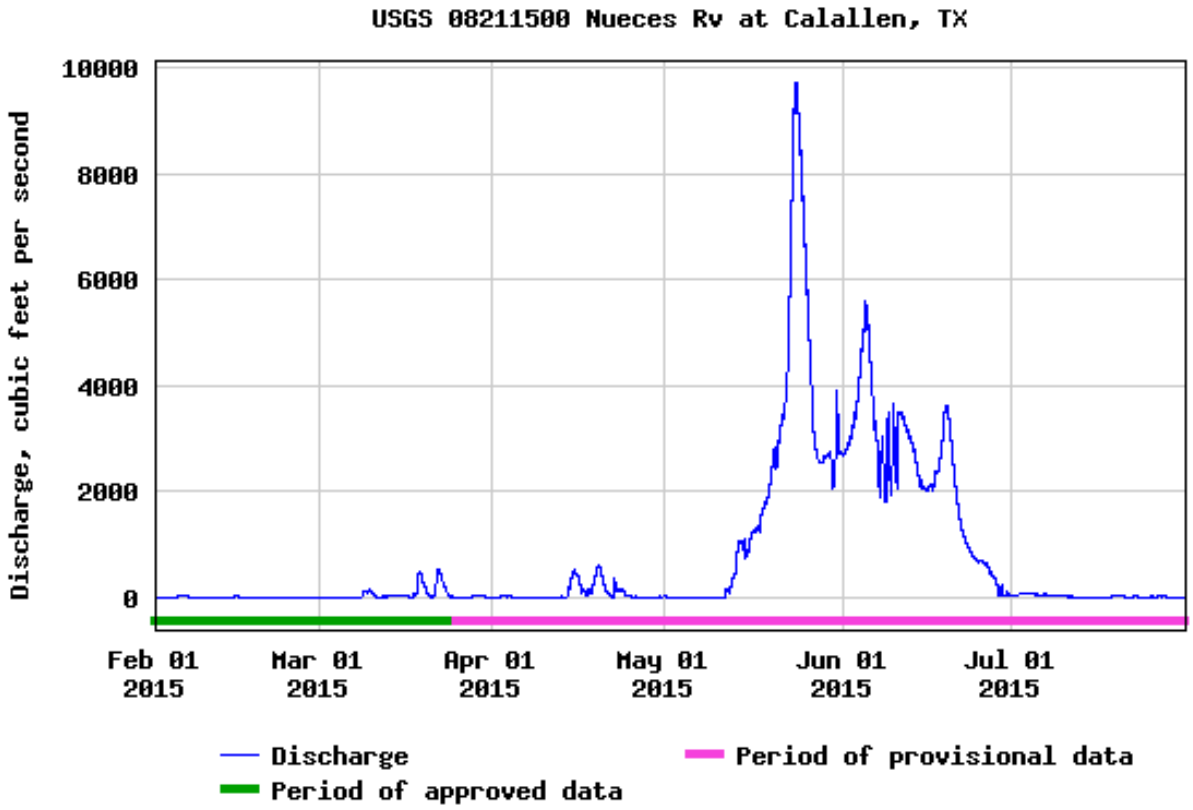


Figure 11. USGS gage along Nueces River showing increased discharge from the river during May and June, 2015 flooding.

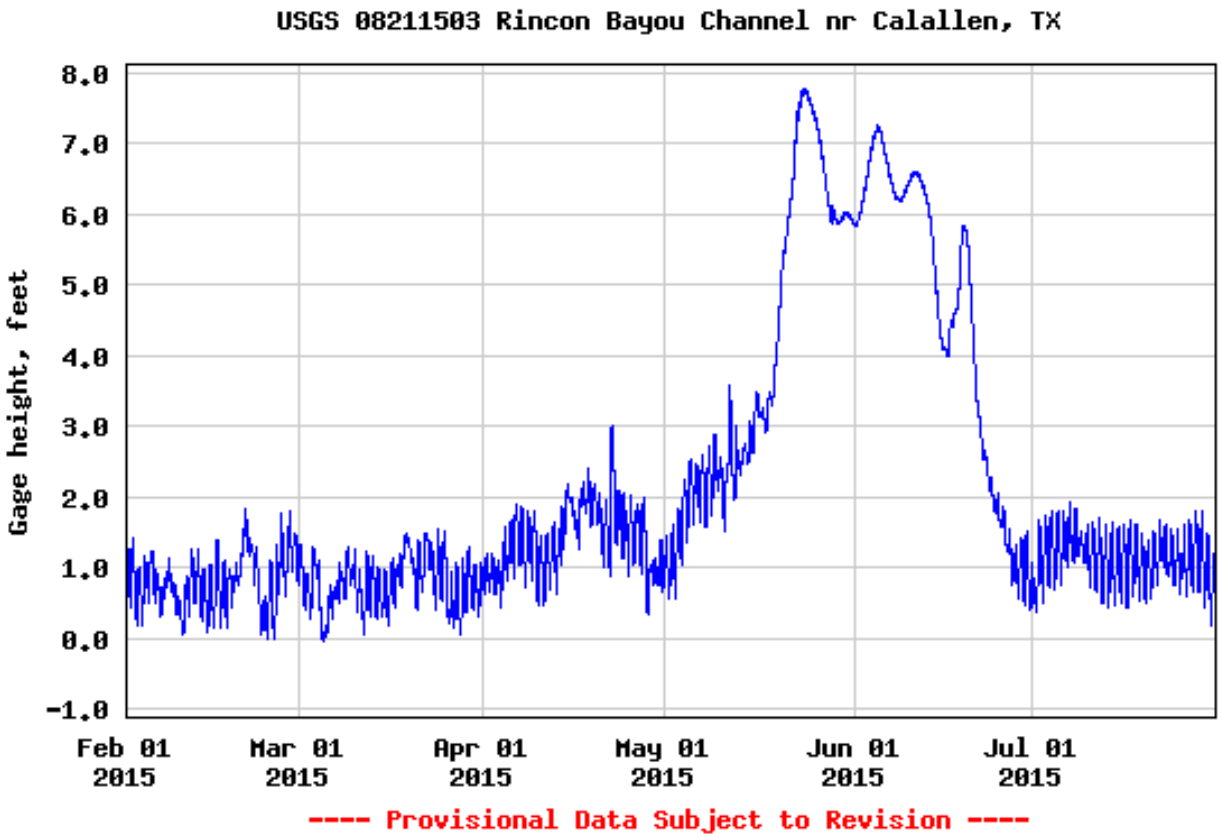


Figure 12. USGS gage in the Rincon Bayou near the head of the Nueces River showing increased water level during May and June, 2015 flooding.

Figure 13. NUDE02 during a May 2015 flood event (left) and during July 2014 normal water level conditions (right).

In addition to freshwater inflows, the salinities in the Nueces Delta are also influenced by tidal variations that will cause movements of fresh and saltwater separated by a horizontal halocline (Adams and Tunnell 2010). There is no evidence of vertical stratification between saltwater and inflowing freshwater in the Nueces Delta or Nueces Bay, likely due to shallow water and persistent high winds. 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 14).

At least some tidal influence on salinity levels at SALT08 appeared to be present during periods of all pumping events during the 2014-2015 sampling year. Diurnal tidal variation appeared to have little to no effect on salinities at NUDE2 and NUDE3 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).

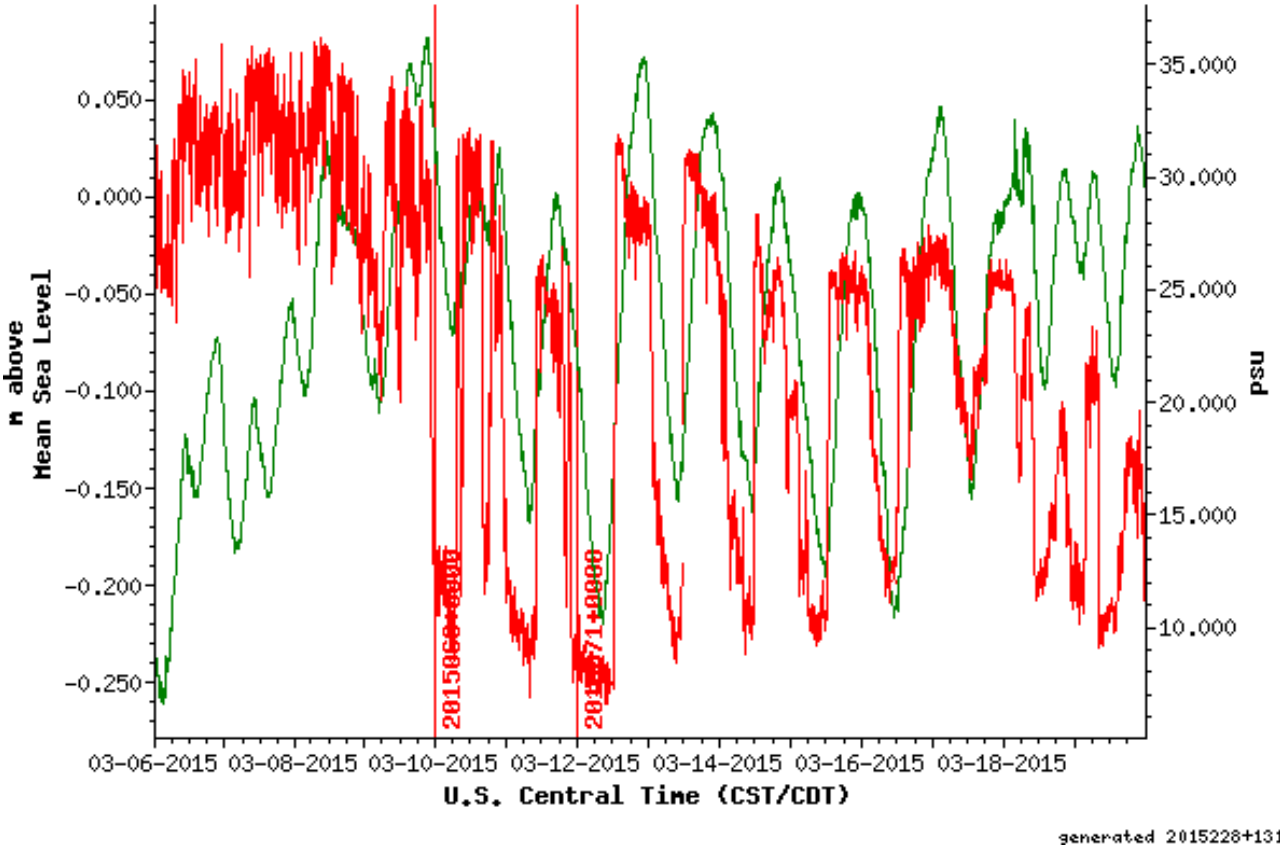


Figure 14. Salinity (red line) and water level (green line) at SALT08 at the end of pumping event 21. Vertical lines represent the start (left line) and end (right line) of the pumping event.

CONCLUSIONS

The most recent sampling year provided an opportunity to study pumping events in the Nueces Delta during the wettest year to date with uncommon flooding events along the Nueces River. The 2014-2015 sampling year also had more total pumped water via the RBP to date with a total of 14,097 acre-feet, 2,403 acre-feet more than the previous sampling year (Figure 15). The majority of the 2014-2015 sampling year pumping volume and number of total pumping days is attributed to pumping event 24 which represented 63.0% of the total pumped water (8,883 of 14,097 total acre-feet) and 45.5% of the total number of days pumped (35 of 77 total pumping days). The high volume of water pumped during the 2014-2015 sampling year is mainly attributed to the high amount of passthrus during the months of May and June, 2015, when Lake Corpus Christi reached fill capacity.

All of the pumping events from the 2014-2015 sampling year were relatively typical with salinities at NUDE02 dropping below 5 PSU within 3-5 days of pumping and slowly rising after the end of the pumping event. However, the contribution of freshwater from natural flooding along the Nueces River into the Nueces Delta during pumping event 24 is unknown.

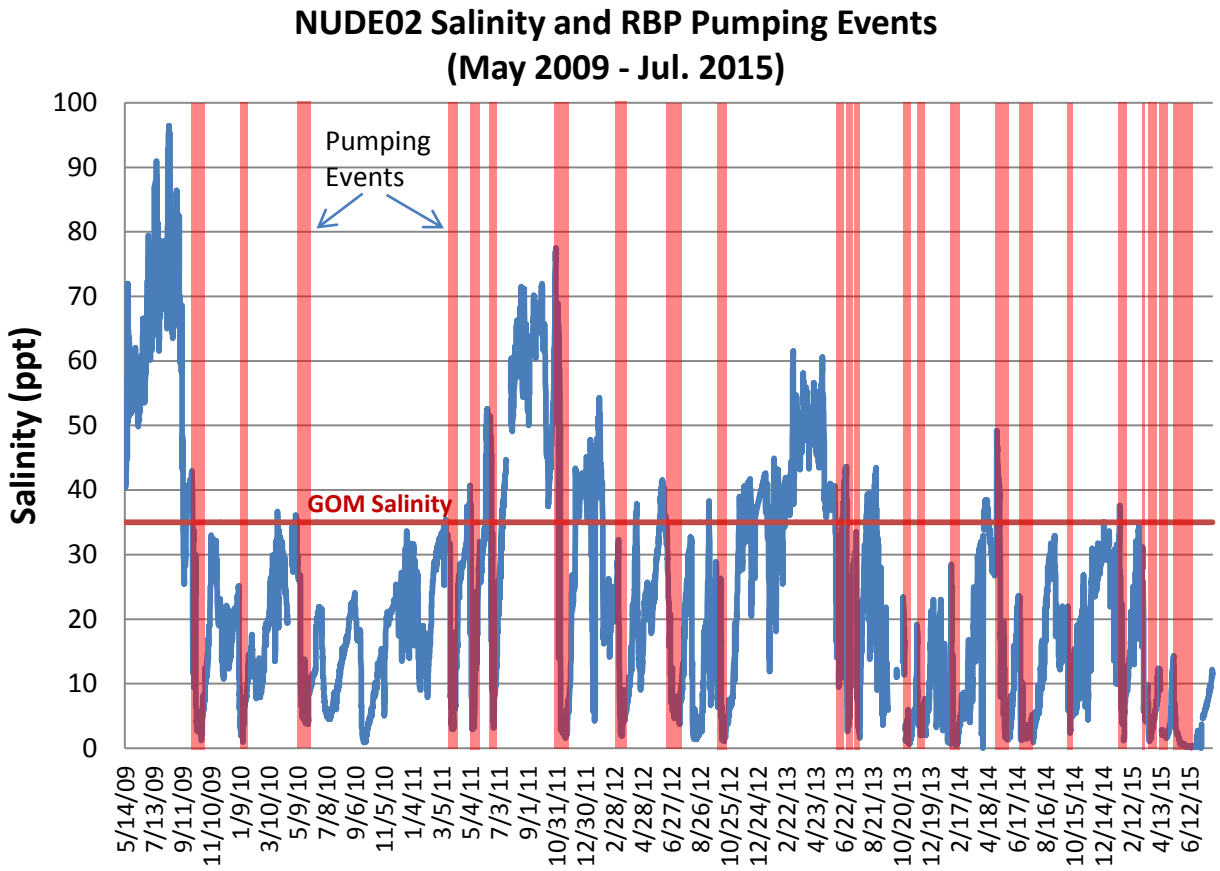


Figure 15. NUDE2 salinity during the 24 pumping events to date. Shaded areas denote the pumping events that have occurred for the project during the period of May 2009 to July 2015. Thickness of each shaded area represents duration (days) of pumping. The horizontal red line represents 35 PSU, which is typical Gulf of Mexico (GOM) salinity.

A review of all the pumping events since this project began in 2009 appears to indicate that the pipeline is an effective tool for managing salinities within the Rincon Bayou. The combined effects of precipitation, wind direction and velocity, tidal variations and evaporation has a significant effect on salinity levels in the Nueces Delta, and the data gathered from this project will be incorporated into the overall water management strategy for reestablishing the connectivity and salinity gradient back in the Nueces Delta.

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