# Spatial Effects of Rincon Bayou Pipeline Freshwater Inflows on Salinity in the Lower Nueces Delta, Texas

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## Introduction

Restoring freshwater to the Nueces Delta (Figure 1) has been an environmental concern since the negative ecological and biological effects of hypersaline conditions were identified (Matthews and Mueller 1987; Whitledge and Stockwell 1995; Montagna et al. 2009; Hill et al. 2011; Nueces BBEST 2011; Nueces BBASC 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 and receives inflows only during locally heavy rainfall events or flood events that cause over-banking of the river, or ample inflow to move through the man-made Rincon Bayou diversion channel (BOR 2000; Pulich et al. 2002; Hill et al. 2011). These decreased inflows into the delta have resulted in periods of hypersaline conditions that have affected biological productivity.

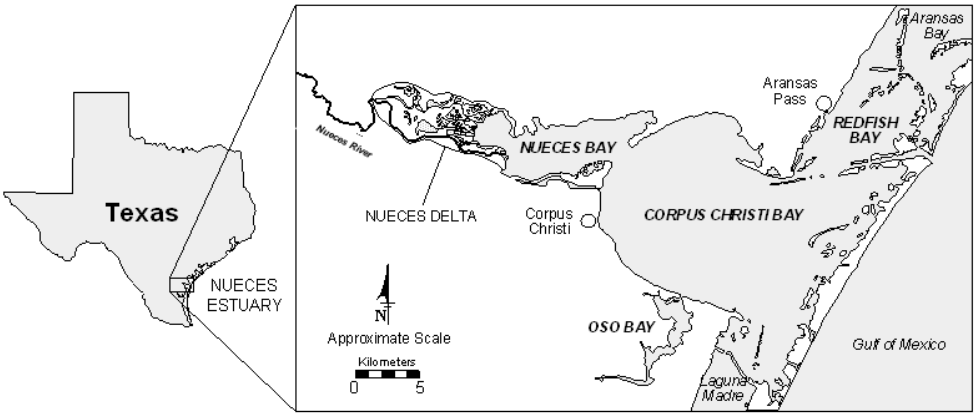



Figure 1. Nueces Estuary, Corpus Christi, Texas USA.

The stress hypersalinity poses to ecological and biological processes and general health of estuaries prompted the state of Texas to develop an inflow criterion for freshwater inflows for the Nueces Estuary in 1990 (Alexander and Dunton 2000; Montagna et al. 2002; Palmer and others 2002). The resultant 2001 Agreed Order, from the Texas Commission on Environmental Quality (TCEQ) (formerly Texas Natural Resource Conservation Commission), requires the City of Corpus Christi (City) to provide no less than 151,000 acre-feet per year (186,106 $m^3$) 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 (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).

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 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.

| | Rincon Bayou Pumps | | |
|---|---|---|---|
| | 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 |

A) B)

Figure 2. A) RBP pumps located on the Nueces River above the Calallen Dam and B) RBP outfall in the Rincon Bayou.

This project assessed freshwater inflows coming into the Rincon Bayou via the RBP by measuring salinity at various stations downstream of the pipeline and in areas adjacent to the main channel. Salinity measurements were used to identify if freshwater from the RBP reached adjacent areas connected to the Rincon Bayou channel. This report will focus on describing the distribution of RBP freshwater inflows in the lower Nueces Delta and provide a descriptive analysis for the three (3) RBP inflow events that occurred November 2011, March 2012, and June 2012.

**Method**

*Conrad Blucher Institute*

The Conrad Blucher Institute for Surveying and Science (CBI) at Texas A&M University - Corpus Christi (TAMU-CC) has a network of fixed salinity monitoring stations in the Nueces River, Nueces Delta, and Nueces Bay under contract with the Coastal Bend Bays & Estuaries Program (CBBEP) and the City. The CBI installed monitoring stations downstream of the RBP outfall (Figure 3) to capture the extent of freshwater flow in the Rincon Bayou and into Nueces Bay.

Salinity monitoring stations consist of a single piling jetted into the mud and positioned in the deepest part of the Rincon Bayou channel. NUDE02 (Figure 3), is located in the middle reach of Rincon Bayou (27.888611°N, -97.569444°W) and NUDE03 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) (Figure 3). 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.


Figure 3. Map of the Nueces Delta and locations of CBI salinity monitoring stations and USGS flow gauge. RBP = Rincon Bayou Pipeline.

A tide gauge (NUEBAY 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 (see Figure 3), located on Rincon Bayou is located 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 and NUEBAY 185 was serviced every 6 months.

The CBI salinity monitoring stations consist of Hydrolab® water quality datasondes interfaced with line of sight spread spectrum radios aimed back to TAMU-CC. Stations are radio polled by an automated computer program designed and implemented by the Information Technology staff at CBI. Data are 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. Instruments are exchanged monthly with freshly calibrated units. 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.

*Center for Coastal Studies*

The Center for Coastal Studies (CCS) deployed satellite stations to capture the three (3) RBP events and determine salinity effects to habitats connected to the main Rincon Bayou channel that included small tidal channels, mudflats, and ephemeral ponds (Figure 4; Table 2). Stations consisted of one 6920 YSI datasonde attached to a PVC bipod with chain and lock. Datasondes were programmed to sample every 15 minutes while *in situ*. Datasondes were deployed up to three weeks prior to the RBP release and recovered up to three weeks after the RBP event was completed. Field maintenance of the CCS occurred every two weeks during the RBP release. Data were downloaded from the datasondes to a computer during field maintenance. Calibration and post-calibration of datasondes were performed at the CCS wet lab and all quality control forms were retained in the laboratory.

Salinity data were binned according to the RBP pumping event period: Pre-RBP, During-RBP, and Post-RBP. IBM SPSS version 19 (IBM SPSS, 2012) was used to analyze salinity data. ANOVA was used to determine mean salinity differences between stations at times of Pre-RBP, During-RBP, and Post-RBP to identify the spatial extent of the RBP event in the Rincon Bayou. A first order variant of local polynomial interpolation method was used to interpolate between the salinity data between Pre-RBP, During-RBP, and Post-RBP using ArcGIS software (version 10; ESRI, 2011). Table 2 provides latitude and longitude for each CCS station and station distance to the Rincon Bayou. The distance was measured using instream distance from the closest inlet connecting to Rincon Bayou. Salt03 and Salt05 salinity data were included in tables as a reference to salinity in the middle of Nueces Bay and Nueces River but these values were not included in statistical analyses.

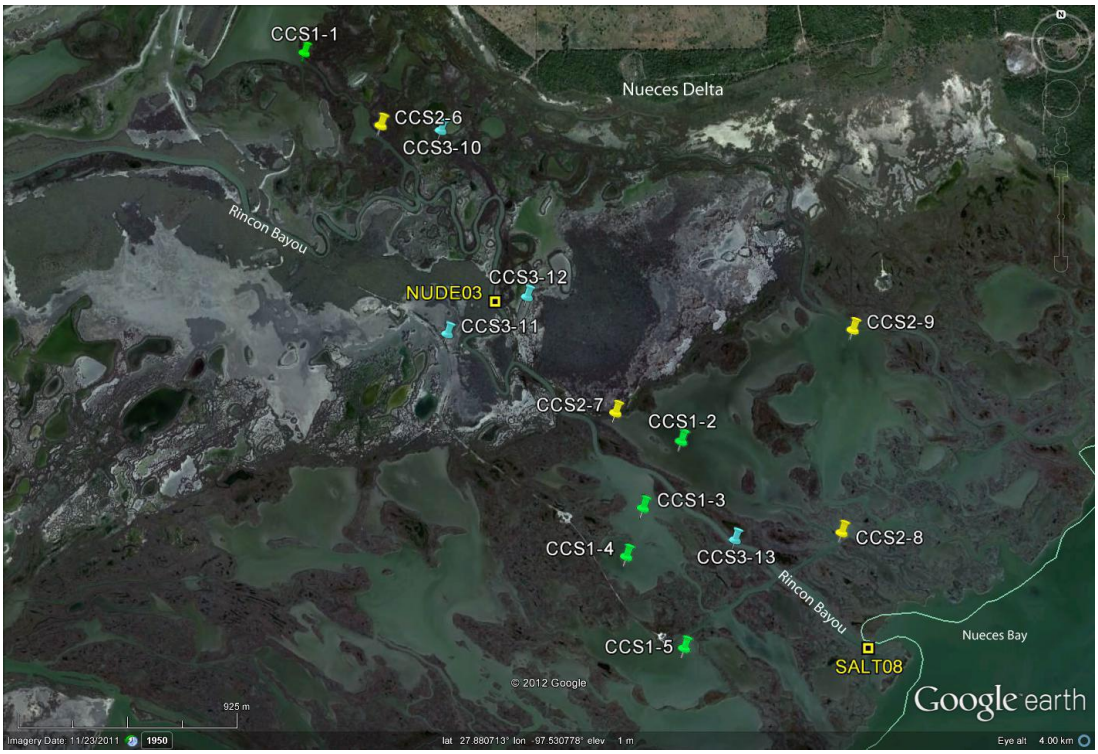



Figure 4. Location of CCS satellite stations, NUDE03, and Salt08. Green pins = Event 1, Yellow pins = Event 2, and blue pins = Event 3.

Table 2. Location of CCS stations and distance from the Rincon Bayou main channel by event.

| Event | Station | Latitude | Longitude | Distance from Rincon Bayou Channel (m) |
|---|---|---|---|---|
| 1 | CCS1 | 27.89266°N | -97.54141°W | 655 |
| 1 | CCS2 | 27.87786°N | -97.52623°W | 150 |
| 1 | CCS3 | 27.87533°N | -97.52688°W | 182 |
| 1 | CCS4 | 27.87310°N | -97.52758°W | 393 |
| 1 | CCS5 | 27.87001°N | -97.52511°W | 593 |
| 2 | CCS6 | 27.88987°N | -97.53815°W | 191 |
| 2 | CCS7 | 27.87895°N | -97.52806°W | 83 |
| 2 | CCS8 | 27.87439°N | -97.51834°W | 278 |
| 2 | CCS9 | 27.88208°N | -97.52672°W | 4043 |
| 3 | CCS10 | 27.88966°N | -97.53556°W | 361 |
| 3 | CCS11 | 27.88195°N | -97.5353°W | 104 |
| 3 | CCS12 | 27.88335°N | -97.53186°W | 110 |
| 3 | CCS13 | 27.87411°N | -97.52293°W | 555 |

**Summary of Past and Current Pumping Events**

Nine pumping events have taken place since the RBP became operational in late 2007. During the four year pumping period, 14,709 acre-feet of water has been pumped into the upper Rincon Bayou (Table 3). Drought conditions that occurred in late 2008 persisted until fall 2009 did not permit RBP pumping events to occur in Year 1. In Year 2, the RBP pumped a total of 6,017 acre-feet to the Rincon Bayou. Year 3 a total of 2,997 acre-feet was passed through and in Year 4 a total of 5,695 acre-feet was released into the Rincon Bayou (Figure 5 shows individual pumping events and the effect on salinity at the NUDE02 station). A reference line (35 PSU) was added to the graph to indicate hypersalinity at NUDE02, as salinity measurements will be above the reference line (>35 PSU). The figure also shows periods when salinities were naturally maintained or managed via the RBP or rainfall at NUDE02 and are identified when salinity is between 0 and 35 PSU.

Table 3. RBP pumping events including pumping dates, duration, and acre-feet pumped.

| Year | Pumping Event | Dates of Event | Duration (days) | Acre-Feet Pumped |
|---|---|---|---|---|
| 1 | - | No pumping occurred | - | - |
| 2 | 1 | September 28 to October 21, 2009 | 24 | 2,987 |
| 2 | 2 | January 6 to January 14, 2010 | 9 | 742 |
| 2 | 3 | May 10 to May 31, 2010 | 21 | 2,288 |
| 3 | 4 | March 21 to March 30, 2011 | 10 | 1,001 |
| 3 | 5 | May 3 to May 12, 2011 | 10 | 1,002 |
| 3 | 6 | June 13 to June 22, 2011 | 10 | 994 |
| 4 | 7 | November 2 to November 22, 2011 | 21 | 2,031 |
| 4 | 8 | March 7 to March 19, 2012 | 13 | 1,310 |
| 4 | 9 | June 21 to July 13, 2012 | 23 | 2,354 |

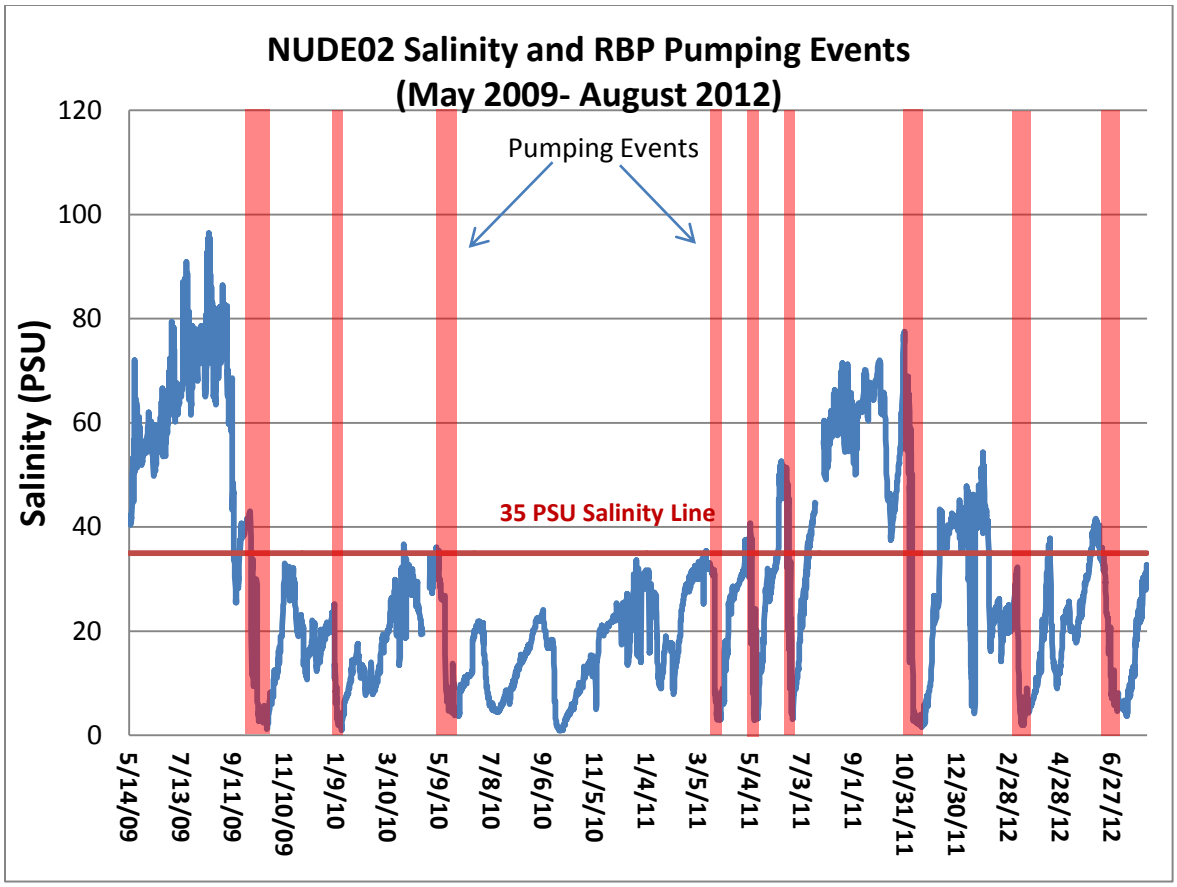
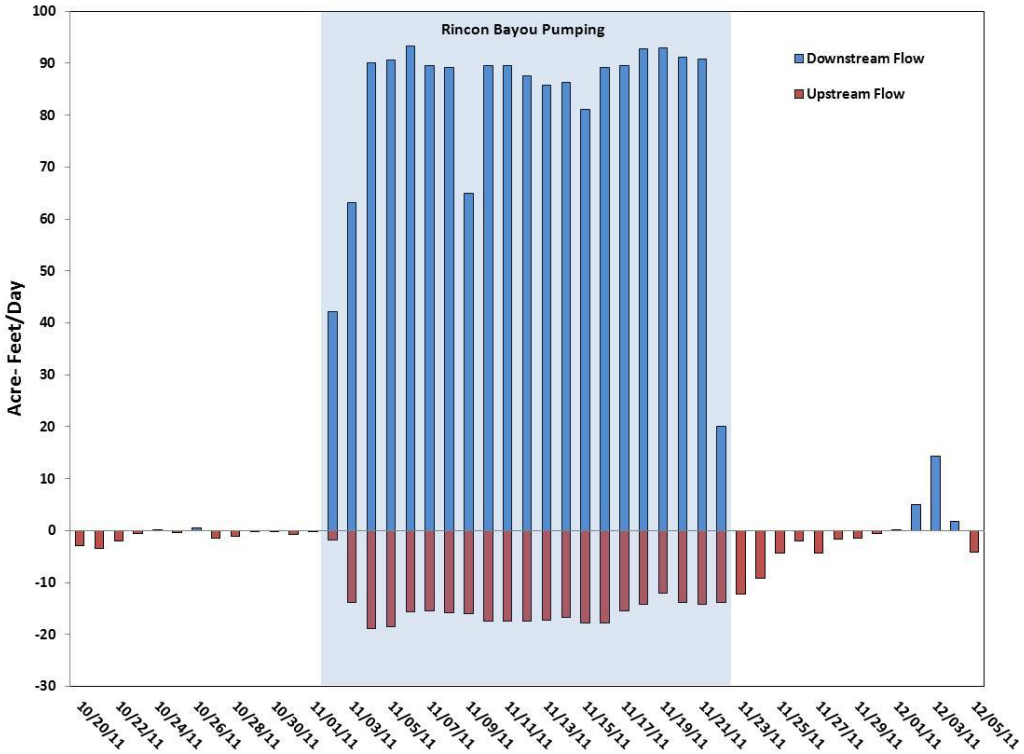



Figure 5. NUDE02 salinity during the nine pumping events relative to 35 PSU. Shaded areas denotes the nine pumping events that have occurred for the project during the period of May 2009 and early August 2012. Thickness of each shaded area represents duration (days) of pumping.

The Rincon Bayou has no distinct elevation gradient at the RBP outfall so water naturally flows both, downstream to the Rincon Bayou and upstream back to the Nueces River. As cited in Tunnell and Lloyd (2011), during the RBP operational testing phases the City installed a swing gate to prevent upstream flow. A United States Geological Survey gauge (USGS 08211503) has been in operation since 1996 and is located upstream of the RBP outfall. The USGS gauge measures discharge rates of both the RBP and natural flows through the Rincon Bayou. Data from this gauge were used to calculate the percentage of RBP backflow to the Nueces River and total water flowing downstream to the Rincon Bayou for each of the three pumping events during this study (Figure 6).

A)


Rincon Bayou Pumping
Downstream Flow
Upstream Flow
Acre- Feet/Day
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
10/20/11
10/22/11
10/24/11
10/26/11
10/28/11
10/30/11
11/01/11
11/03/11
11/05/11
11/07/11
11/09/11
11/11/11
11/13/11
11/15/11
11/17/11
11/19/11
11/21/11
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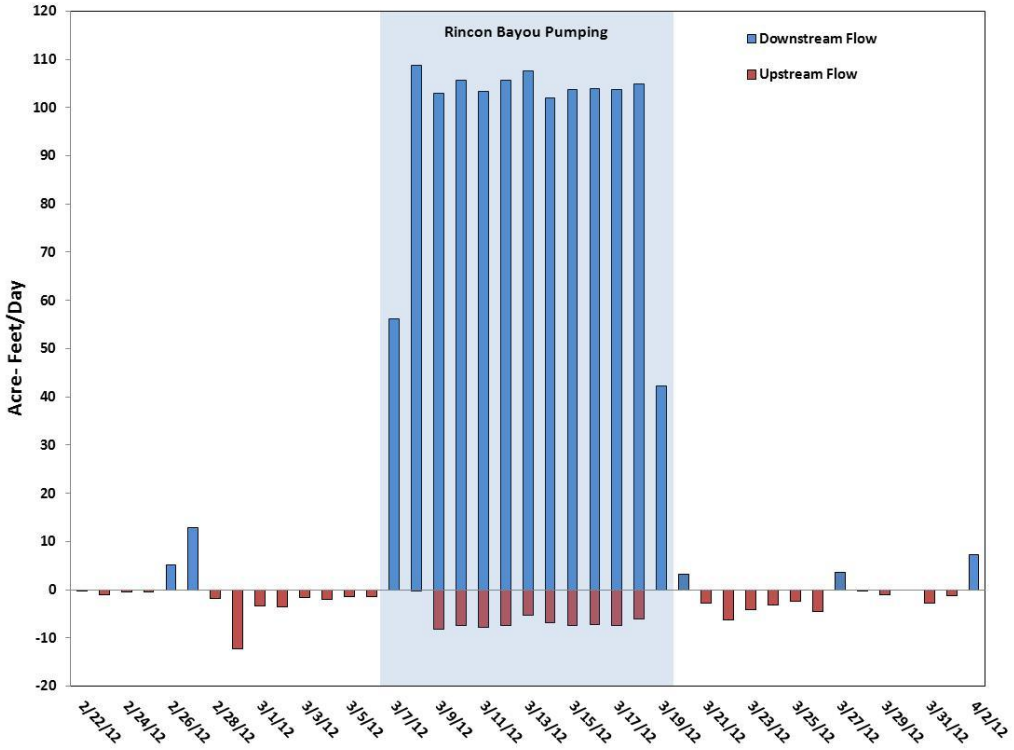
11/27/11
11/29/11
12/01/11
12/03/11
12/05/11

B)


Rincon Bayou Pumping
Downstream Flow
Upstream Flow
Acre- Feet/Day
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
2/22/12
2/24/12
2/26/12
2/28/12
3/1/12
3/3/12
3/5/12
3/7/12
3/9/12
3/11/12
3/13/12
3/15/12
3/17/12
3/19/12
3/21/12
3/23/12
3/25/12
3/27/12
3/29/12
3/31/12
4/2/12

C)

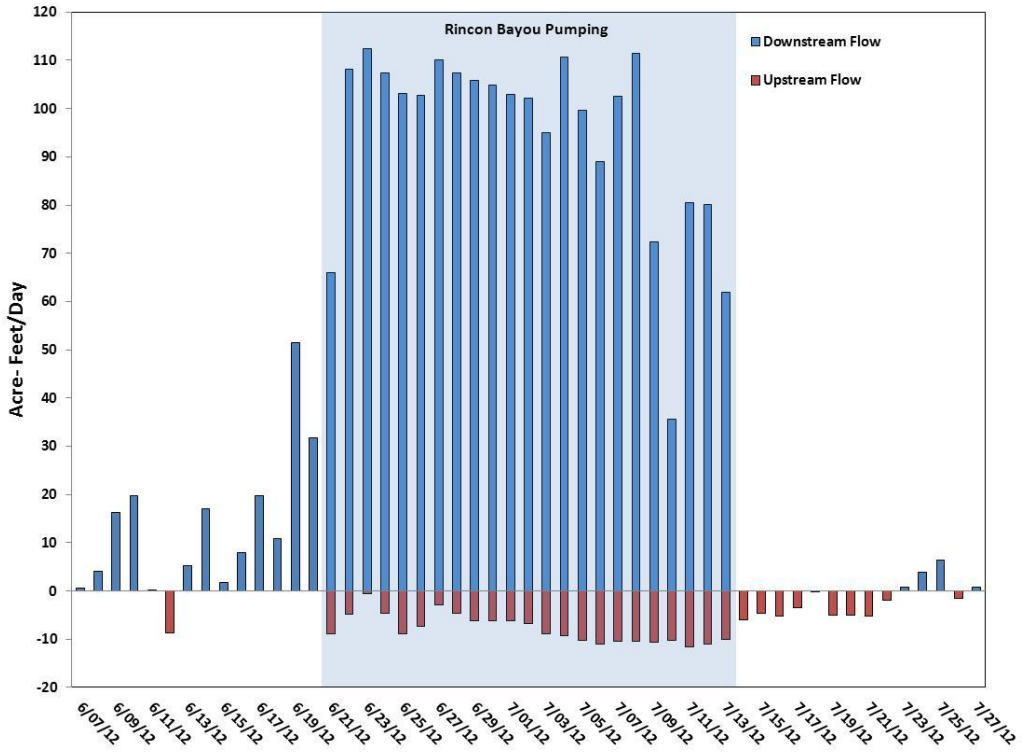



Figure 6. Discharge rates of freshwater through the RBP during the A) November 2011 pumping event, B) March 2012 pumping event, and C) June-July 2012 pumping event showing the amount of water following downstream (blue) through the Rincon Bayou or the loss (red) upstream to the Nueces River measured at USGS Gauge 08211503. Light blue shaded area depicts the RBP Event.

## Results and Discussion

*Event 1*

A total of 2,031 acre-feet of water was pumped to the Rincon Bayou from November 2 through November 22, 2011. Widespread hypersaline conditions (> 35 PSU) were in the Rincon Bayou channel prior to the RBP event. Five datasondes deployed in the lower delta identified hypersaline conditions in areas outside of the Rincon Bayou channel prior to the November 2011 RBP event (Table 4). CCS1 was not deployed until November 6, 2011, after the RBP started. As 8.0 mm of rainfall was recorded at the NUDEWX station during Event 1, salinity changes observed in the Rincon Bayou were likely a direct result from the RBP.

Table 4. Rincon Bayou Pipeline November 2011 event daily mean salinity (PSU). Shaded areas: gray = time period of the RBP release and green with bold type = salinity < 35 PSU.

| Rain mm | RBP Date | RBP Flow Acre-feet | Date | CCS1 | CCS2 | CCS3 | CCS4 | CCS5 | NUDE2 | NUDE3 | Salt 08 | Salt 03 | Salt 05 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | 10/25/11 | | 51.8 | 49.7 | 48.7 | 46.9 | 55.8 | 41.9 | 46.3 | 44.7 | 10.9 |
| 0 | | | 10/26/11 | | 51.5 | 48.8 | 48.7 | 45.9 | | | 47.3 | 44.6 | 11.2 |
| 0 | | | 10/27/11 | | 52.0 | 48.9 | 49.5 | 44.3 | | | | | |
| 0 | | | 10/28/11 | | 51.6 | 53.2 | 50.6 | 47.2 | 75.6 | | 53.9 | 46.5 | 11.1 |
| 0 | | | 10/29/11 | | 53.1 | 53.8 | 52.6 | 48.4 | 75.4 | 43.3 | 49.3 | 46.3 | 11.1 |
| 0 | | | 10/30/11 | | 51.1 | 50.8 | 50.6 | 47.4 | 61.3 | 41.2 | 47.9 | 46.2 | 11.3 |
| 0 | | | 10/31/11 | | 51.2 | 48.9 | 50.0 | 46.8 | 60.2 | | 49.6 | 46.0 | 11.2 |
| 0 | | | 11/1/11 | | 50.7 | 47.9 | 49.8 | 44.9 | 54.7 | 40.1 | 49.1 | 46.0 | 10.2 |
| 0 | 11/2/11 | 44 | 11/2/11 | | 48.9 | 46.5 | 49.2 | 42.5 | 57.4 | 39.0 | 47.4 | | 9.9 |
| 1.0 | 11/3/11 | 77 | 11/3/11 | | 48.7 | 49.8 | 48.9 | 41.9 | 64.0 | 42.8 | 54.5 | 45.6 | 8.9 |
| 0 | 11/4/11 | 109 | 11/4/11 | | 37.1 | 52.4 | 54.2 | 45.0 | 62.2 | 44.8 | 51.0 | 45.8 | 9.1 |
| 0 | 11/5/11 | 109 | 11/5/11 | | **32.5** | 50.9 | 51.1 | 44.3 | 40.5 | 42.3 | 48.4 | 45.8 | 9.0 |
| 0 | 11/6/11 | 109 | 11/6/11 | 43.9 | 35.6 | 44.2 | 48.3 | 44.1 | 54.2 | 38.8 | 46.3 | 45.5 | 9.1 |
| 0 | 11/7/11 | 105 | 11/7/11 | 44.6 | 44.5 | 44.8 | 47.7 | 41.1 | 49.5 | 37.6 | 46.1 | 45.0 | 9.1 |
| 0 | 11/8/11 | 105 | 11/8/11 | 45.7 | 46.3 | 46.9 | 47.2 | 45.7 | **11.5** | 39.1 | 45.8 | 44.0 | 8.6 |
| 0 | 11/9/11 | 81 | 11/9/11 | 47.8 | 47.0 | 41.1 | 46.6 | 41.8 | **4.1** | **30.7** | 44.2 | 46.1 | |
| 0 | 11/10/11 | 107 | 11/10/11 | 40.7 | 46.5 | **27.0** | **33.3** | 39.1 | | **17.5** | | | |
| 0 | 11/12/11 | 105 | 11/11/11 | **31.5** | 44.9 | **30.4** | **27.4** | 38.7 | **3.6** | **17.0** | 44.0 | 45.0 | 8.7 |
| 0 | 11/13/11 | 103 | 11/12/11 | **34.9** | 41.8 | 39.6 | 39.9 | 39.3 | **2.9** | **22.1** | 43.6 | 46.5 | 8.8 |
| 0 | 11/14/11 | 103 | 11/13/11 | **32.7** | 40.2 | 40.1 | 41.2 | 40.4 | **2.8** | **19.7** | 38.8 | 46.1 | 8.0 |
| 0 | 11/15/11 | 99 | 11/14/11 | **30.5** | 39.5 | 41.1 | 41.3 | 40.5 | **3.0** | | **34.4** | 45.6 | 8.7 |
| 4.0 | 11/16/11 | 107 | 11/15/11 | **29.0** | 39.5 | **31.4** | 39.7 | 40.7 | | **12.5** | **17.1** | 45.4 | 5.9 |
| 0 | 11/17/11 | 105 | 11/16/11 | **25.2** | 39.3 | **19.3** | **24.0** | 40.1 | **3.5** | **9.9** | **12.3** | 45.5 | 6.5 |
| 0 | 11/18/11 | 107 | 11/17/11 | **12.9** | 38.7 | **13.5** | **12.8** | **30.0** | **4.0** | | **34.9** | 46.3 | 11.6 |
| 0 | 11/19/11 | 105 | 11/18/11 | **9.2** | 37.0 | **23.5** | **22.0** | 37.9 | **3.0** | **23.9** | 41.5 | 46.3 | 9.3 |
| 0 | 11/20/11 | 105 | 11/19/11 | **28.1** | 38.6 | 36.9 | 40.3 | 41.7 | **3.7** | 43.2 | 45.2 | 45.1 | |
| 0 | 11/21/11 | 105 | 11/20/11 | **32.1** | 39.5 | 38.8 | 42.2 | 40.9 | **4.0** | 41.6 | 44.1 | 44.7 | 8.8 |
| 0 | 11/22/11 | 34 | 11/21/11 | **28.9** | 38.8 | 37.7 | 42.8 | 42.0 | **6.0** | **30.1** | 45.6 | 44.7 | 8.6 |
| 0 | | | 11/22/11 | **30.4** | 38.5 | **32.0** | 36.4 | 42.5 | **2.5** | **14.0** | 43.8 | 45.1 | 6.8 |
| 0 | | | 11/23/11 | **30.9** | 38.5 | **16.4** | **19.7** | 38.7 | **4.6** | **9.2** | 39.8 | 45.4 | 8.4 |
| 0 | | | 11/24/11 | **29.3** | **34.1** | **13.7** | **13.0** | 36.1 | **7.2** | **10.0** | 39.7 | 45.1 | 8.7 |
| 0 | | | 11/25/11 | **20.0** | **34.5** | **33.6** | **34.5** | 37.6 | **6.5** | **12.4** | 36.6 | 45.1 | 8.5 |
| 0 | | | 11/26/11 | **29.8** | **27.4** | **33.7** | 38.1 | 39.2 | **7.5** | **18.0** | **32.5** | 45.5 | 5.1 |
| 0 | | | 11/27/11 | **14.2** | **18.5** | **11.1** | **18.0** | 36.8 | | **9.9** | | 47.1 | 6.5 |
| 0 | | | 11/28/11 | | | **8.0** | **11.9** | **34.1** | | **11.5** | **13.8** | 45.8 | 4.2 |
| 0 | | | 11/29/11 | | | **14.6** | | **30.5** | | | | 45.9 | |
| 0 | | | 11/30/11 | | **22.2** | **32.8** | **19.7** | 37.3 | | **27.5** | 40.3 | 44.7 | |

Table 4 Continued. Rincon Bayou Pipeline November 2011 event daily mean salinity (PSU). Shaded areas: gray = time period of the RBP release and green with bold type = salinity < 35 PSU.

| Rain mm | RBP Date | RBP Flow Acre-feet | Date | CCS1 | CCS2 | CCS3 | CCS4 | CCS5 | NUDE2 | NUDE3 | Salt 08 | Salt 03 | Salt 05 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | 12/1/11 | **33.9** | 41.8 | 40.5 | 39.5 | 40.4 | | 43.9 | 43.3 | 44.5 | 6.4 |
| 0 | | | 12/2/11 | 41.7 | 42.1 | 42.3 | 42.2 | 40.0 | | 41.9 | 43.0 | 43.7 | 6.5 |
| 0 | | | 12/3/11 | 40.9 | 40.1 | 42.2 | 42.4 | 37.1 | | 42.3 | 42.9 | 43.7 | 6.2 |
| 0 | | | 12/4/11 | 40.1 | 41.1 | 42.1 | 42.4 | 36.0 | | 42.7 | 42.7 | 42.8 | |
| 0 | | | 12/5/11 | 42.2 | **27.6** | 37.5 | 35.5 | 36.1 | | 37.5 | 42.2 | 43.2 | 4.6 |
| 0 | | | 12/6/11 | **29.9** | **19.5** | **24.2** | **23.0** | **30.6** | | **34.6** | 39.2 | | |
| 0 | | | 12/7/11 | **8.5** | **15.0** | **23.3** | **15.4** | **33.6** | **25.5** | **31.7** | 44.2 | 43.8 | |
| 0 | | | 12/8/11 | **5.5** | **20.2** | **24.1** | **15.3** | 39.2 | **25.8** | 37.4 | 44.4 | 43.3 | 6.3 |
| 0 | | | 12/9/11 | **29.5** | 37.8 | 35.4 | **34.9** | 41.0 | | 43.3 | 44.1 | 43.4 | 7.3 |
| 2.0 | | | 12/10/11 | 41.7 | 42.0 | 36.7 | 42.7 | 42.5 | 41.7 | 42.7 | 44.1 | 43.1 | |
| 1.0 | | | 12/11/11 | 40.6 | 40.0 | 37.8 | 42.3 | 41.7 | 39.4 | 43.7 | 43.7 | 42.9 | 11.3 |
| 0 | | | 12/12/11 | 39.8 | 39.3 | 36.4 | 41.7 | 40.4 | 38.8 | 42.2 | 42.2 | 42.4 | 10.3 |
| 0 | | | 12/13/11 | 38.7 | 38.5 | 35.9 | 41.1 | 41.1 | 38.2 | 41.0 | 41.4 | | |
| 0 | | | 12/14/11 | 38.9 | 38.1 | **34.3** | 41.8 | 39.0 | 38.9 | 40.8 | 41.3 | 42.0 | 11.2 |
| 0 | | | 12/15/11 | 38.7 | 38.8 | 38.1 | 42.3 | 37.3 | | 42.9 | 42.2 | 42.4 | |

Once the RBP pumping event was complete, hypersaline conditions (>35 PSU) persisted throughout the Rincon Bayou at CCS5 and Salt08 (Table 5). The RBP freshwater signal was recognized at all stations in the Rincon Bayou during Event 1. An ANOVA identified the decrease in salinity significant between Pre-RBP, During-RBP, and Post-RBP conditions (Table 6). CCS1 was not included in the ANOVA analysis since Pre-RBP data does not exist. Mean salinity During-RBP and Post-RBP were significantly lower compared to the Pre-RBP conditions. Tukey HSD tests identified Pre-RBP mean salinity statistically significantly higher compared to During-RBP and Post-RBP at all CCS stations. Salt08 mean salinity was not statistically different from Pre-RBP, During-RBP, and Post-RBP salinity. The freshwater volume released was not enough to offset the hypersaline conditions in the lower Rincon Bayou during this event.

Table 5. Pre-RBP, During-RBP, and Post-RBP mean salinity, November 2011 event.

| | CCS 1 | CCS 2 | CCS 3 | CCS 4 | CCS 5 | NUDE 2 | NUDE 3 | Salt 08 | Salt 03 | Salt 05 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Mean PSU Pre-RBP** | | 51.63 | 50.25 | 50.07 | 46.48 | 63.83 | 41.63 | 49.06 | 45.76 | 11.00 |
| **Mean PSU During-RBP** | 32.35 | 41.24 | 37.81 | 40.00 | 40.87 | 21.11 | 30.70 | 41.33 | 45.50 | 8.74 |
| **Mean PSU Post-RBP** | 30.37 | 33.44 | 30.28 | 31.89 | 37.86 | 23.05 | 31.35 | 38.58 | 44.13 | 7.39 |

Table 6. ANOVA salinity analysis for the November 2011 RBP pumping event. Tukey HSD means are arranged from low (left) to high (right); ns = not significant.

| Station | df | F | *p* | Tukey Test |
|---|---|---|---|---|
| CCS2 | 2, 49 | 24.34 | <0.001 | PostRBP RBP PreRBP |
| CCS3 | 2, 51 | 13.21 | <0.001 | PostRBP RBP PreRBP |
| CCS4 | 2, 50 | 10.26 | <0.001 | PostRBP RBP PreRBP |
| CCS5 | 2, 51 | 22.39 | <0.001 | PostRBP RBP PreRBP |
| NUDE02 | 2, 35 | 13.42 | <0.001 | RBP PostRBP PreRBP |
| NUDE03 | 2, 44 | 1.56 | 0.222 | ns |
| Salt08 | 2, 47 | 3.51 | 0.38 | ns |

Spatial interpolation of salinity in the Rincon Bayou Pre-RBP identified a classic negative estuarine system with salinity increasing as you move upstream from Nueces Bay (Figure 7). Once RBP pumping started, salinity decreased alleviating the reverse estuary conditions in the channel. Even though the salinity measured outside the channel proper During-RBP decreased by 10 PSU the areas remained hypersaline (Figure 7). The RBP November 2011 event lasted 21 days and Post-RBP mean salinity in the channel ranged from 23.05 PSU at NUDE2 to 38.58 PSU at Salt08 located at the mouth of Nueces Bay. The mean salinity outside the channel was below hypersaline conditions except at the station located closest to Nueces Bay (mean 37.86 PSU).

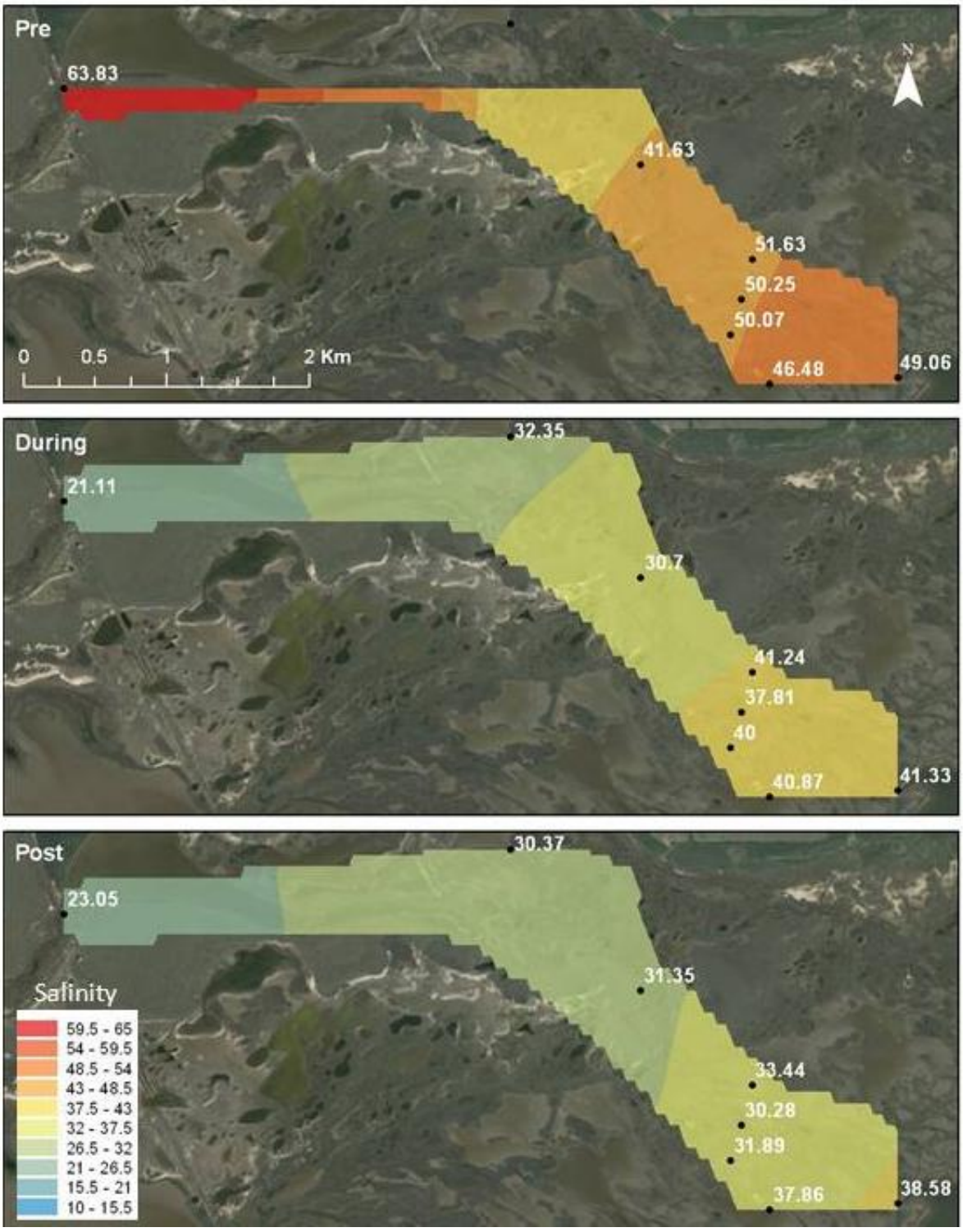



Figure 7. Spatial interpolation was calculated using the mean salinity of Pre-RBP, During-RBP, and Post-RBP for the November 2011 event.

*Event 2*

A total of 1,309 acre-feet of water was pumped to the Rincon Bayou from March 7 through March 19, 2012. Salinity in the Rincon Bayou channel ranged from 20-30 PSU and at the four stations outside of the Rincon Bayou channel ranged from 24-36 PSU prior to the March 2012 RBP event (Table 7). A total of 40 mm of rainfall was recorded at NUDEWX during Event 2, with most of the rainfall during the Post-RBP period (39.0 mm). Rainfall coupled with the RBP event lowered salinity to below hypersaline conditions Post-RBP and an estuarine gradient was achieved.

Table 7. Rincon Bayou Pipeline March 2012 event daily mean salinity (PSU). Shaded areas: gray= time period of the RBP release and green= salinity < 35 PSU.

| Rain mm | RBP Date | RBP Flow Acre-feet | Date | CCS6 | CCS7 | CCS8 | CCS9 | NUDE2 | NUDE3 | Salt08 | Salt03 | Salt05 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | 3/2/12 | **30.4** | 35.9 | **33.3** | 35.1 | **20.5** | **26.9** | **30.9** | **30.8** | |
| 0 | | | 3/3/12 | **29.7** | 35.7 | **33.5** | **24.4** | **23.1** | **25.4** | **28.6** | **31.9** | 5.4 |
| 0 | | | 3/4/12 | **26.3** | **29.6** | **34.1** | 37.1 | **23.7** | | **31.8** | **32.0** | 5.0 |
| 0 | | | 3/5/12 | **29.0** | **30.6** | **34.6** | **33.0** | | **26.2** | | **32.1** | |
| 0 | | | 3/6/12 | 35.7 | **28.8** | 35.0 | 36.5 | **28.1** | **31.4** | **32.0** | **32.1** | 7.3 |
| 0 | 3/7/12 | 52 | 3/7/12 | 35.2 | 37.2 | **34.8** | 36.8 | **31.1** | | | | |
| 0 | 3/8/12 | 109 | 3/8/12 | 35.3 | 37.3 | **34.8** | 36.8 | **32.3** | | **31.8** | **32.6** | 7.5 |
| 1.0 | 3/9/12 | 111 | 3/9/12 | 38.3 | **8.0** | **31.8** | **29.9** | **17.9** | | **32.6** | | |
| 0 | 3/10/12 | 113 | 3/10/12 | **30.0** | **23.6** | **32.7** | 36.2 | | **21.7** | **32.8** | **33.1** | 6.6 |
| 0 | 3/11/12 | 111 | 3/11/12 | **26.5** | **26.6** | **33.7** | 35.1 | **5.3** | **27.2** | | **33.1** | |
| 0 | 3/12/12 | 113 | 3/12/12 | **25.5** | **27.1** | **33.5** | 35.1 | **3.5** | | **31.3** | **32.9** | |
| 0 | 3/13/12 | 113 | 3/13/12 | **25.9** | **23.1** | **32.2** | **34.1** | **3.1** | **27.5** | **31.5** | **32.6** | |
| 0 | 3/14/12 | 109 | 3/14/12 | **27.7** | **29.1** | **32.5** | **34.3** | **7.3** | **28.9** | **33.2** | **34.1** | |
| 0 | 3/15/12 | 111 | 3/15/12 | **26.4** | **33.9** | **33.7** | **34.8** | **1.9** | **22.9** | **33.8** | **34.1** | |
| 0 | 3/16/11 | 111 | 3/16/12 | **23.9** | **33.8** | **34.4** | 35.2 | | **14.7** | **34.0** | **34.3** | |
| 0 | 3/17/12 | 111 | 3/17/12 | **22.7** | **33.6** | **34.1** | 35.0 | | | **34.4** | **34.5** | |
| 0 | 3/18/11 | 111 | 3/18/12 | **16.8** | **33.5** | **33.6** | 35.0 | | 9.3 | **34.1** | **34.7** | 4.8 |
| 0 | 3/19/12 | 34 | 3/19/12 | **31.2** | **33.1** | **33.6** | **33.8** | **6.6** | **27.3** | **33.7** | **34.5** | 7.8 |

Table 7 Continued. Rincon Bayou Pipeline March 2012 event daily mean salinity (PSU). Shaded areas: gray= time period of the RBP release and green= salinity < 35 PSU.

| Rain mm | RBP Date | RBP Flow Acre-feet | Date | CCS6 | CCS7 | CCS8 | CCS9 | NUDE2 | NUDE3 | Salt08 | Salt03 | Salt05 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 17.0 | | | 3/20/12 | **30.5** | **31.4** | **32.1** | **33.1** | | | **31.9** | **34.3** | |
| 0 | | | 3/21/12 | **27.5** | **28.4** | **29.5** | **31.9** | **5.2** | **14.8** | **22.4** | **34.7** | 5.2 |
| 0 | | | 3/22/12 | **27.8** | **22.7** | **24.9** | **32.0** | **4.8** | 13.1 | **30.4** | **33.8** | |
| 0 | | | 3/23/12 | **21.2** | **23.9** | **27.2** | **32.3** | | | **32.0** | **34.4** | |
| 0 | | | 3/24/12 | **19.5** | **24.2** | **27.3** | **34.2** | **6.1** | **18.9** | **31.7** | **34.4** | |
| 0 | | | 3/25/12 | **19.4** | **24.2** | **27.2** | **33.5** | | **19.3** | **31.5** | | |
| 0 | | | 3/26/12 | **20.0** | **28.0** | **26.5** | **32.9** | | **19.8** | **31.8** | **34.2** | |
| 0 | | | 3/27/12 | **22.3** | **31.8** | **27.8** | **33.1** | **7.1** | | **34.7** | | |
| 6.0 | | | 3/28/12 | **24.0** | **30.9** | **28.0** | **33.6** | **8.1** | **32.5** | **34.5** | 35.1 | |
| 4.0 | | | 3/29/12 | **23.5** | **29.9** | **27.1** | **32.6** | **8.3** | | **33.8** | **34.1** | |
| 0 | | | 3/30/12 | **22.6** | **29.3** | **26.2** | **32.0** | **9.0** | | | **34.1** | |
| 0 | | | 3/31/12 | **24.0** | **25.5** | **26.4** | **32.7** | **9.8** | | | | |
| 0 | | | 4/1/12 | **24.5** | **27.0** | **26.5** | **31.5** | **10.7** | | | **34.1** | |
| 12.0 | | | 4/2/12 | **27.5** | **32.6** | **26.1** | **30.8** | | | | **34.0** | 8.0 |
| 0 | | | 4/3/12 | **28.3** | **34.1** | **25.9** | **31.4** | **14.8** | **32.0** | 35.0 | **34.7** | |
| 0 | | | 4/4/12 | **27.2** | 35.5 | **26.1** | **31.2** | | **32.9** | **34.7** | **34.4** | |
| 0 | | | 4/5/12 | **26.7** | 35.9 | **26.4** | **30.8** | | **30.5** | **34.7** | **34.5** | 8.1 |
| 0 | | | 4/6/12 | **26.4** | 36.4 | **26.5** | **31.0** | **20.9** | **30.3** | | **33.8** | |
| 0 | | | 4/7/12 | **27.5** | **33.9** | **26.5** | **29.8** | **21.6** | **34.4** | **33.8** | **34.3** | |
| 0 | | | 4/8/12 | **26.7** | **33.2** | **26.6** | **29.3** | **21.4** | **33.2** | **34.1** | **34.6** | |
| 0 | | | 4/9/12 | **25.6** | **31.6** | **26.4** | **29.2** | **23.1** | **32.7** | **33.7** | **34.4** | 9.0 |
| 0 | | | 4/10/12 | **25.3** | **27.7** | **26.5** | **28.3** | **24.6** | **34.5** | **33.9** | **34.8** | 9.2 |

Mean salinities in the Rincon Bayou channel and adjacent stations prior to the RBP March 2012 event were below hypersaline conditions (Table 8). An ANOVA identified a significant difference in salinity means between Pre-RBP, During-RBP, and Post-RBP conditions (Table 9). Mean salinity During-RBP and Post-RBP were significantly lower compared to the Pre-RBP

conditions. Because Pre-RBP salinity in the Rincon Bayou was not hypersaline the changes between event periods at CCS7, NUDE3, and Salt08 were not significant. During this event, an estuarine salinity gradient was achieved.

Table 8. Pre-RBP, During-RBP, and Post-RBP mean salinity, March 2012 event.

| | CCS6 | CCS7 | CCS8 | CCS9 | NUDE2 | NUDE3 | Salt08 | Salt03 | Salt05 |
|---|---|---|---|---|---|---|---|---|---|
| **Mean PSU Pre-RBP** | 30.24 | 32.12 | 34.12 | 33.21 | 23.85 | 27.48 | 30.83 | 31.78 | 5.90 |
| **Mean PSU during RBP** | 28.10 | 29.21 | 33.49 | 34.77 | 12.11 | 22.44 | 33.02 | 33.68 | 6.68 |
| **Mean PSU Post-RBP** | 24.91 | 29.92 | 26.98 | 31.69 | 13.03 | 27.06 | 32.62 | 34.35 | 7.90 |

Table 9. ANOVA salinity analysis for the March 2012 RBP pumping event. Tukey HSD means are arranged from low (left) to high (right); ns = not significant.

| Station | df | F | p | Tukey HSD Test |
|---|---|---|---|---|
| CCS6 | 2, 39 | 4.46 | <0.05 | PostRBP RBP PreRBP |
| CCS7 | 2, 39 | 0.49 | 0.62 | ns |
| CCS8 | 2, 39 | 142.33 | <0.001 | PostRBP RBP PreRBP |
| CCS9 | 2, 39 | 7.51 | <0.05 | PostRBP PreRBP RBP |
| NUDE02 | 2, 27 | 2.80 | 0.08 | RBP PostRBP PreRBP |
| NUDE03 | 2, 25 | 1.20 | 0.32 | ns |
| Salt08 | 2, 31 | 1.28 | 0.29 | ns |

Spatial interpolation of salinity in the Rincon Bayou Pre-RBP identified an estuarine salinity gradient, atypical of the Rincon Bayou (Figure 8). Once the 13 day RBP event ended, salinity decreased at all stations (Figure 8). The CCS9 station was not included in the interpolation because of the distance from Rincon Bayou. Salinity at CCS9 fluctuated likely from rainfall during the event period and was not a result of the RBP. Overall, a typical estuarine salinity gradient was achieved Post-RBP in the Rincon Bayou.

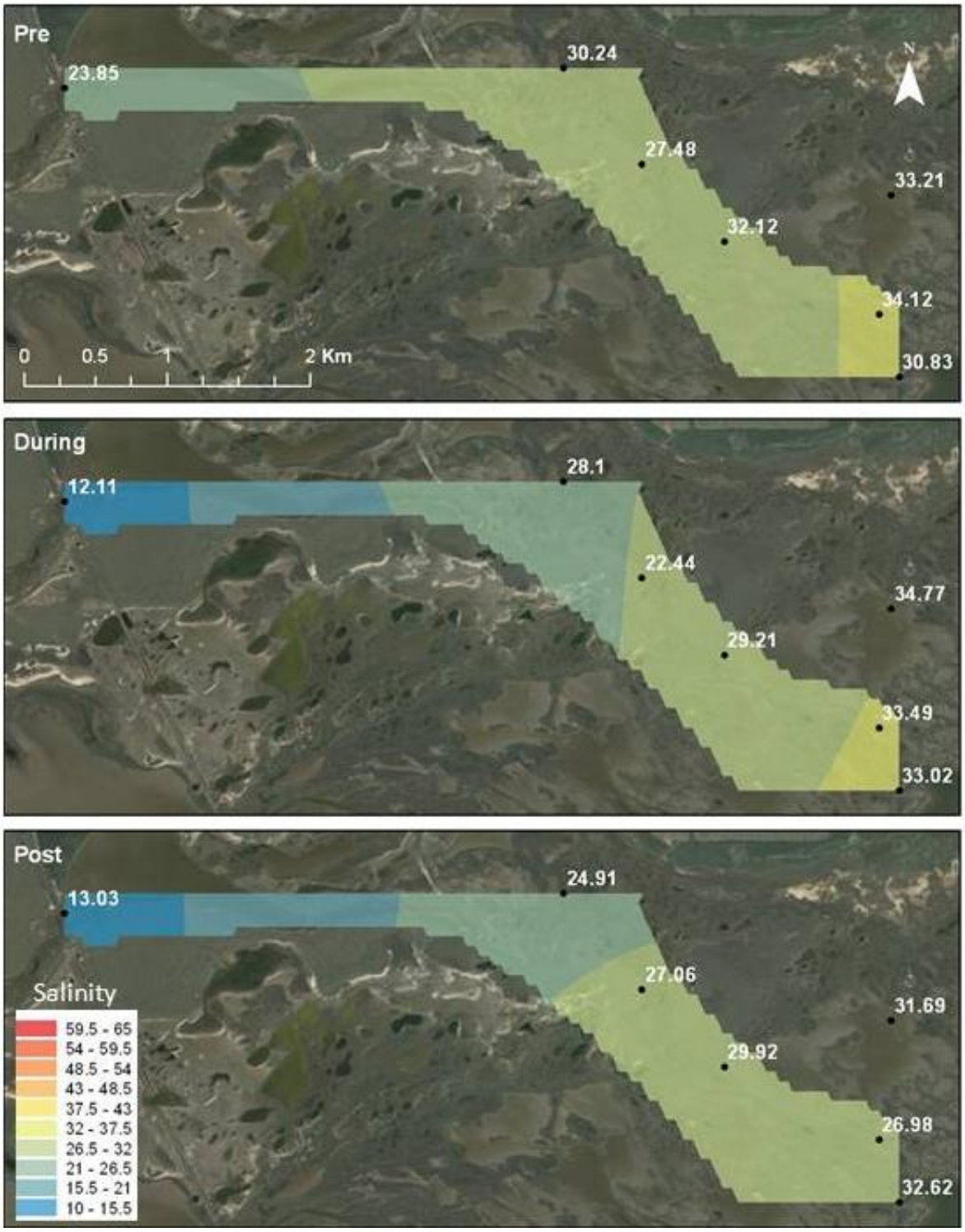



Figure 8. Spatial interpolation was calculated using the mean salinity of Pre-RBP, During-RBP, and Post-RBP for the March 2012 event.

*Event 3*

A total of 2,354 acre-feet of water was pumped to the Rincon Bayou from June 21 through July 13, 2012. Salinity in the Rincon Bayou channel prior to the release ranged from 20-38 PSU and from 2-119 PSU at four stations outside of the channel prior to the June 2012 RBP event (Table 10). The rain gauge on NUDEWX station failed May 19, 2012 resulting in no rain data being collected during Event 3.

Table 10. Rincon Bayou Pipeline June 2012 event daily mean salinity (PSU). Shaded areas: gray= time period of the RBP release and green= salinity < 35 PSU.

| Rain mm | RBP Date | RBP Flow Acre-feet | Date | CCS 10 | CCS 11 | CCS 12 | CCS 13 | NUDE 2 | NUDE 3 | Salt 08 | Salt 03 | Salt 05 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6/6/12 | **32.2** | 36.8 | 74.5 | **2.7** | 38.8 | **28.3** | **28.0** | **30.2** | |
| | | | 6/7/12 | **33.2** | 38.6 | 76.8 | **8.3** | 38.9 | **27.3** | | **30.5** | **0.7** |
| | | | 6/8/12 | **33.9** | 36.4 | 80.0 | **17.3** | 36.9 | | **26.4** | **29.2** | |
| | | | 6/9/12 | **31.2** | **33.3** | 83.2 | **16.3** | 38.4 | **25.2** | **24.1** | | **0.6** |
| | | | 6/10/12 | **26.0** | **29.0** | 87.4 | **15.7** | 36.3 | **27.0** | **26.7** | **27.2** | **0.6** |
| | | | 6/11/12 | **28.9** | **32.1** | 90.5 | **16.0** | | **27.6** | **25.7** | **22.4** | |
| | | | 6/12/12 | **32.9** | **34.0** | 94.0 | **15.4** | 34.0 | | **23.5** | **24.5** | |
| | | | 6/13/12 | **33.7** | **34.4** | 102.2 | **14.9** | 33.7 | **24.3** | **22.3** | **25.5** | **0.6** |
| | | | 6/14/12 | **28.4** | **29.4** | 111.1 | **13.7** | 34.7 | | **20.9** | **23.1** | **0.6** |
| | | | 6/15/12 | **27.9** | **26.6** | 118.5 | **17.5** | **32.9** | **23.0** | **21.3** | **24.2** | |
| | | | 6/16/12 | **29.5** | **27.8** | 119.8 | **19.1** | **32.5** | **20.2** | **19.5** | **25.5** | **0.6** |
| | | | 6/17/12 | **26.5** | **24.3** | 67.9 | **20.9** | **31.6** | **20.4** | **20.4** | **28.2** | **0.6** |
| | | | 6/18/12 | **23.8** | **26.2** | **1.9** | **21.6** | | **20.9** | **21.5** | | **0.6** |
| | | | 6/19/12 | **26.3** | **27.5** | **13.1** | **21.4** | **26.5** | **20.5** | **22.3** | | **0.6** |
| | | | 6/20/12 | **30.8** | **27.6** | 49.5 | **22.2** | **23.5** | | **23.4** | **29.7** | **0.6** |
| | 6/21/12 | 75 | 6/21/12 | **27.6** | **24.3** | 51.7 | **21.3** | **22.4** | | **21.6** | **29.5** | |
| | 6/22/12 | 113 | 6/22/12 | **23.9** | **23.2** | 51.2 | **21.0** | **20.4** | **20.1** | **21.7** | **29.0** | **0.6** |
| | 6/23/12 | 113 | 6/23/12 | **23.6** | **23.2** | 47.0 | **21.4** | | **18.9** | **22.2** | **30.2** | |
| | 6/24/12 | 112 | 6/24/12 | **25.1** | **23.8** | 46.7 | **21.8** | **20.7** | | **22.4** | **28.1** | **0.6** |
| | 6/25/12 | 112 | 6/25/12 | **25.3** | **25.9** | 45.6 | **23.4** | | | **22.4** | **28.1** | **0.6** |
| | 6/26/12 | 110 | 6/26/12 | **24.3** | **26.1** | 44.1 | **23.0** | **8.3** | | **22.9** | **28.3** | **0.6** |
| | 6/27/12 | 113 | 6/27/12 | **24.4** | **24.6** | 43.7 | **23.1** | **12.3** | **21.4** | **23.3** | **29.2** | |
| | 6/28/12 | 112 | 6/28/12 | **25.2** | **27.5** | 42.8 | **23.6** | **12.5** | **26.8** | **26.4** | **28.9** | **0.7** |
| | 6/29/12 | 112 | 6/29/12 | **25.7** | **27.1** | 43.5 | **23.9** | | **26.3** | **27.2** | | **0.7** |
| | 6/30/12 | 111 | 6/30/12 | **24.7** | **25.2** | 42.4 | **22.0** | **7.0** | **24.4** | | **30.3** | **0.7** |
| | 7/1/12 | 109 | 7/1/12 | **23.1** | **24.7** | 41.0 | **20.6** | **7.3** | **24.2** | | **29.3** | **0.7** |
| | 7/2/12 | 109 | 7/2/12 | **22.4** | **24.7** | 40.9 | **20.9** | **6.6** | **24.8** | **25.9** | **29.9** | **0.7** |
| | 7/3/12 | 104 | 7/3/12 | **21.9** | **24.5** | 41.5 | **20.5** | **8.1** | **24.0** | **27.6** | **30.7** | **0.7** |

Table 10 Continued. Rincon Bayou Pipeline June 2012 event daily mean salinity (PSU). Shaded areas: gray= time period of the RBP release and green= salinity < 35 PSU.

| Rain mm | RBP Date | RBP Flow Acre-feet | Date | CCS 10 | CCS 11 | CCS 12 | CCS 13 | NUDE 2 | NUDE 3 | Salt 08 | Salt 03 | Salt 05 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 7/4/12 | 120 | 7/4/12 | **21.1** | **23.8** | 42.5 | **19.9** | **6.7** | **23.2** | **27.3** | **30.0** | **0.7** |
| | 7/5/12 | 110 | 7/5/12 | **20.7** | **23.3** | 43.4 | **19.2** | **5.7** | **23.9** | **29.5** | | **0.7** |
| | 7/6/12 | 100 | 7/6/12 | **18.4** | **22.0** | 44.2 | **17.7** | **5.9** | | **26.9** | **29.7** | **0.7** |
| | 7/7/12 | 113 | 7/7/12 | **16.7** | **23.8** | 45.4 | **15.8** | | **11.3** | **27.6** | **29.6** | |
| | 7/8/12 | 122 | 7/8/12 | **14.4** | **24.3** | 46.7 | **14.9** | | | | | |
| | 7/9/12 | 83 | 7/9/12 | **14.4** | **28.2** | 48.0 | **13.8** | | **9.2** | **26.3** | **29.1** | **0.7** |
| | 7/10/12 | 46 | 7/10/12 | **19.3** | 37.0 | 48.8 | **8.5** | **6.7** | **7.7** | **15.2** | **28.9** | |
| | 7/11/12 | 92 | 7/11/12 | **23.3** | 36.8 | 49.2 | **6.3** | | **7.7** | **11.3** | **29.2** | |
| | 7/12/12 | 91 | 7/12/12 | **21.5** | 38.7 | 49.6 | **6.4** | **4.4** | **8.7** | **21.7** | **29.3** | **0.7** |
| | 7/13/12 | 72 | 7/13/12 | **12.1** | **34.8** | 49.9 | **8.7** | | **7.2** | **19.9** | | **0.7** |
| | | | 7/14/12 | **9.4** | **28.4** | 50.4 | **10.3** | **4.4** | **13.4** | **24.1** | **29.2** | **0.6** |
| | | | 7/15/12 | **10.6** | **27.8** | 51.0 | **11.8** | **8.6** | | **24.8** | **29.0** | **0.6** |
| | | | 7/16/12 | **10.5** | **23.1** | 51.7 | **12.3** | **7.2** | | **24.9** | | **0.6** |
| | | | 7/17/12 | **11.2** | **22.7** | 52.5 | **13.1** | **7.6** | | **24.9** | **30.5** | **0.6** |
| | | | 7/18/12 | **14.0** | **23.5** | 53.1 | **14.1** | **8.6** | | **27.7** | **31.3** | **0.6** |
| | | | 7/19/12 | **15.4** | **23.9** | 53.8 | **14.5** | **9.0** | | **26.2** | **29.9** | **0.6** |
| | | | 7/20/12 | **15.3** | **23.7** | 54.2 | **10.7** | **11.1** | **25.6** | **26.2** | **29.7** | **0.7** |
| | | | 7/21/12 | **15.7** | **24.3** | 55.3 | **8.3** | **12.7** | **25.1** | **25.9** | **29.4** | |
| | | | 7/22/12 | **17.1** | **19.7** | 56.7 | **9.4** | | | | | |
| | | | 7/23/12 | **20.7** | **17.6** | 58.1 | **12.0** | **18.8** | **26.8** | **27.1** | | |
| | | | 7/24/12 | **22.3** | **20.6** | 60.1 | **12.5** | **22.3** | **26.8** | **27.5** | | **0.8** |
| | | | 7/25/12 | **24.0** | **24.1** | 62.6 | **13.2** | **19.0** | | **28.7** | **31.3** | |
| | | | 7/26/12 | **24.5** | **25.9** | 65.3 | **13.6** | **23.9** | **28.5** | **28.3** | | |
| | | | 7/27/12 | **25.0** | **26.9** | 66.8 | **14.0** | | **29.9** | **27.3** | **32.7** | **0.8** |
| | | | 7/28/12 | **26.2** | **27.5** | 68.9 | **14.4** | **25.4** | **31.0** | **27.2** | **32.9** | |
| | | | 7/29/12 | **26.0** | **28.2** | 71.7 | **14.4** | **25.4** | **30.9** | **27.2** | **32.1** | **0.9** |

Mean salinity in the Rincon Bayou and adjacent stations prior to the RBP March 2012 event was below hypersaline conditions except at CCS12 (Table 11). The RBP event lasted 23 days and Post-RBP mean salinity in the channel ranged from 14.57 PSU at NUDE2 to 26.53 PSU at Salt08. ANOVA identified a significant difference in mean salinity between Pre-RBP, During-RBP, and Post-RBP conditions at all stations (Table 12). Mean salinity During-RBP and Post-RBP were significantly lower compared to Pre-RBP conditions for all stations, except at Salt08 which had significantly lower salinity Pre-RBP compared to Post-RBP.

Table 11. Pre-RBP, During-RBP, and Post-RBP mean salinity, June 2012 event.

| | CCS 10 | CCS 11 | CCS 12 | CCS 13 | NUDE2 | NUDE3 | Salt 08 | Salt 03 | Salt 05 |
|---|---|---|---|---|---|---|---|---|---|
| **Mean PSU Pre-RBP** | 29.68 | 30.94 | 78.02 | 16.21 | 33.75 | 24.06 | 23.29 | 26.68 | 0.61 |
| **Mean PSU during RBP** | 21.70 | 26.85 | 45.63 | 18.17 | 10.33 | 18.22 | 23.47 | 29.33 | 0.68 |
| **Mean PSU Post-RBP** | 18.00 | 24.25 | 58.27 | 12.42 | 14.57 | 26.44 | 26.53 | 30.73 | 0.68 |

Table 12. ANOVA salinity analysis for the June 2012 RBP pumping event. Tukey HSD means are arranged from low (left) to high (right).

| Station | *Df* | *F* | *p* | Tukey HSD Test |
|---|---|---|---|---|
| CCS10 | 2, 53 | 26.76 | <0.001 | PostRBP RBP PreRBP |
| CCS11 | 2, 53 | 9.29 | <0.001 | PostRBP RBP PreRBP |
| CCS12 | 2, 53 | 13.89 | <0.001 | RBP PostRBP PreRBP |
| CCS13 | 2, 53 | 6.98 | <0.05 | PostRBP PreRBP RBP |
| NUDE02 | 2, 41 | 54.68 | <0.001 | RBP PostRBP PreRBP |
| NUDE03 | 2, 36 | 6.32 | <0.05 | RBP PreRBP PostRBP |
| Salt08 | 2, 48 | 4.83 | <0.05 | PreRBP RBP PostRBP |

Spatial interpolation of salinity in the Rincon Bayou Pre-RBP identified a negative estuarine system with salinity increasing as you move upstream from Nueces Bay, as seen in Event 1; hypersalinity was not observed at CCS13 (Figure 9). The RBP decreased salinity, relieving the reverse estuarine conditions in the channel and areas outside the channel. The area that remained hypersaline (CCS12) throughout most of Event 3 was a tidal pool cut off from exchange to the main Rincon Bayou. The decrease in salinity at CCS12 was likely due to rainfall; however, conditions remained hypersaline throughout the event. Tidal ponds and creeks located at higher elevations (e.g. CCS12) are restricted from the benefits of the reduced salinity in the Rincon Bayou Channel during RBP pumping events. The RBP inflows can only reach these elevated adjacent areas when water level in the channel proper breaches the threshold allowing for inundation. Overall, a typical estuarine salinity gradient in areas connected to the main Rincon Bayou channel Post-RBP was achieved during this event.

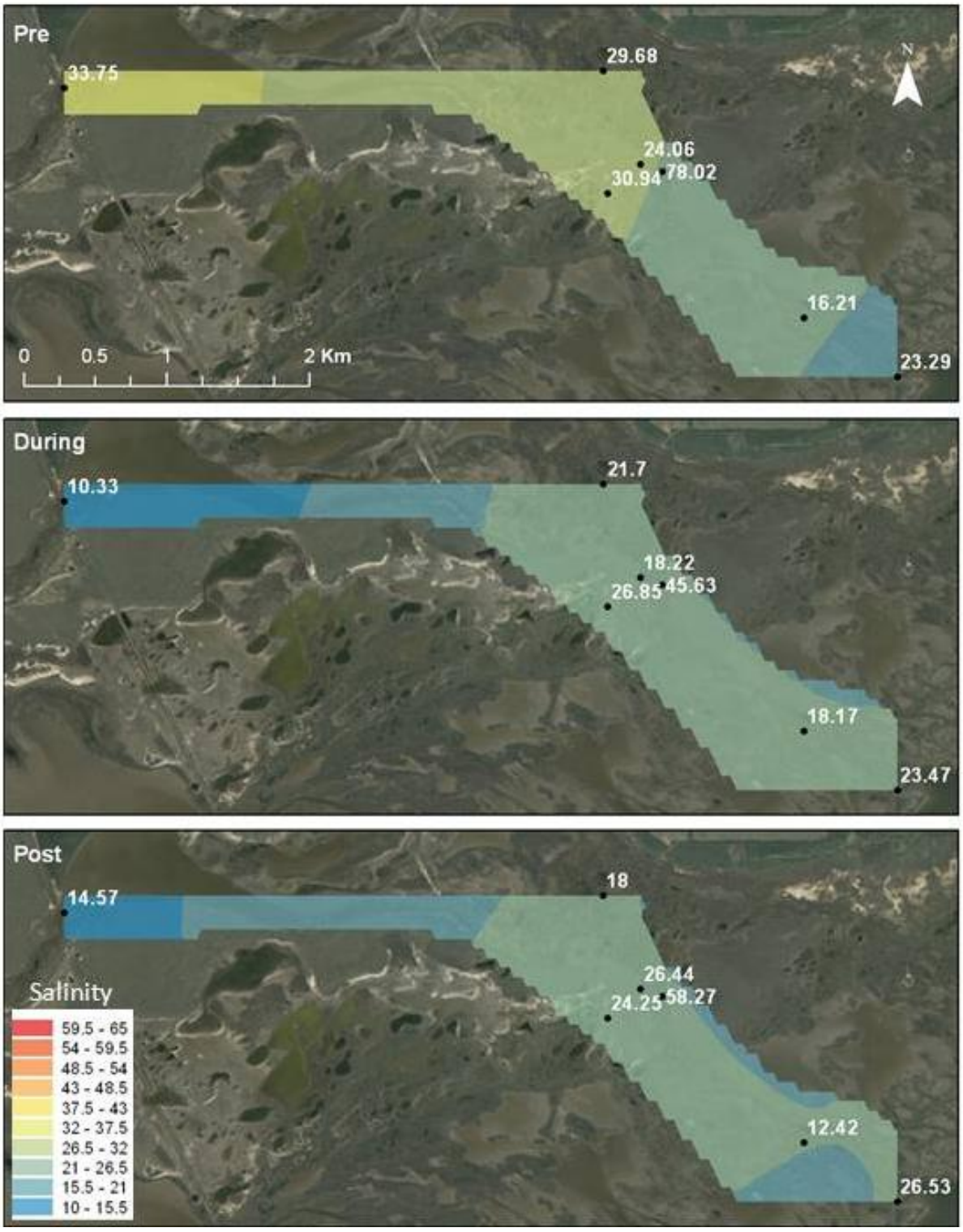



Figure 9. Spatial interpolation was calculated using the mean salinity of Pre-RBP, During-RBP, and Post-RBP for the June 2012 event.

The timing and volume of freshwater inflow to the Rincon Bayou is vitally important to the functioning of this system (Montagna et al. 2002). The RBP inflows during hypersaline conditions result in extreme salinity fluctuations in the Rincon Bayou that may not be the most biologically productive way to manage the system. However, managing the bayou so hypersaline conditions are not reached by using the RBP inflows to maintain an estuarine salinity gradient may afford a process to restore biological productivity.

Spatial interpolation of salinity in the lower Nueces Delta during the three pumping events showed the RBP freshwater reduced salinity beyond the Rincon Bayou channel proper to the lower connecting marsh areas. Additional environmental factors influencing the spatial coverage and flow of the RBP include: quantity of freshwater pumped through the RBP, wind speed and direction, tide level, and rainfall. Management of the RBP pumping events must consider these factors when scheduling a release.

This project accomplished the goal in determining if freshwater from the RBP influences the lower Nueces Delta. The hot and dry climate of the Nueces Delta coupled with variable rainfall patterns often creates a negative estuary. The RBP pumping events relieved the hypersalinity conditions and created an estuarine salinity gradient in the Rincon Bayou channel proper and in connecting habitats. This information will help to further refine the freshwater inflow management plan for the Nueces Delta and in developing an operational and scheduling plan for the Rincon Bayou Pipeline.

**References**

Adams, J.S. and J.W. Tunnell. 2010. Rincon Bayou Salinity Monitoring. Final Report submitted to the Coastal Bend Bays & Estuaries Program for project number 0921, Coastal Bend Bays & Estuaries Program, Corpus Christi, Texas. Publication No. CBBEP-66, 18 pp.

Bureau of Reclamation (BOR). 2000. Concluding Report: Rincon Bayou Demonstration Project. Volume II: Findings. United States Department of the Interior, Bureau of Reclamation, Oklahoma-Texas Area Office, Austin, Texas.

ESRI. 2011. ArcGIS Desktop 10. Environmental Systems Research Institute, Redlands, California.

Forbes, M.G. and K.H. Dunton. 2006. Response of a subtropical estuarine marsh to local climatic change in the southwestern Gulf of Mexico. Estuaries and Coasts 29, pp. 1242-1254.

Hill, E. M., B. A. Nicolau, and P. V. Zimba. 2011. Habitat Management History of the Nueces Estuary, Texas, USA. Texas Water Journal (2)1: 97-111.

IBM SPSS 19.0 2012, IBM SPSS Inc., Chicago Ill.

Montagna, P. A., E. M. Hill and B. Moulton. 2009. Role of science-based and adaptive management in allocating environmental flows to the Nueces Estuary, Texas, USA. In: Brebbia, C.A. and E. Tiezzi (eds.), Ecosystems and Sustainable Development VII, WIT Press, Southampton, UK, pp. 559-570.

National Climatic Data Center. 2011. http://www.ncdc.noaa.gov/oa/ncdc.html

National Weather Service. 2010. http://www.srh.noaa.gov/images/crp/docs/stwj/STWJFall10.pdf

Nueces River Authority. 2011. http://www.nueces-ra.org/CP/CITY/month.php

Nueces River and Corpus Christi and Baffin Bays Basin and Bay Expert Science Team (BBEST). 2011. Environmental Flows Recommendations Report. Final Submission to the Environmental Flows Advisory Group, Nueces River and Corpus Christi and Baffin Bays Basin and Bay Area Stakeholder Committee, and Texas Commission on Environmental Quality, 285 pp.

Nueces River and Corpus Christi and Baffin Bays Basin and Bay Area Stakeholder Committee (BBASC). 2012. Environmental Flow Standards and Strategies Recommendations Report. Final Submission to the Environmental Flows Advisory Group, and Texas Commission on Environmental Quality, 112 pp.

Ockerman, D.J. and F.T. Heitmuller. 2010. Simulation of streamflow and suspended-sediment concentrations and loads in the lower Nueces River watershed, downstream from Lake Corpus

Christi to the Nueces Estuary, South Texas, 1958–2008: U.S. Geological Survey Scientific Investigations Report 2010–5194, 50 pp.

Olsen, S.B., T.V. Padma, B.D. Richter. 2007. Managing Freshwater Inflows to Estuaries: a Methods Guide. USAID. Washington, DC. 44 pp.

Palmer, T.E., P.A. Montagna, and R.D. Kalke, 2002. Downstream effects of restored freshwater inflow to Rincon Bayou, Nueces Delta, Texas, USA. Estuaries 25 pp. 1448-1456.

Pulich Jr., W. J. Tolan, W. Y. Lee, and W. Alvis. 2002. Final Report. Freshwater inflow recommendation for the Nueces Estuary. Texas Parks and Wildlife Department. Austin, Texas. 69 pp.

Rasser, M. 2009. The role of biotic and abiotic processes in the zonation of salt marsh plants in the Nueces River Delta, Texas. Dissertation. University of Texas at Austin, Austin, Texas.

Ryan, A.J. and B.R. Hodges. 2011. Modeling Hydrodynamic Fluxes in the Nueces River Delta. Draft Report submitted to the Coastal Bend Bays & Estuaries Program for project number 1001. The University of Texas at Austin, Center for Research in Water Resources, 98 pp.

Texas Commission on Environmental Quality (TCEQ). 1995. Agreed Order Establishing Operational Procedures Pertaining to Special Condition B, Certificate of Adjudication No. 21-3214, Held by City of Corpus Christ, et al., April 28, 1995.

Tunnell, J.W. and L. Lloyd. 2011. Effects of Rincon Bayou Pipeline inflows on salinity structure within the Nueces Delta, Texas. Coastal Bend Bays & Estuaries Program project 1106. Corpus Christi, Texas. Publication No. CBBEP-76, 23 pp.

Webb, J.W. 1983. Soil water salinity variations and their effects on *Spartina alterniflora*. Contributions in Marine Science. 26: 1-13.