Using Landform and Hydraulic Modifications to Increase the Benefit of Fresh Water Inflows to Nueces Bay and Nueces Delta

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PURSUANT TO SENATE BILL 1 AS APPROVED BY THE 83RD TEXAS LEGISLATURE, THIS STUDY REPORT WAS FUNDED FOR THE PURPOSE OF STUDYING ENVIRONMENTAL FLOW NEEDS FOR TEXAS RIVERS AND ESTUARIES AS PART OF THE ADAPTIVE MANAGEMENT PHASE OF THE SENATE BILL 3 PROCESS FOR ENVIRONMENTAL FLOWS ESTABLISHED BY THE 80TH TEXAS LEGISLATURE. THE VIEWS AND CONCLUSIONS EXPRESSED HEREIN ARE THOSE OF THE AUTHOR(S) AND DO NOT NECESSARILY REFLECT THE VIEWS OF THE TEXAS WATER DEVELOPMENT BOARD.

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Executive Summary

The Nueces River supports the southernmost deltaic marsh of any appreciable size in the Gulf of Mexico. The Delta is classified as semi-arid and is composed of a 5700 ha (14,000 +/- acre) complex of salt marsh, mud flats, tidal channels, and open water. The Nueces estuary is the second driest in Texas, and the Delta is part of a negative estuary, where the hypersaline waters of Corpus Christi Bay mix with freshwater inflows from the Nueces River via the Rincon Bayou channel. Yet despite the low freshwater inflows, the Nueces Delta vegetation is diverse, physiologically resilient, and at times, very productive.

Creek bank and interior marsh areas are subject to highly irregular flooding patterns that are driven more by meteorological conditions than lunar tidal cycles. In the absence of any kind of regular exposure to fresh waters, the resulting vegetation patterns are highly unstable, which lowers its habitat value for birds, fish, and other estuarine species. One rationale for this study was to explore the potential for providing minimum flows of freshwater to portions the Nueces Marsh to ameliorate hypersaline conditions. Various options included construction of water control structures and hydraulic modifications, use or reuse of treated wastewater, and changes in pass-through events (see Nueces River and Corpus Christi and Baffin Bays Basin and Bay Area Stakeholder Committee "Work Plan for Adaptive Management" (Nueces BBASC, 2012).

The second rationale for this investigation is the finding, made during the recent Senate Bill 3 program for the determination of the "environmental flow" needs within the Nueces River Basin, "that all rivers, streams, and bays were sound ecological environments, except the Nueces Bay and Delta, which were determined to be unsound ecological environments." (BBEST, 2011) (*Underline added for emphasis*) The Nueces River and Corpus Christi and Baffin Bays Basin and Bay Expert Science Team (Nueces BBEST) made this determination based on their conclusion that it was:

> *. . . the substantial alterations in freshwater reaching the bay and delta which have led to a failure to sustain a healthy complement of native species and its associated beneficial physical processes . . .* (and that) *a modification of flow regime will be required to rebuild these species and processes to sound levels.* (Ibid.)

One of the major factors affecting the freshwater inflow regime for this area of the Nueces Estuary is attributed to "major modification and channelization that redirected flow away from the delta to the lower bay near Corpus Christi Bay. (Ibid.)

This report thus summarizes an evaluation of several strategies, recommended by the Nueces BBASC (2012), involving the potential use of hydraulic and landform modifications within the Nueces Delta/Bay system. The main purpose of any proposed modification would be to increase the benefit of the often limited quantities of freshwater inflows by redirecting and delivering those flows into areas of the Nueces Delta where they would help to restore some level of pre-development ecosystem function.

Members of the "Project Team" on this study include scientists and engineers who have amassed years of professional experience and expertise through their work on this very issue affecting the Nueces Delta/Bay system. This provided the basis for utilizing an "Expert Judgment" process to initially define and evaluate a range of potential landform and hydraulic modification projects.

Additional evaluation of the various options was accomplished by utilizing the Nueces Delta Hydrodynamic Model (NDHM), developed at the University of Texas at Austin, to simulate different locations and configurations of diversion channels, water control structures and effluent discharges. Results of the preliminary evaluations of all potential projects were shared with groups of stakeholders in two *charrettes*, which served to generate comments and suggestions for the project team to use in refining the list of potential projects.

Based on the feedback from these two charrettes and the preliminary modeling analysis, the project team elected to recommend three projects for further definition and analysis. These included two diversion channels, one from the Middle Rincon Bayou into South Lake, and the other from the North Lake portion of Rincon Bayou into the South Lake area. Additionally, the project team recommended the diversion of the treated wastewater effluent discharge from the City of Odem's wastewater treatment plant, redirecting it from its current location in an uplands area into an area of wetlands within West Lake.

The two proposed new diversion channels were incorporated into the NDHM, which was then run to simulate two different flow rate scenarios (1,200 ac-ft/mo. and 3,000 ac-ft/mo.) based on the quantity of freshwater which could be pumped into Rincon Bayou via the City of Corpus Christi's Rincon Bayou Diversion Pipeline. The output from these model runs were used to generate data on inundation period, coverage, depth and water column salinity, which was then compared to baseline conditions (i.e., no new channels) to determine the anticipated ecological effects these changes could have on areas within the Nueces Delta.

Analysis of these results indicates an increase in the acreages inundated under the pumping scenarios when certain objective criteria are applied, but as the objective criteria (primarily water column salinity) becomes stricter (i.e., lower salinity levels), the effect diminishes. A summary table (Table 3.1.3) captures the overall picture, which is that the simple inclusion of the two new overflow channels is effective in increasing the area flooded with 20-25 salinity, but at the expense of reducing some of the areas that would otherwise see salinities less than 15 . However, ecological studies have demonstrated that the 20-25 salinity range is a desirable target as this range meets the needs of many estuarine dependent species.

Just as hydrodynamic modeling was valuable in the evaluation of project alternatives, additional modeling should be undertaken to assist in the design and permitting of recommended projects, and to evaluate the benefits of a "systems management/operations" concept for coordinating the pumping of required Pass-Thru flows into Rincon Bayou with the operation of the water control structures which would be associated with the two proposed diversion channels.

Further activities associated with the implementation of the three proposed projects should include: 1) securing funding for the construction of the facilities as well as ongoing operation and maintenance expenses, 2) securing access to the sites of the proposed projects (both legal and physical access), 3) satisfying permitting and regulatory requirements, and 4) employing construction techniques applicable to wetland areas,

Overview

1.1 Managing freshwater inflows available to the Nueces Delta/Estuary

1.1.1 The importance of freshwater inflows and where they enter an estuary

Freshwater is the lifeblood of estuaries, which are, by definition, a place where rivers flow into the ocean, mixing freshwater with seawater, and producing a highly variable, but extremely productive environment. The availability of the seawater component of the estuarine mixing zone is relatively a constant, so the freshwater component largely determines the amount and extent of the mixing which occurs, and the resulting ecological conditions.

The quantity, timing and location of freshwater inflows are critically important. In estuaries located in drier regions, like the Nueces Estuary on the mid-Texas Coast, these factors, which can be the primary constraint on estuarine productivity, are governed by the complex combination of climate/meteorology, hydrology/hydrogeology described previously, and, increasingly, federal, state and local water resources management policies.

1.1.2 From Headwaters to Tidewaters – water's journey within the Nueces River Basin

The Nueces Estuary is situated on the cusp of two distinct climatic regions characterizing the Texas Coast -- a wetter region "up" the coast, and a drier region "down" the coast -- but most of the Nueces River watershed is located on the west side of the north/south line segregating Texas into relatively wetter and drier zones with respect to precipitation.

Regarding that portion of Texas in which the Nueces River watershed is located, in the introduction to his novel "The Time It Never Rained," author Elmer Kelton keenly observed that:

"Each new generation tends to forget—until it confronts the sobering reality—that dryness has always been the normal condition in the western half of the state. Wet years have been the exceptions" (Kelton, 1984).

The harsh climate and mercurial weather of this drier side of Texas play a major role in determining how often, and how much, water will make its way down the Nueces River to its hydraulic goal: sea level, and the tidal waters of the Nueces Bay/Estuary system. However, even under the best of conditions -- in those wet years which are the "exceptions" -- river flow within the Nueces River Basin has a challenging journey on its way to the sea. Some of the challenges are due to natural features of the watershed, while others stem from man's efforts to eke out a place and a living in this harsh setting.

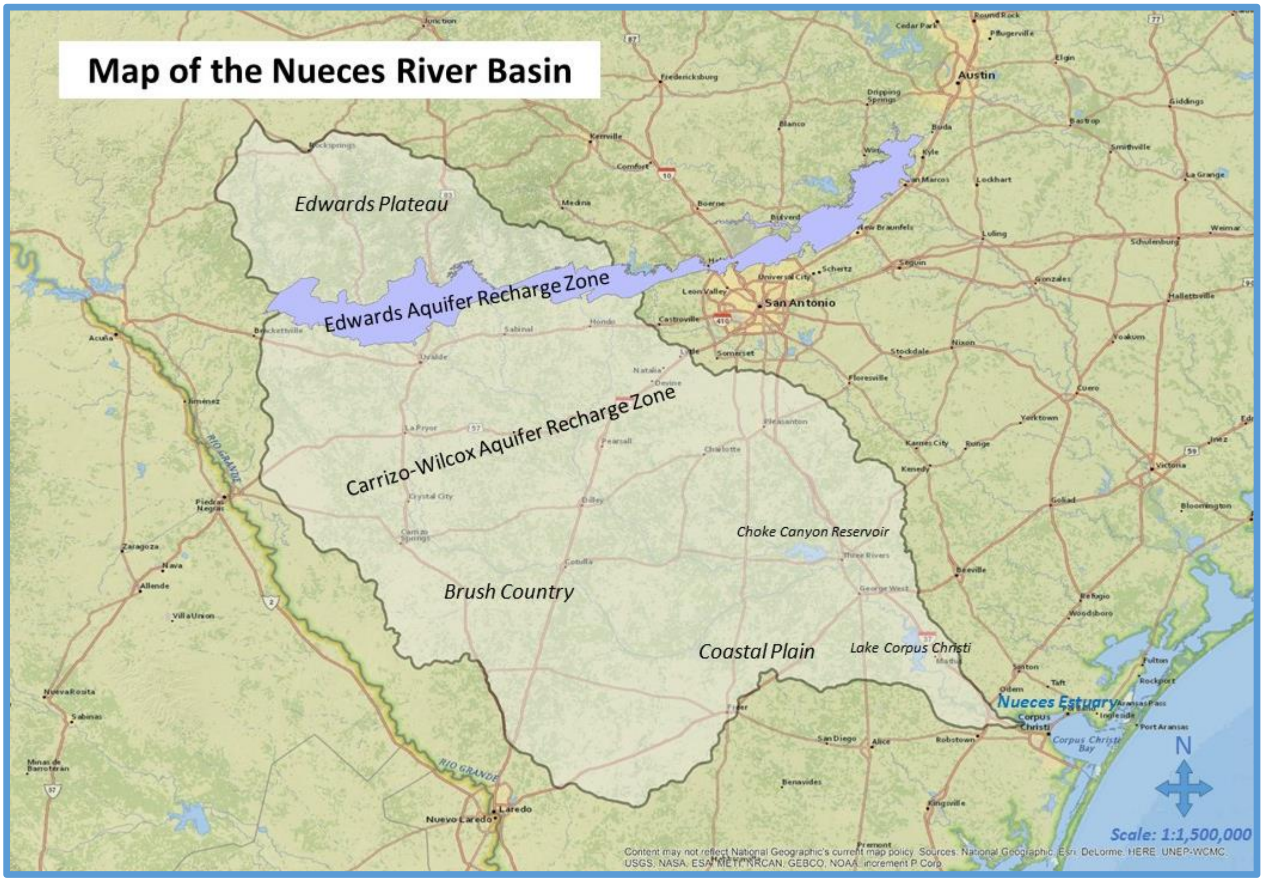


Figure 1.1.2: Map of the Nueces River Basin (*shape file courtesy of Rocky Freund, Nueces River Authority*)

The headwaters of the Nueces River, and its several major tributaries, originate in the springs and canyons of the Edwards Plateau, flowing strong and clear through narrow, rocky streambeds -- and then, before reaching the shallower gradients of the Gulf Coastal Plain, this flow largely disappears into the sinkholes and porous gravels of the recharge zone of the Edwards Aquifer. There it travels underground – if not captured by large capacity wells – only to be discharged by springs located to the north and east, where it then again contributes to river flow, albeit in other river basins: i.e., the San Antonio and the Guadalupe.

What flow escapes this recharge zone loss then meanders downstream across the flatlands of the "Wild Horse Desert," and through the "Braided Reach," where the Nueces River splits into a myriad of channels lined with vegetation that flourishes because of the consistent availability of moisture. In this reach too, when the water rises out of the channels, it spreads out across the floodplain, running slow and wide, with much of it percolating into the ground and replenishing another underlying aquifer, the Carrizo-Wilcox Aquifer.

Water making it past this middle section of the river basin must then rest in either, or both, of two major impoundments – Choke Canyon Reservoir, on the Frio River, and, downstream, below the juncture of the Nueces River and the Frio River, Lake Corpus Christi. The water stored in these still pools is scorched by the sun and whipped by the wind, so much so that, much of the time, more of it is lost to the atmosphere than is released from storage to continue its journey downstream to either be withdrawn for human use, or to flow into the Nueces Estuary.

Although the Nueces River Basin covers 16,800 square miles of South Texas landscape, by the time the Nueces River nears the coast, without the supplement of water released from these reservoirs' storage, its natural flow would often not be enough to provide a reliable water supply for the cities and industries in the Coastal Bend region. Nor, in those instances, would its natural flow be enough to spill over the "Calallen Dam," a saltwater barrier which divides the flowing "freshwater" of the river basin from the tidal "saltwater" of the Nueces Estuary.

1.1.3 Where does the freshwater go when it gets to the Nueces Estuary?

Unfortunately, even when there is ample freshwater making it over the Calallen Dam and into the tidal segment of the Nueces River, its most desired destination -- the marsh systems within the Nueces Delta and fringing the shallow open waters of Upper Nueces Bay -- are still elusive. The main flow of the Nueces River Tidal Segment is now diverted around the southern periphery of its delta due to the evolution of the lower reach of the river, which is thought to be natural and pre-date European settlement. More often than not, freshwater flowing over the Calallen Dam simply mixes with, or flows over, the more saline water in the Nueces River tidal segment and makes its way out into the open waters of the Nueces Bay/Corpus Christi Bay complex, where it may have some beneficial effects, but not nearly what is desired from an ecological perspective.

Prior to the Rincon Bayou Demonstration Project and the Rincon Bayou Pipeline (discussed below), the only flows to enter the Nueces Delta at its head were due to overtopping of the natural bank levee into a few distributaries, most notably Rincon Bayou, a relict river channel making its way through the heart of what now constitutes the Nueces Delta, connecting eventually to Upper Nueces Bay. These flows occurred intermittently, associated with flood events on the Nueces River. Even with this intermittent behavior the influx of freshwater under natural conditions was sufficient to maintain the physical structure and the biological functions of the delta/marsh complex until regulation of river hydrology by upstream reservoir operations.

Prior to the development of the two reservoirs upstream and the significant municipal and industrial water supply diversions now being made from the Calallen Pool, and before the successful efforts made to block off and "disconnect" it from the Nueces River tidal segment, during medium to high river flows Rincon Bayou conveyed fresh water through the middle of the Nueces Delta, spilling it out onto the tidal flats along the way, feeding the marshes with nutrients and sediments, and mitigating the salinity levels within the soil and the standing water. This was the natural and most important destination for the fresh water coursing its way from the far reaches of the watershed to the sea. It allowed the Nueces Delta ecosystem to function as it should when provided with the proper mixing of fresh and salt water environments.

With the development of Corpus Christi and the surrounding area, and the need for a reliable source of freshwater, dam construction began on the Nueces River. While the human use of water reduced the inflow available to Nueces Bay, the more important effect was the alteration in the time signal of river flow. The Nueces basin hydroclimatology is arid to semi-arid, and storm events are much rarer than in the basins farther up the coast. Any reservoir with a constant water-supply draft will be drawn down between storm events, due to the combined loss to diversion and evaporation. For the sparse occurrence of storm events on the Nueces together with its high evaporation rates, this drawdown period can be substantial. When an event finally occurs, the reservoir must be filled to conservation stage before spills occur. Thus the size and frequency of occurrence of hydrograph events downstream are both reduced by the presence of the dam. The frequency of such events downstream was certainly reduced by Lake Corpus Christi. When Choke

Canyon Reservoir was built the impacts upon flood hydrograph occurrence and the inundation of Rincon from the Nueces were even greater. Irlbeck and Ward (2000) analyzed the historical period of flow measurements in three sub periods: 1940-58 when the La Fruta dam was in place, 1958-82 when Wesley Seale dam replaced La Fruta, and 1982-99 when Choke Canyon was added upstream from Lake Corpus Christi (Wesley Seale dam). The difference in return period for a flood event between the first two periods was negligible (perhaps because the first period included the Drought of the Fifties), but the Choke Canyon period increased the return period for the same event magnitude by a factor of three.

Corpus Christi Bay (the primary bay of the Nueces Estuary) is one of the larger of the Texas bays, and like most of the Texas bays, it is morphologically separated into several secondary and tertiary estuarine systems. Nueces Bay is the most important secondary estuary in Corpus Christi Bay (some would say the only secondary estuary). This importance derives from the facts that it is the largest secondary estuary, it receives the greatest proportion of freshwater inflow into the bay system, and because it serves as a nursery for many species. With respect to the last, the opinion is held widely among estuarine ecologists working in the bay system that the health of the overall Corpus Christi Bay ecosystem is intimately dependent upon Nueces Bay (e.g., Montagna et al., 1996; Bureau of Reclamation, 2000; Brier and Edmonds, 2007; Hill et al, 2011; BBEST, 2011), and especially the Nueces delta.

An important hydrographic determinant of Corpus Christi Bay is the exchange between these component subsystems and with the Gulf of Mexico, which is one of the mechanisms for dilution. One of the processes effecting exchange is the tide. This may be surprising to most casual observers of the bay, because the tide range within the bay is small, a matter of inches. This is the variation of the diurnal and semi-diurnal components only, however, and indeed their range is reduced as the tide traverses the Aransas Pass inlet, and further attenuated with passage through the Harbor Island reach of the Corpus Christi Channel. As the tide enters the pass into Nueces Bay, it is even further reduced. The net effect is that the tide in Nueces Bay is nominally only 5-10 cm in range. The associated tidal prism averages only about 20% of the volume of Nueces Bay, with an associated tidal excursion of about 1.5 km. More importantly, water exchange between Nueces and the main body of Corpus Christi Bay at this frequency (about 12 hours) occurs faster than it can be mixed with water in either bay, but rather retains much of its integrity through the tidal cycle. Exchange is an oscillatory replacement rather than a dilution.

There are, however, other components of the tide with considerably longer periods and therefore not as obvious to the casual observer. Moreover, because of their long periods, they are subject to minimal attenuation with passage into and throughout the bay system from the Gulf of Mexico. One of these is the fortnightly tide with a period of about two weeks, driven by the variation in lunar declination. In Nueces Bay, the prism of the fortnightly tide averages about the same as the diurnal tide, about 25% of the volume of the bay, but the rise is much slower, about 6 days, so there is much greater opportunity for this volume to be mixed with waters of Nueces Bay on the rise, and with upper Corpus Christi Bay on the fall, thereby achieving much greater dilution than the diurnal (and semi-diurnal) tide. Of even greater importance is the secular semi-annual "tide" with higher high water in the early fall and lower low water in winter. There is considerable variation in this component of the tide from year to year, but its range is typically 25-40 cm. In Nueces Bay, the prism is usually about 35-50% of the volume of the bay with duration of about 3 months. This component of the tide is responsible for much of the long-term exchange with the Gulf, and its mixing and dilution within the Corpus Christi Bay system. It is a prime factor in the long-term water exchange between Nueces Bay and the main body of Corpus Christi Bay (for additional detail on local tides see Ward, 1997).

In addition, the Corpus Christi Bay system, and Nueces Bay in particular, receives substantial flushing due to "wind tides" driven by changes in wind velocity over the bay system and adjacent Gulf of Mexico. The most dramatic of these is the frontal passage, which typically produces an influx of water from the Gulf with the approach of the front, then an efflux driven by north winds after the frontal passage. Data compiled in Ward (1997) suggest a net efflux ranging 10-30% of the volume of Nueces Bay, which of course will return to the bay over the course of several days when winds after the frontal passage diminish then turn back to the south.

Finally, the river itself represents an influx of water, which accomplishes dilution and flushing. An important difference between this and the tidal and meteorological exchanges described above is that the river influx is a through flow. The hydrology of the Nueces River has been described in several references including the BBEST report (BBEST, 2011). Because the average volume of river flow is so small compared to the volume of Corpus Christi Bay (a replacement time on the order of 600 days), this mechanism provides little long-term dilution. Much more importantly, even at its low flows compared to the volume of the bay, riverine inflow is essential to the ecology of the system, acting as a source for nutrients and sediments, and moderating the salinities in Nueces Bay.

1.1.4 Altering course: "Ordering" freshwater inflows to go where they count

The aforementioned factors – drought, losses, storage and diversions – would seriously limit, or in some instances totally deplete, the amount of freshwater inflows available to the Nueces Estuary were it not for the implementation of the freshwater inflow operating plan required by Special Condition 5.B. of Certificate of Adjudication No. 21-3214 for Choke Canyon Dam and Reservoir (Texas Water Rights Commission, 1976). Initiated in 1989 by order of the then Texas Water Commission, and amended by a subsequent series of consensus-based "Agreed Orders" on operational procedures for the Choke Canyon Reservoir/Lake Corpus Christi Reservoir System, the current freshwater inflow operating plan is designed to mimic the natural variability of streamflow which would have reached the Nueces Estuary under "predevelopment" conditions (i.e., no upstream reservoirs or major diversions). Thus, the Agreed Order recognizes that in wet periods the monthly freshwater inflow requirements should be higher than in dry periods, with the relative "wet" and "dry" periods being determined by the amount of water in storage in the Choke Canyon Reservoir/Lake Corpus Christi Reservoir System for any month.

The maximum amount of freshwater inflow required to be delivered in any month is based on an "inflow target" determined by an analysis of historical inflow patterns and estuary productivity measures to be the optimal inflow amount for that month (see Table 1.1.4, below). The "Pass-Thru Plan" contained in the current Agreed Order for freshwater inflows to the Nueces Estuary only requires that reservoir inflows <u>up to</u> these monthly target must be delivered to the Nueces Estuary. Estuary inflows have historically been determined to be the amount of water measured, by USGS Stream Monitoring Station No. 08211500, as flowing over the Saltwater Barrier Dam at Calallen and into the Nueces River Tidal Segment – however, since 2003, as will be discussed below, the total inflow amount also includes any additional amount pumped via the Rincon Bayou Diversion Pipeline from the Calallen Pool to Rincon Bayou.

The actual amount of freshwater inflow required to be delivered is determined by measuring streamflow entering into the Choke Canyon/Lake Corpus Christi reservoir system. This amount is assumed to be what would have "naturally" flowed into the Nueces Estuary before the construction of the reservoirs. If reservoir system inflows are less than the target in any month, only those measured reservoir inflows must be "passed thru." No water is required to be "released" from reservoir storage to make up the difference between the reservoir inflows and the monthly target. If the measured reservoir inflow in any month is greater than the monthly target, only that month's target amount must be "passed thru" to the estuary -- the remaining reservoir inflow in that month may be captured and kept in storage for municipal and industrial water supply use.

Table 1.1.4: Target amounts for freshwater inflows to the Nueces Estuary under the 2001 Agreed Order (*from*: https://www.nueces-ra.org/CP/CITY/faq.php)

Passthru Targets (AcFt)				
Month	**Capacity >= 70%**	**40% <= Capacity < 70%**	**30% <= Capacity < 40%**	**Capacity < 30%**
January	2,500	2,500	1,200	0
February	2,500	2,500	1,200	0
March	3,500	3,500	1,200	0
April	3,500	3,500	1,200	0
May	25,500	23,500	1,200	0
June	25,500	23,000	1,200	0
July	6,500	4,500	1,200	0
August	6,500	5,000	1,200	0
September	28,500	11,500	1,200	0
October	20,000	9,000	1,200	0
November	9,000	4,000	1,200	0
December	4,500	4,500	1,200	0

While initially focused simply on providing for the delivery of a minimum amount of freshwater into the Nueces Bay portion of the Nueces Estuary, via the Nueces River Tidal Segment, the freshwater inflow operating plan for the Nueces Estuary eventually recognized and incorporated the importance of delivering freshwater inflows to areas of optimal ecological benefit, particularly during drought periods, when the estuary inflow targets are reduced to reflect the lower flow conditions in the watershed. This change in emphasis reflected the influence of the Nueces Estuary Advisory Council (NEAC), a stakeholder group created under the 1993 Agreed Order to advise the Texas Natural Resources Conservation Commission (TNRCC, now the Texas Commission on Environmental Quality (TCEQ)) on matters related to the Agreed Order. This new emphasis on delivering available freshwater inflows to the best location, ecologically speaking, within the Nueces Delta gave rise to a series of studies and projects intended to implement this approach. The following is a discussion of two projects designed and constructed to increase freshwater diversions into the Nueces Delta via Rincon Bayou.

Re-opening exchange between the Nueces River Tidal Segment and Rincon Bayou

The first opportunity to actually affect the location of where the "pass-thru" amounts required under the Agreed Order enter the Nueces Estuary was the re-establishment of the connection between the Nueces River tidal segment and the upper Rincon Bayou. This initially took place under the "Rincon Bayou Demonstration Project" conducted between 1993 and 1999 by the U.S. Bureau of Reclamation (BoR), the federal agency which financed, constructed and owns Choke Canyon Dam and Reservoir (the City of Corpus Christi and the Nueces River Authority are the local project sponsors and owners of the state water rights permit authorizing the impoundment of water in, and diversion water from, the federal reservoir project).

In this project, the BoR removed material on the banks of the Nueces River which restricted overbanking flow into Rincon Bayou, and excavated a filled-in portion of the historic Rincon Bayou channel to increase flow capacity between the Nueces River and areas "downstream" on Rincon Bayou. These changes created what the BoR called the "Nueces Overflow Channel," which "lowered the minimum flooding threshold of the upper Nueces Delta from 1.64 m (5.4 ft) mean sea level (msl) to about 0.0 m msl, thereby increasing the opportunity for larger, more frequent diversion of fresh water." *(*Bureau of Reclamation, 2000)

The BoR report on the Rincon Bayou Demonstration Project classified these "diversion events" into three types:

1. Exchange events: "frequent, low-volume interactions between the channels and pools of Rincon Bayou and either adjacent water body (i.e., Nueces Bay or Nueces River)" . . . "primarily caused by daily differences in water level elevations" and in which the net flow volume for the event was generally low (<100 ac-ft). "Exchange events were important because they diminished the extreme concentration of salt in the upper delta, contributing to the quality of aquatic habitat regularly available to estuarine organisms."

2. Positive-flow events: "considered to be infrequent, large-volume events that resulted in a net flow of water from the Nueces River into Rincon Bayou" . . . "primarily driven by rises in the Nueces River" which "typically occurred during the spring or fall" and which "were not confined to the Rincon Bayou channel but frequently affected the lower adjacent flats and pools." "Positive-flow events were important because they preserved seasonally-critical salinity and nutrient regimes in the upper delta, thereby allowing the delta to support a nursery area for estuarine organisms emigrating from the bays and Gulf."

3. Tidal flat inundation events: were "considered to be very large, positive-flow events during which some amount of water passed through the Rincon Overflow Channel. These events were important because they lowered open water and soil salinity concentrations in the delta to the benefit of marsh plants, and transported organic material to the lower bay for use by fish and shellfish." (Ibid.)

Despite the fact that during most of the duration of the Rincon Bayou Demonstration Project the region was in a severe drought and both reservoir and estuary inflows were greatly reduced, the BoR report on the project noted that:

> *In a relatively short period of time (only 4.2 years after the opening of the Nueces Overflow Channel), the average salinity gradient in the upper delta reverted to a more natural form, with average salinity concentrations in upper Rincon Bayou becoming the lowest in the Nueces Delta." "Without the demonstration project, average salinity concentrations in the upper Rincon Bayou channel would have remained strongly hypersaline (likely greater than 50 parts per thousand instead of the observed range of 21 to 28.* (Ibid.)

The study also documented measurable improvement in water column primary productivity, benthic community abundance and diversity, and vegetative community structure and productivity.

The results of the Rincon Bayou Demonstration Project confirmed the anticipated ecological value of enhancing the exchange of water between the Nueces River and the Rincon Bayou/Nueces Delta complex. However, under the terms of the temporary easement agreements BoR entered into with private landowners in order to excavate the Nueces Overflow Channel, at the end of the project term, the BoR was required to return these private properties to their "pre-project" condition. This included re-establishing the elevation of the Nueces Overflow Channel to 1.64 m msl. While local efforts were made to acquire the properties on which the BoR had temporary easements, these efforts did not come to fruition in time to forestall the partial filling of the Nueces Overflow Channel, which the BoR completed in September 2000.

Fortunately, the BoR demonstration project's encouraging results stirred local interest in finding a way to permanently secure the property through which the Nueces Overflow Channel was located and to re-open a permanent diversion channel. The City of Corpus Christi was able to acquire the necessary properties and, by October 2001, a permanent diversion channel was constructed to restore flows to the Rincon Bayou/Nueces Delta system (Hill et al, 2011).

Routing freshwater from the Calallen Pool directly to Rincon Bayou by pipeline

While the permanent opening of the Nueces Overflow Channel provided increased opportunity for exchange, positive-flow and tidal flat inundation events, the utility of the diversion channel in moving the often small volumes of freshwater inflows available to the estuary during drought conditions was limited. These limited amounts of water, often 1,200 ac-ft/mo. or less, if passed over the Calallen Dam, would not increase water surface levels in the Nueces River tidal segment enough to generate flow into Rincon Bayou.

In 2001, the NEAC recommended, and TCEQ approved, amendments to the 1995 Agreed Order that required the City of Corpus Christi, in exchange for some lowering of the drought period freshwater inflow targets, to build and operate a 1.5 m diameter water pipeline capable of conveying up to 3,000 ac-ft/month of freshwater from the Calallen Pool directly into the Upper Rincon Bayou, in accordance with the monthly pass-thru plan. The City of Corpus Christi's Rincon Bayou Pipeline and Pump Station was designed, permitted, and constructed between 2001 and 2003, with operations beginning in 2003.

These two projects, the permanent opening of the Nueces Overflow Channel and the construction of the Rincon Bayou Pipeline set the stage for a new era of freshwater inflow management within an area encompassing the tidal reach of the Nueces River, Rincon Bayou and the surrounding Nueces Delta, and Upper Nueces Bay.

1.1.5 The Current Study: Determining how to deliver limited quantities of freshwater inflows to where they count the most

This report looks at the potential use of hydraulic and landform modifications within the Nueces Delta/Bay system (the "Study Area" -- see Figure 1.1.5, next page) to increase the benefit of the often limited quantities of freshwater inflows by delivering those flows into areas of the Nueces Delta where they would help to restore some level of pre-development ecosystem function. The basis for this investigation is the finding, made during a recent determination of the "environmental flow" needs within the Nueces River Basin, "that all rivers, streams, and bays were sound ecological environments, except the Nueces Bay and Delta, which were determined to be unsound ecological environments." (*Underline added for emphasis*)

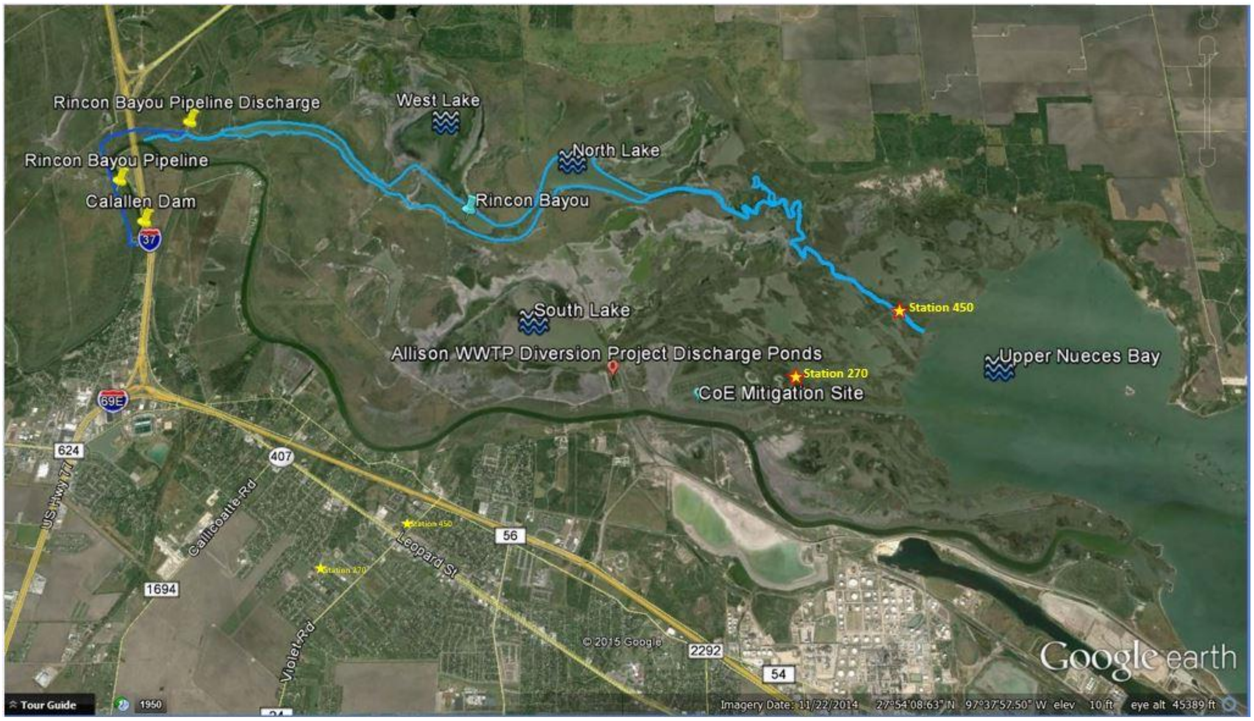


Figure 1.1.5: The Nueces Delta Landform Modifications Study Area

Pursuant to Senate Bill 3 (SB3), the landmark "environmental flows" bill adopted in 2007 by the 80th Texas Legislature, the Nueces River and Corpus Christi and Baffin Bays Basin and Bay Area Stakeholder Committee (Nueces BBASC) has developed a "Work Plan for Adaptive Management" (Work Plan) (Nueces BBASC, 2012) to, among other things, guide studies of potential strategies for better managing freshwater inflows to the Nueces Estuary in order to meet adopted SB3 environmental flow standards. In 2013, the Texas Legislature appropriated funding for the SB3 Environmental Flows program to support some of the studies proposed in the Nueces BBASC's Work Plan.

One of the studies recommended in the Work Plan (*Tier 1, Priority 7*) is to "*Explore Landform Modifications to Nueces Bay and Nueces Delta*" in order to maximize "the benefits of available freshwater inflows from managed events such as pumped discharge, low volume natural or induced "overbank", and/or reuse of effluent." The description of the proposed study in the Work Plan notes that this would likely involve "earthwork and related facilities of landscape scale within the Delta" and "construction of water control structures." The "Nueces Delta/Bay Landform Modification Study" project was one of five projects recommended in the Work Plan which were selected by the Nueces BBASC and funded by the Texas Water Development Board under the 2013 state appropriation.

The project scope ultimately focused on potential landform and hydraulic modifications to increase the ecological benefit of the freshwater inflows required under the terms of the 2001 Agreed Order and being delivered into the Nueces Delta via the Rincon Bayou Pipeline, but also included an examination of several options for increasing effluent reuse and the re-routing of the flow of the Nueces River tidal segment to increase freshwater flows into other portions of the Nueces Delta.

2 Material and Methods

2.1 Literature Review and Synthesis

The morphology of Nueces Bay has changed over the years due both to human and natural processes. Associated with the dredging and construction of the Inner Harbor, the south shore of Nueces Bay has been extended northward by the construction of protective dikes and backfilling with dredge spoil. Over the period 1920-1958, this has reduced the surface area of Nueces Bay by about 15%, according to data of Ward (1997). Over approximately the same period, the volume of Nueces Bay has been *doubled* due to the removal of huge volumes of shell (Ward, 1997; Venable et al, 2011). This would have substantially reduced the flushing and dilution of Nueces Bay relative to the years before human development.

Potential water quantity and habitat enhancement projects in the Nueces Delta have been studied since the construction of Wesley Seale Dam, on the Nueces River, and Choke Canyon Reservoir, on the Frio River. Although both reservoirs clearly play a significant role in the current amount and timing of freshwater inflows to the Nueces Delta/Estuary system, local climatological events are also important. The lack of freshwater inflows to the Nueces Delta has created a "reverse estuary" and hypersaline environment atypical of classic deltaic habitats (Dunton et al., 2001; see also Day et al., 2014). The Nueces Delta projects already implemented were designed to enhance and create habitat as well as alleviate hypersaline conditions. The following project reviews and synthesis are summarized after: Ward (1985); United States Department of the Interior/FWS (1984); HDR, (1993); Nicolau and Tunnell (1999); Bureau of Reclamation (2000); Dunton and Hill (2005); Hill et al. (2011) and Shockley (2014).

2.1.1 Nueces Delta Hydrodynamic Modeling/Freshwater Diversion Study

In the late 1970's, the U.S. Army Corps of Engineers (Corps) engaged the engineering firm Espey, Huston and Associates to develop a hydrodynamic model of the Nueces Delta and use it to investigate several potential freshwater diversions which would increase the frequency and duration of marsh inundation. In the design considerations for this first proposal of a diversion from the Nueces into the Rincon, reported by Ward (1985), it was determined that a flow in the river of about 200 m^3s^{-1} (7,000 cfs) was the threshold for inundation of the upper Rincon marsh by flow over the existing levee. Under conditions then existing (Lake Corpus Christi in place), the return period for such an event during the high-flow seasons of May-July or September-October was about two years, the occurrence of the threshold of flooding in the Rincon delta. To achieve more extensive and sustained inundation would require considerably larger flows. Scenarios of various flood events exceeding this threshold were input to the model and various control structures for routing and retention of flood waters were explored to determine how best to achieve sustained inundation of the delta. Such strategies were planned as mitigation for proposed dredged material deposition in Nueces Bay. Ultimately, the Corps elected a mitigation plan that involved the creation of a new marsh on the delta (see following section) and shelved plans for hydraulic modifications.

2.1.2 Nueces Delta Mitigation Project 1989 – 1997

The Nueces Delta Mitigation Project created approximately 0.81 km^2 of salt marsh habitat within the southern part of the Nueces Delta. The US Army Corps of Engineers along with the Port of Corpus Christi Authority excavated an upland borrow area and planted a *Spartina alterniflora* marsh to offset habitat losses from the Corpus Christi Ship Channel 45-Foot Dredging Project. The initial excavation was in March 1987 with biological monitoring beginning in 1989 and ending in 1997. Environmental factors, such as wind and tides were factors that initially affected the establishment of *S. alterniflora*, but by August 1997 the Corps acknowledged the project was a success. This project increased salt marsh habitat that provides essential nursery and adult habitat for birds, fish, shrimp, crabs, and terrapins in the Nueces Delta. (United States Department of the Interior/FWS, 1984)

2.1.3 Rincon Bayou Overflow Channel Demonstration Project 1993 – 1999

The Rincon Bayou Overflow Channel Demonstration Project was initiated and funded through the US Bureau of Reclamation. This project increased freshwater inflows to the upper Nueces Delta using two diversion channels: 1) The Nueces Overflow Channel and 2) The Rincon Overflow Channel. Both channels were built October 1995 (Figure 2.1.3, below).

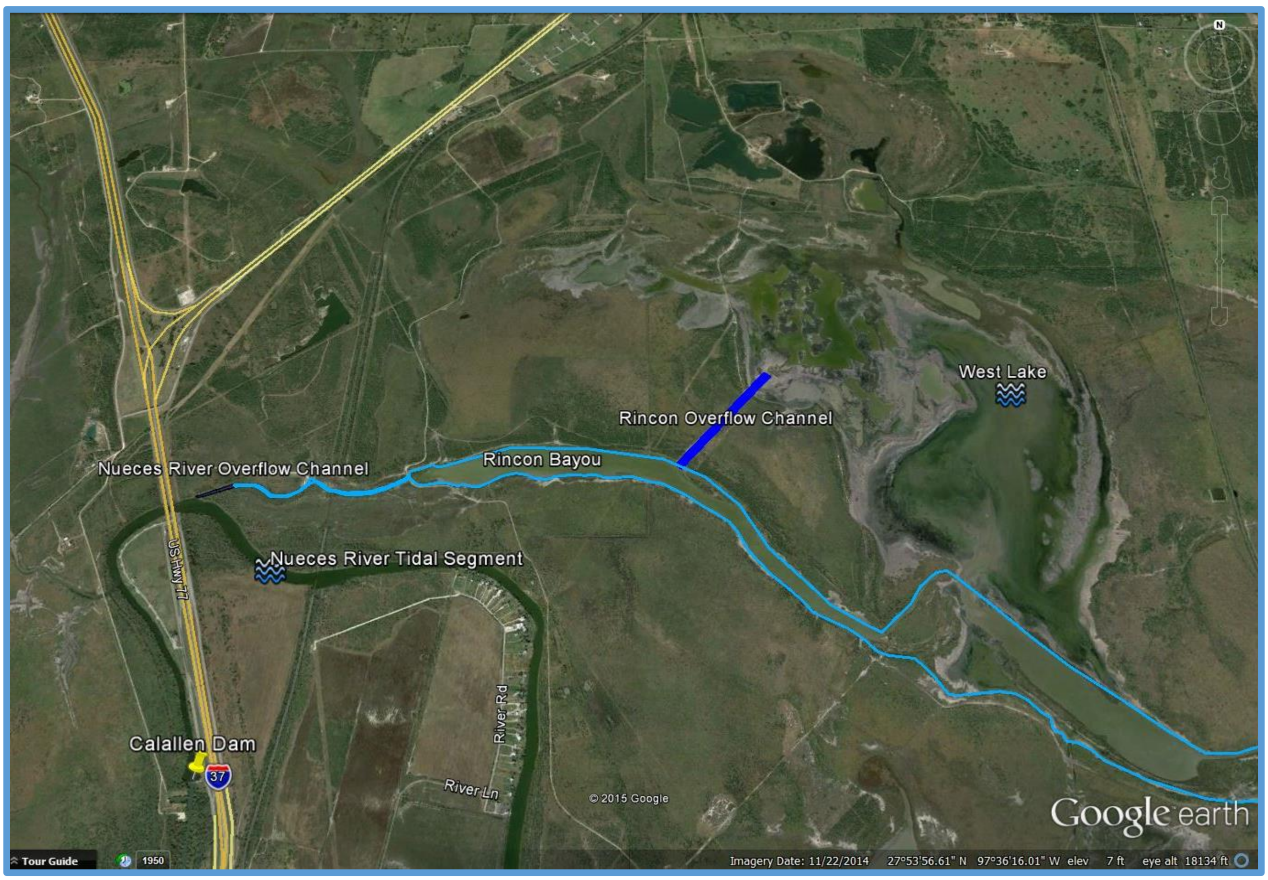


Figure 2.1.3: Features of the BoR Rincon Bayou Overflow Channel Demonstration Project

The Nueces Overflow Channel was excavated to 0.6 m msl and connects the Nueces River to the interior delta during flood and high tide events. The Rincon Overflow Channel, connecting Upper Rincon Bayou with West Lake, was excavated to 1.22 m msl on the south end and 0.91 m msl on the north end of the channel. Biological monitoring consisting of water column productivity, benthic macrofauna, and emergent vegetation took place from October 1994 through December 1999. The 50-month study showed the amount of freshwater diverted by the Nueces Overflow Channel into the delta increased by approximately 732% when comparing inflow data from 1982 to 1995. Both overflow channels are currently still permanent features of the Nueces Delta. For further detail of this project see: Bureau of Reclamation, 2000.

2.1.4 Effluent Diversion Demonstration Project 1998 - 2003

The Effluent Diversion Demonstration Project was funded through the City of Corpus Christi and was a full-scale demonstration project that used treated municipal effluent as an alternative freshwater source to the lower Nueces Delta. This project was initiated based on the recommendations in the Regional Wastewater Planning Study Phase II Nueces Estuary. Three 0.013 km^2 ponds were built approximately north of the Nueces River, 900 m northeast of the Allison Wastewater Treatment Plant along the southern edge of South Lake.

The design of the project and discharge permit diverted up to 2 mgd of treated effluent to the ponds. The effluent provided a constant supply of nutrient-rich freshwater and also reduced hypersaline conditions in the area. The effluent diverted to the South Lake area also created a 0.07 km^2 emergent vegetation marsh that provided valuable bird habitat, especially during drought times. Birds utilized the area for feeding, resting, and breeding. Algal blooms in the Nueces River were also reduced since the Allison Wastewater Treatment Plant decreased the effluent load to the river. The biological monitoring for this project ended in 2003 but the city still pumped effluent to the Allison cells until 2010, when the EPA/TCEQ imposed a new 4mg/L ammonia limit on discharges into the demonstration project – a standard that was not able to be met by the current levels of treatment at the Allison WWTP. There are current stakeholder efforts to persuade EPA/TCEQ to amend the ammonia limit for discharges into receiving waters at the demonstration project site since monitoring and evaluation of the ecological effects of the effluent diversions demonstrated substantial benefits (Nicolau and Albert, 2003).

2.1.5 Nueces Delta Preserve Land Acquisition

The Nueces Delta Preserve was established in 2003 by the Coastal Bend Bays & Estuaries Program (CBBEP). To date, approximately 8,500 acres (34.4 km^2) of Nueces River Delta property has been purchased with the assistance of various state, federal, and local funding entities. Most recently, in 2014, CBBEP purchased 2,500 acres (10.12 km^2) of habitat with funds received from a Natural Resource Damage Assessment settlement. CBBEP has an additional 2,000 acres under contract and intends to have those acres purchased by the end of 2015. With the forthcoming purchase CBBEP will own and manage approximately 10,500 acres (42.5 km^2) within the Nueces River Delta. (Herring, 2015)

CBBEP has also directed millions of dollars into the protection and restoration of rookery islands in Nueces Bay. Six rookery islands and approximately 0.025 km^2 of colonial waterbird island habitat in Nueces Bay have been protected by the Coastal Bend Bays & Estuary Program. The Program has constructed 176 acres (.71 km^2) of estuarine marsh along HWY 181 in Nueces Bay. The constructed marsh was planted with *S. alterniflora* which will help to protect the marsh from erosion and provide essential habitat to juvenile fish, shrimp, and crabs. (Ibid.)

2.1.6 Rincon Bayou Nueces Delta Study 2003 – 2010

The Rincon Bayou Nueces Delta Study was funded by the City of Corpus Christi. The goal was to assure that the freshwater "pass-throughs" being delivered to the Rincon Bayou via the Rincon Bayou Pipeline, completed by the City of Corpus Christi in 2003, were providing additional ecological benefit to areas within the Nueces Delta, while also causing no harm. Ecological monitoring was implemented to evaluate the effects of these new diversions and it was determined "no harm" resulted from the three pipeline releases that occurred during the study period (2003-2010). Since the pumped events that occurred during the study were not large enough in volume to "overflow" into adjacent wetland areas, the ecological benefits over the larger area of the Nueces Delta could not be determined, but it has been documented that any freshwater inflow through Rincon Bayou is generally beneficial (Montagna et al, 2009, Tunnell and Lloyd, 2011, Hill et al, 2012, and Lloyd et al, 2013).

2.1.7 Salinity Monitoring and Real Time (SMART) Inflow Management Program Evaluation 2013-14

Another effort, the "Tier 1, Priority 1" project recommended in the 2012 Nueces BBASC Work Plan for Adaptive Management, was the 2013-14 evaluation of the proposed use of Salinity Monitoring and Real Time (SMART) data to better manage inflows to the Nueces Delta/Estuary system. The resulting SMART Inflow study, funded by a grant from the Texas Commission on Environmental Quality (TCEQ), was a joint project between the Coastal Bend Bays and Estuaries Program (CBBEP) and the City of Corpus Christi.

The study investigated how the amounts and timing of the freshwater "pass-throughs" required by the TCEQ Agreed Order might be better managed to create additional ecological benefits to the Nueces Delta while protecting, or enhancing, regional water supplies. The concept being tested was whether inflows to the estuary should be made as needed, based on salinity conditions in the bay and delta, rather than following the adopted schedule of monthly inflow targets. The City of Corpus Christi's existing Lower Nueces River Basin/Bay (NuBay) hydrologic/systems operations model was used to evaluate numerous scenarios for reservoir system operating policies, taking into account varied targets for estuary inflows, reservoir system yield and salinity target attainment frequencies. Preliminary results indicate that opportunities exist to use SMART Inflow Management as a tool to achieve these multi-objective goals (Shockley, 2014).

2.2 Expert Team Workshops for Preliminary Project Scoping, Stakeholder Charrettes and Hydrodynamic Modeling to Refine Alternatives and Identify Recommended Options

2.2.1 Employing the Professional Judgment of an Expert Team

The literature review documents that a small group of scientists and resource managers have focused a significant amount of time and effort in analyzing the problem of the Nueces River Delta being "fresh-water starved" (Ward, 1985), in designing and recommending diversion projects to address the problem, and in monitoring the effects of those projects which were eventually constructed. This study was fortunate to have on the project team a number of those scientists who, collectively, have brought to the project well over a hundred years of experience and expertise.

Capturing the professional judgment of this group of experts through a series of project team workshops was an extremely valuable part of the process of identifying a preliminary set of potential landform/hydraulic modifications intended to meet the project goals. These preliminary project concepts were then subject to an initial round of hydrodynamic modeling, which provided the project team with information on each project's individual potential for increasing the area of inundation within the Nueces Delta during a pumping event. This initial modeling also revealed any unanticipated effects of these concepts, and provided information for the project team to make further refinements in some of the potential projects, for grouping potential projects together, or for taking some of them "off the table."

2.2.2 Gathering Stakeholder Input on the Preliminary Project List for Landform Modifications in the Nueces Delta/Nueces Estuary System

Just as there are many ecosystem functions and values associated with the wetlands and waters of the Nueces Delta/Nueces Bay portion of the Nueces Estuary, there are many "voices" in the community of constituents who have a personal or professional interest in this area. As a result of the longstanding, and particularly successful, effort to involve these "stakeholders" in the decision making process with respect to management policies affecting the Nueces Delta, several groups have emerged as being effective focal points for obtaining input on proposed projects and changes in management policies.

The first formal stakeholder group for the Nueces Delta was the Nueces Estuary Advisory Council (NEAC), created under the 1992 Agreed Order for the implementation of the requirements of Special Condition 5.B of the Choke Canyon Certificate of Adjudication No. 21-3214. The membership of this group is specifically designated by the terms of the Agreed Order and includes representatives of a variety of groups with specific interests in the issues surrounding the Nueces Estuary: regional water supply, industry, business, recreation on and around the two reservoirs, commercial and recreational fishing, birding, natural resource agencies and the environment in general. NEAC serves as an advisory group to TCEQ on matters related to the freshwater inflow operating plan for the Nueces Estuary, as contained in the Agreed Order. This group has a long, successful history of making consensus-based decisions on, important issues related to the details of the freshwater inflow operating plan.

The Coastal Bend Bays Foundation (CBBF) is another stakeholder-based organization which is "dedicated to the conservation of freshwater and coastal natural resources for current and future generations through consensus, facilitation, communication, advocacy, research and education. CBBF holds regular "Coastal Issues Forums" on a variety of regional environmental issues and sponsors opportunities for the public to become involved in community-based water quality, wetlands restoration and education projects in the Coastal Bend Bay area.

This project utilized meetings of these two stakeholder groups -- NEAC and CBBF – in order to conduct project "*charrettes*" wherein the project team, after describing the project background and objectives and presenting information on each item on the initial list of proposed projects, elicited stakeholders' comments regarding the proposed projects.

2.2.3 Utilizing the Nueces Delta Hydrodynamic Model to Investigate Potential Landform Modifications in the Nueces Delta/Nueces Estuary System

Even as efforts were occurring under a separate Nueces BBASC recommended project (*Tier 1, Priority #6: "Improve salinity modeling methods for determining environmental flow regimes"*) to update and improve the Nueces Delta Hydrodynamic Model (NDHM) (Ryan and Hodges, 2011), this project was utilizing the most current version of the NDHM to both screen the preliminary list of potential projects resulting from the project expert team workshops and to quantify the impacts of projects recommended for further evaluation. Fortunately for both projects, the Principal Investigator for the project to update the NDHM served as a project team member on this study and was able to incorporate lessons from each study for the benefit of the other.

The NDHM, developed to "analyze fate and transport of freshwater and tidal inflows to the Nueces Delta," uses input data on tides, wind, precipitation, boundary roughness, and freshwater inflows (both Nueces River flow overbanking and pumping through the Rincon Pipeline Diversion) to simulate the movement of water and salt fluxes across the Nueces Delta (Ibid.).

Given a set of defined input parameters (i.e., Rincon Diversion Pipeline freshwater pumping rate and duration, initial salinity values, alterations in bathymetry (*e.g., new channels*)), the model provides output data useable for quantifying the area, depth and period of inundation, as well as the water salinity, resulting within the Nueces Delta. Additionally, and of significant value in making comparisons between discrete preliminary alternatives, the model output can be presented as a video graphically illustrating the constantly changing temporal/spatial distribution of key ecological parameters (area inundated, salinity, etc.) resulting from changes in the hydraulic properties of the system *(for an example video of the model runs, see*: http://youtu.be/mu7mFINgBsg *which also has links to videos of other model runs*).

The NDHM was used in this fashion to screen the initial set of projects compiled as a result of the expert information contributed during project team workshops. The video output also provided a readily accessible format for presenting preliminary modeling results to stakeholders during the two *charrettes*.

After receiving stakeholder feedback from the charrettes, and further project team consideration of the modeling of the preliminary list of alternatives, the NDHM model was used to simulate the effects of implementing the options selected for further evaluation.

2.3 Ecological Basis for Methods of Evaluating Modeling Results

2.3.1 Climate and Hydrology

Freshwater inflows to the Nueces Estuary exhibit significant variation and are characterized by distinct wet and dry periods (Figure 2.3.1-1). Over one decade (2000-2010), there were three periods with measurable freshwater inflow in 2002-2004, 2007, and 2010. These relatively wet periods were preceded by extended drought periods in 1999-2001, 2005-2006, and 2008-2009. The end of the study period in 2011 was characterized by an exceptional drought period (see National Climate Data Center, http://www.ncdc.noaa.gov/sotc/drought/2011/). Average annual freshwater inflow to the Nueces Estuary was 5.57 x 10^8 m^3y^{-1} over the course of this period (Stachelek and Dunton, 2012). Porewater salinity* was lower during wet periods when large freshwater inflow events flushed soils of accumulated salts (Figure 2.3.1-2) but was nearly equivalent to the salinity of nearby tidal creeks (Figure 2.3.1-3). During drought periods and in the absence of freshwater inflow, porewater salinity is often elevated to values several times that of standard seawater, especially for interior marsh areas (Figure 2.3.1-4).

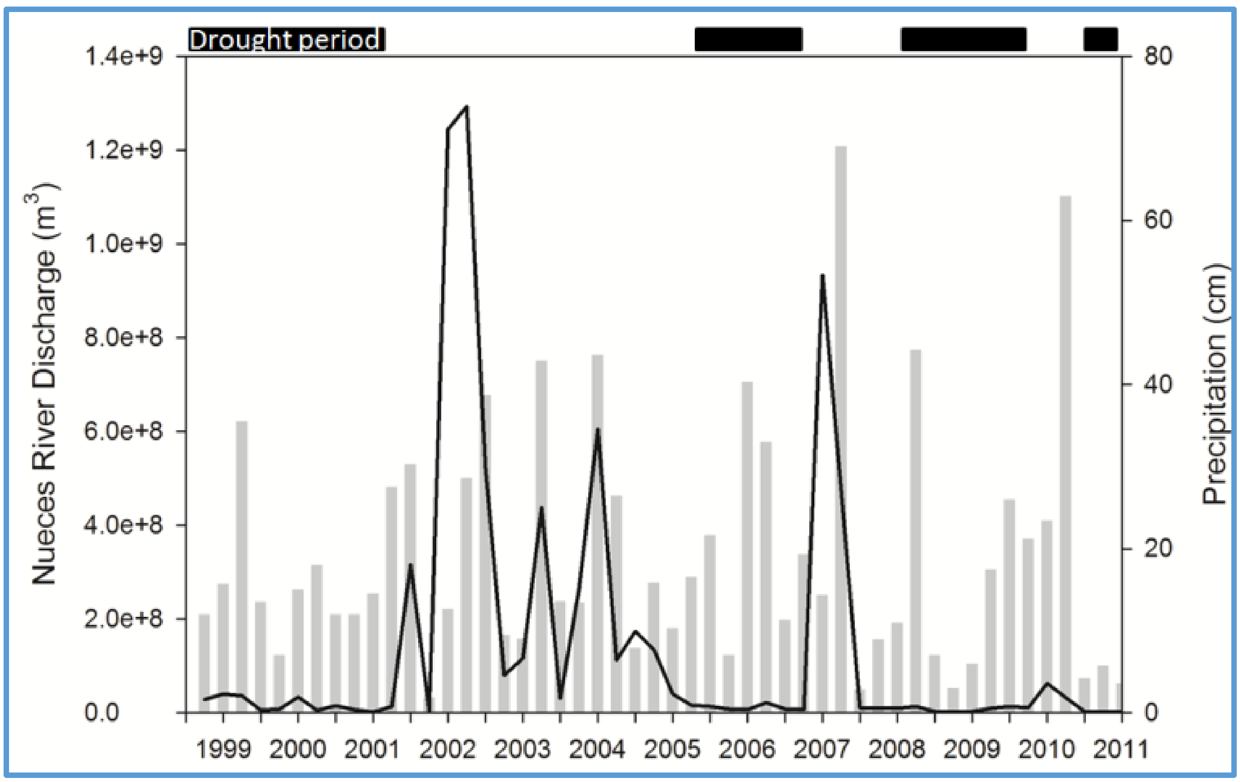


Figure 2.3.1-1: Quarterly precipitation (shaded bars) at the Corpus Christi airport and freshwater inflow (solid line) to the Nueces Estuary via the Nueces River (1999-2011). Four drought periods in 1999-2001, 2005-2006, 2008-2009, and 2011 are identified by shaded boxes. From Stachelek and Dunton (2012).

** See note on next page.*

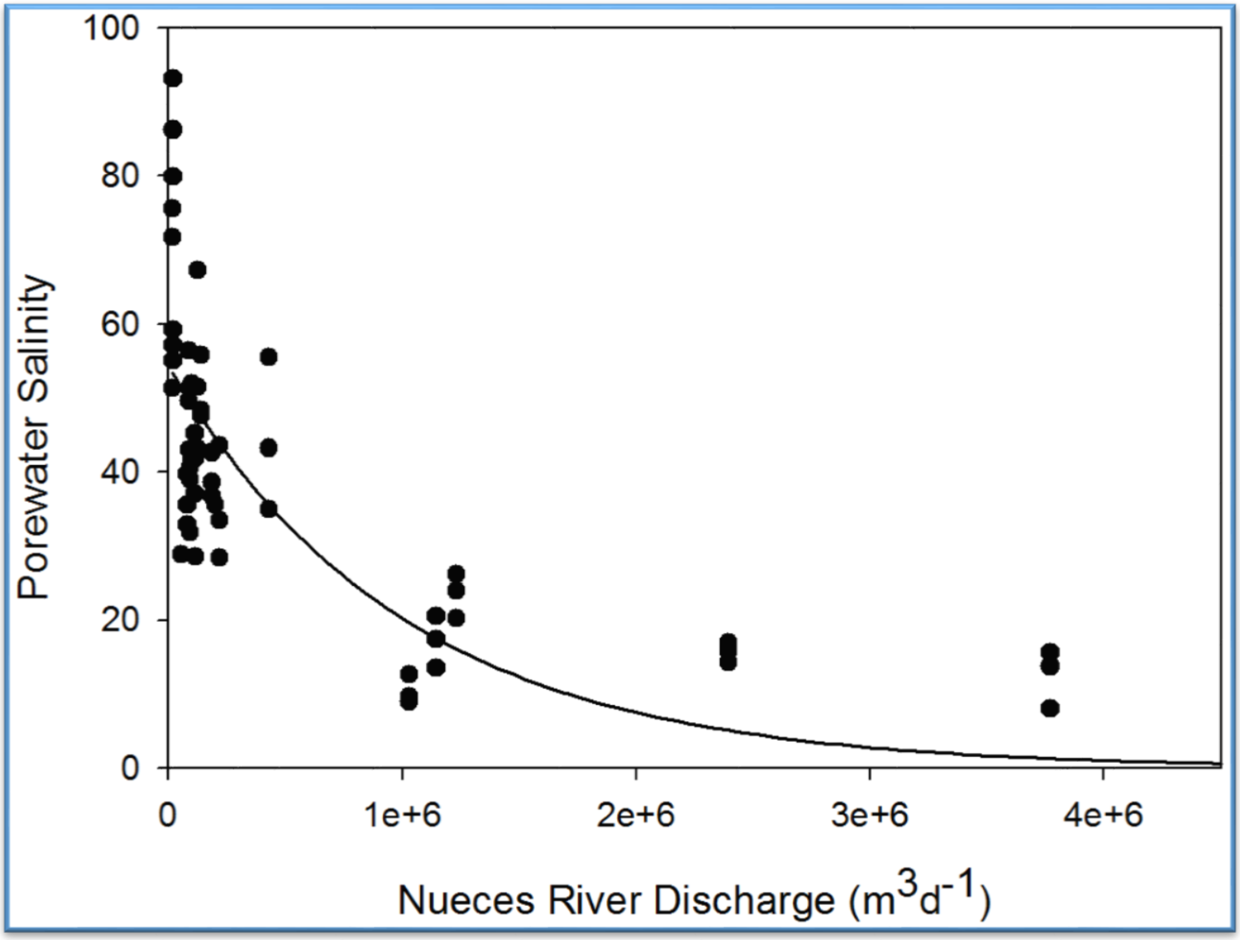


Figure 2.3.1-2: Relationship between freshwater inflow (Nueces River: USGS #08211500) and porewater salinity* along the creek bank in the low marsh. Regression curve is a best fit line for an exponential decay function ($y = 54.39\ e^{(-9.89e-7)x}$, $R^2 = 0.63$). From Stachelek and Dunton (2012).

**Note*: *The editorial convention of not including units with respect to salinity values has been adopted by professional journals in the fields of marine chemistry and physics, and, to some extent, oceanography. This practice, based on the current international system of units, reflects the position that the Practical Salinity Scale is defined as a conductivity ratio, with no units. In keeping with this convention, the text and most figures in this report therefore do not associate units (e.g., typically "ppt" for "parts per thousand," or "psu" for "practical salinity unit") with any measures of salinity. The exceptions are a number of the figures appearing in Section 3.1.3, which were generated by "scripts" within the Nueces Delta Hydrodynamic Model (NDHM) and which do report salinities in terms of the unit "ppt."*

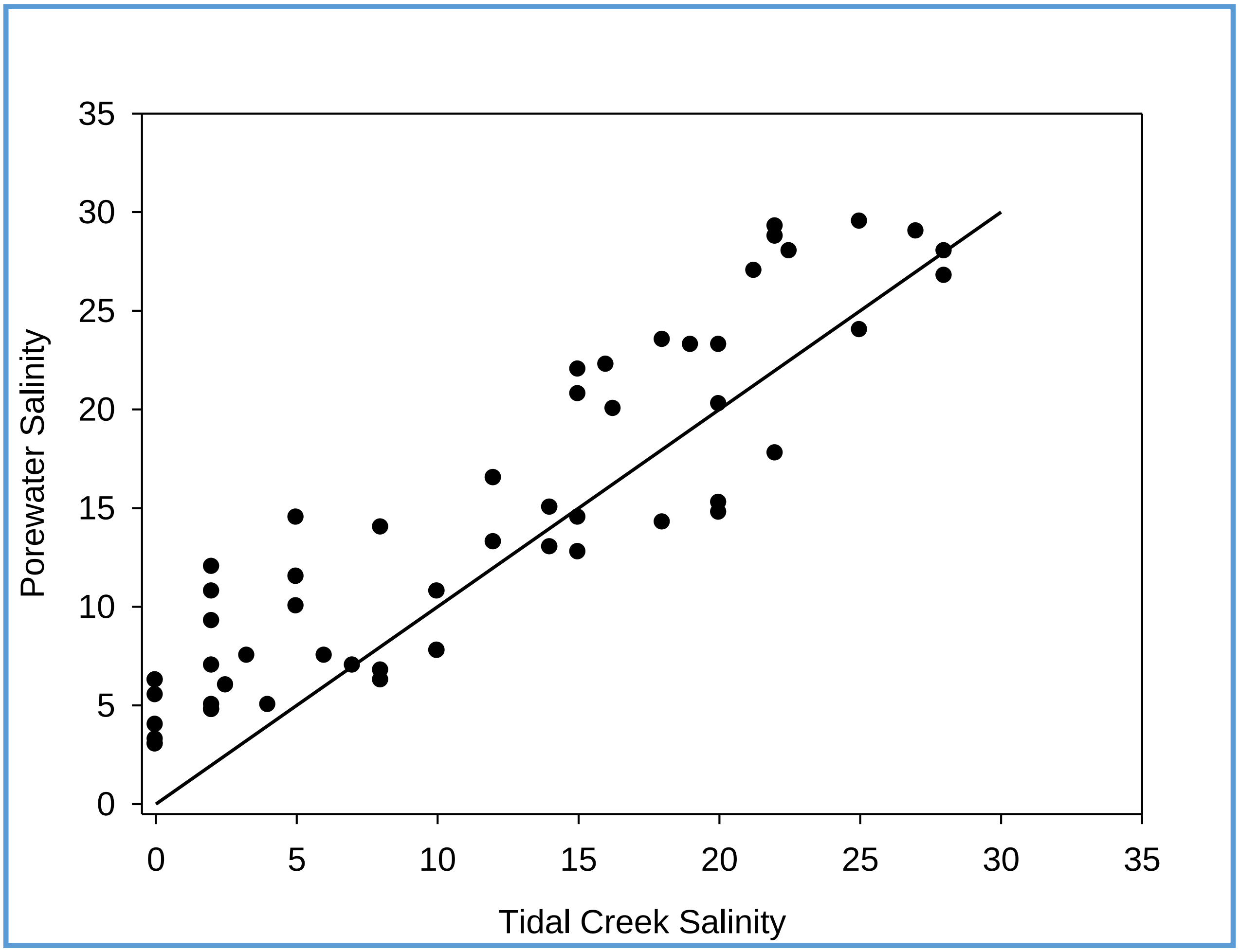


Figure 2.3.1-3: Corresponding measurements of creek bank porewater and tidal creek salinity in relation to their theoretical one-to-one relationship (solid line). From Stachelek and Dunton (2012).

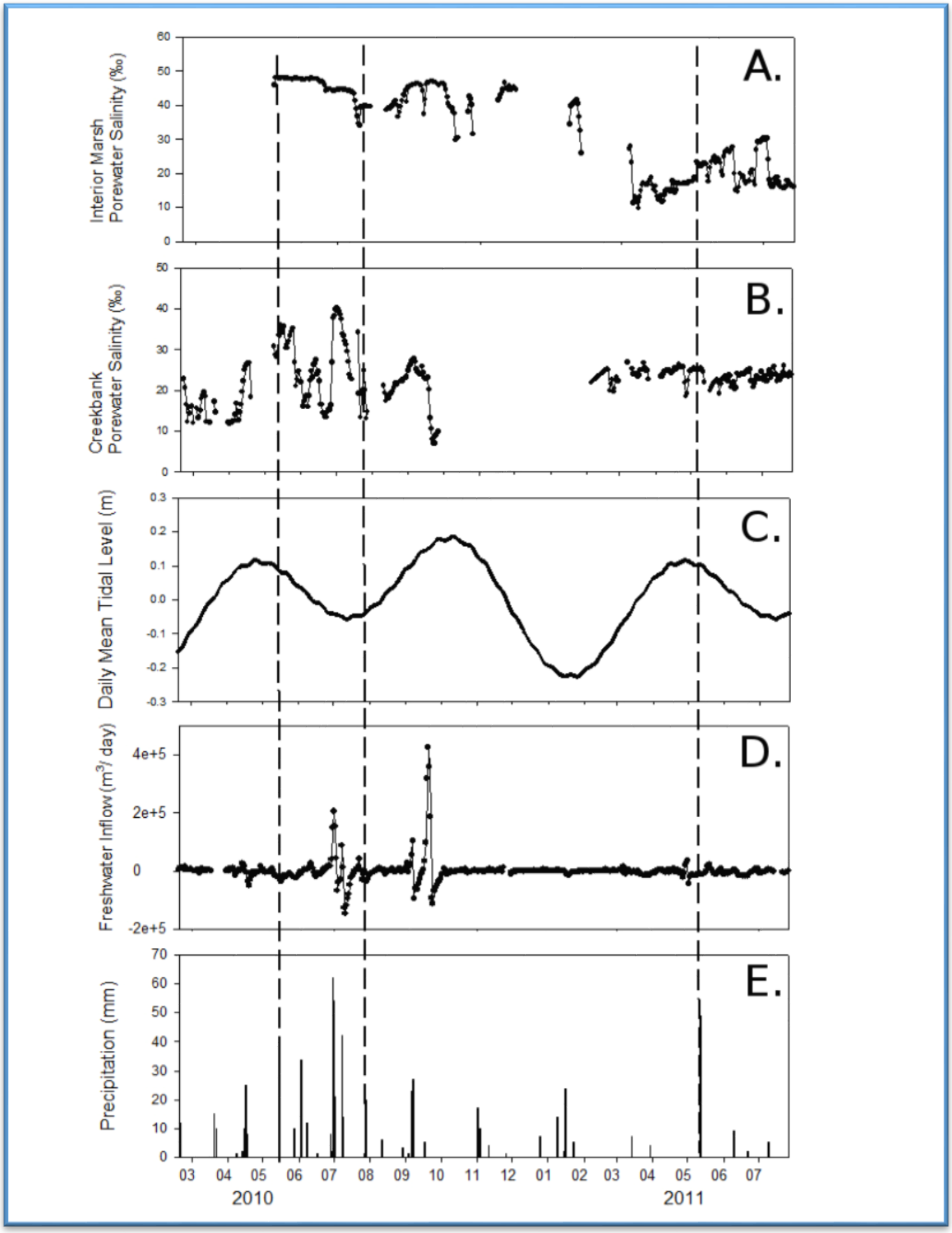


Figure 2.3.1-4: Times series of porewater salinity at site 450 (A and B), mean water level in Nueces Bay (C), freshwater inflow to the Rincon Bayou (D), and precipitation (E). Local precipitation data was recorded at the Nueces Delta weather station (NUDEWX). Freshwater inflow (discharge) data was taken at the USGS Rincon Bayou gage station (#08211503). Gaps in the porewater salinity data occurred as a result of low soil moisture conditions. Dashed lines highlight precipitation events not accompanied by a freshwater inflow event. Note sustained values of interior porewater salinities. From Stachelek and Dunton (2012).

2.3.2 Hydrologic Impacts on Emergent Plants

Hydrology clearly influences that plant community of the Nueces River Delta. An analysis by Stachelek and Dunton (2012) showed that species' habitat is separated primarily according to soil moisture and porewater salinity. They also found that while *S. alterniflora* cover was most common in brackish water-logged sediments, *B. frutescens* cover dominated well-drained saline sediments. The composition of vegetation communities immediately following major freshwater inflow events was highly variable. However, *Spartina alterniflora* was consistently more abundant following freshwater inflow events. Vegetation communities during drought periods were characterized by an abundance of *Salicornia virginica* (Figure 2.3.2-1). Analysis of percent cover data provided evidence of a distinct vegetation assemblage corresponding with identified drought periods.

Based on non-metric multidimensional scaling of emergent plants according to site and time period, Dunton and Stachelek (2012) found that vegetation assemblages were unique during drought periods (Figure 2.3.2-2). They found a distinct clustering according to the hydroclimatic periods identified in Figure 2.3.2-1. For example, almost all (94%) of drought period assemblages at site 254 fell within the same similarity envelope. Likewise, drought period assemblages at site 450 and 270 were also found within the same similarity envelope (73% and 38% respectively). The lack of clustering at site 270 can be attributed to massive disturbance caused by a flooding event in 2002. This flood event eroded almost 4 m from the creek bank and permanently changed the community from a mixed vegetation assemblage to one dominated primarily by *Borrichia frutescens* (Dunton, unpublished data). As a result, early drought assemblages (1999-2002) at this site are not comparable to post-flood assemblages.

2.3.3 Estimation of Freshwater Inflow Requirements

The salinity tolerance of potential indicator species was determined by Stachelek and Dunton (2012) for *S. alterniflora*, *B. frutescens*, and S. *virginica* based on changes in percent cover in relation to porewater salinity (Figure 2.3.3-1, below). The abundance of *S. alterniflora* fluctuated from a minimum cover near 0% (Spring 2009) to a maximum cover of approximately 66% (Summer 2004). Spatial variations in *S. alterniflora* cover were evident among study sites. The site with the highest cover, site 270, is close to Nueces Bay and has the lowest topographic relief. In contrast, the site with the lowest maximum cover, site 254, has a pronounced creek bank levee (Rasser 2009). Observed spatial patterns among sites were consistent with the idea that *S. alterniflora* is limited to regularly flushed low elevation areas. Consistent with their hypothesis, fluctuations in *S. alterniflora* cover were clearly related to porewater salinity and freshwater inflow. Porewater salinities exceeding 25 resulted in dramatic declines in *S. alterniflora* coverage (Figure 2.3.3-2). There were only two outliers where *S. alterniflora* coverage was substantial (>25%) and salinity exceeded 25. These outliers were associated with the lagged response of plants to rapid increases in salinity during the onset of drought in 2005. Although freshwater inflows were concentrated in the summer season, there was no consistent relationship between time of year (season) and standing coverage of *S. alterniflora*. However, increases in cover from one season to the next occurred primarily (74%) during the spring and summer rather than during fall and winter (26%).

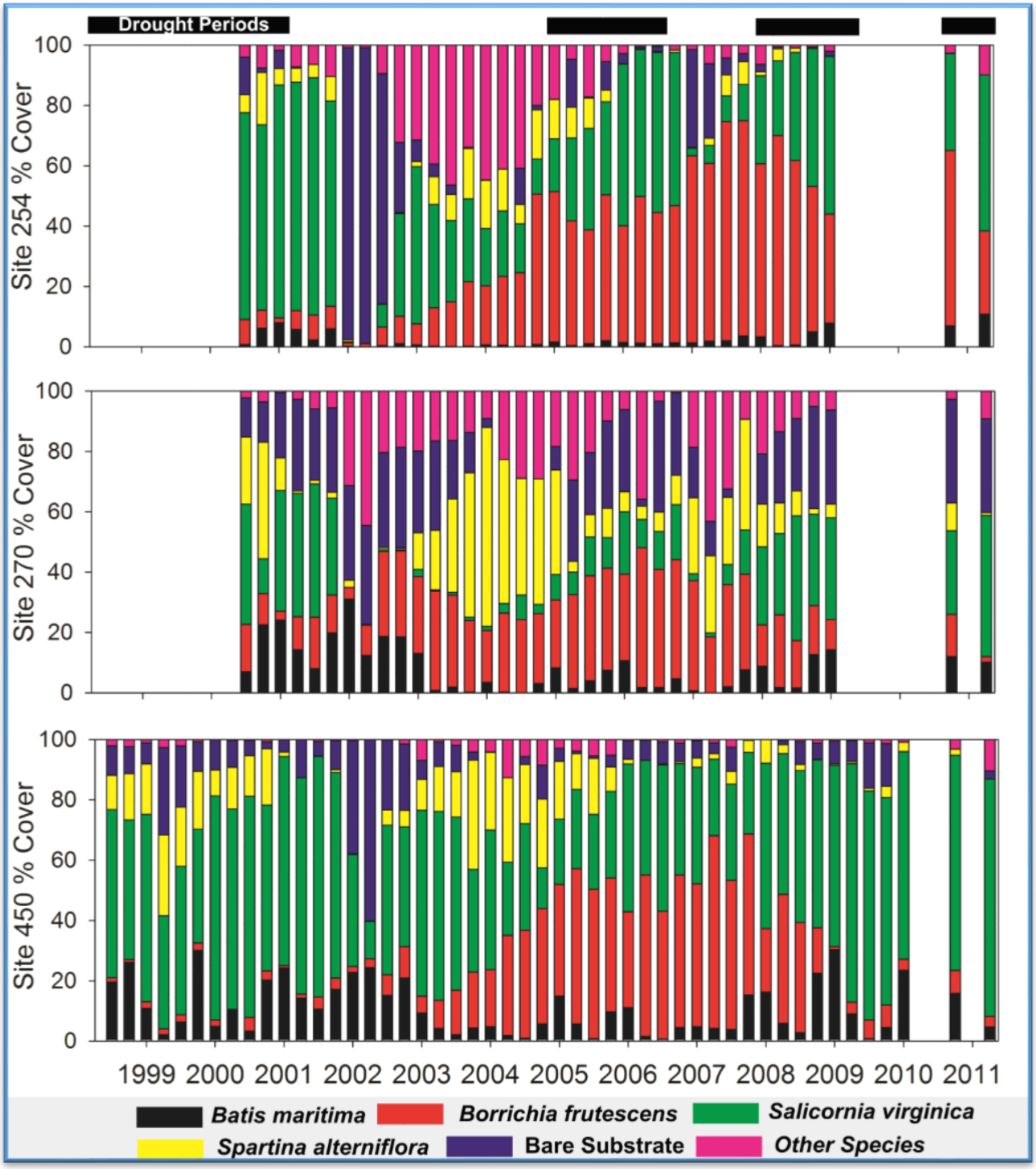


Figure 2.3.2-1: Quarterly percent cover of emergent plants at selected sites in the Nueces River Delta for the period 1999-2011. Shaded boxes at top indicate the occurrence of drought periods. Drought periods were defined as years with inflows below the median. From Stachelek and Dunton (2012).

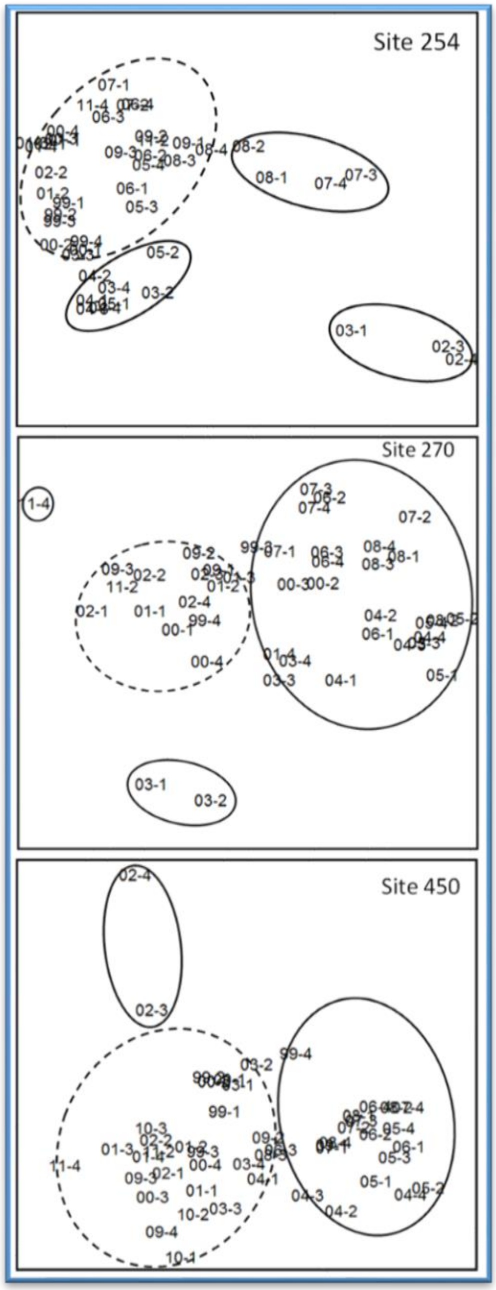


Figure 2.3.2-2: Non-metric multi-dimensional scaling ordination of emergent plant communities averaged by station and quarterly sampling date formatted as YY-Quarter. For example, winter 2000 is denoted by 00-1. Similarity clusters are defined at 60% similarity by the Bray-Curtis method. Clusters are outlined to show corresponding drought period (dashed circles) and wet period (non-dashed circles) vegetation assemblages. From Stachelek and Dunton (2012).

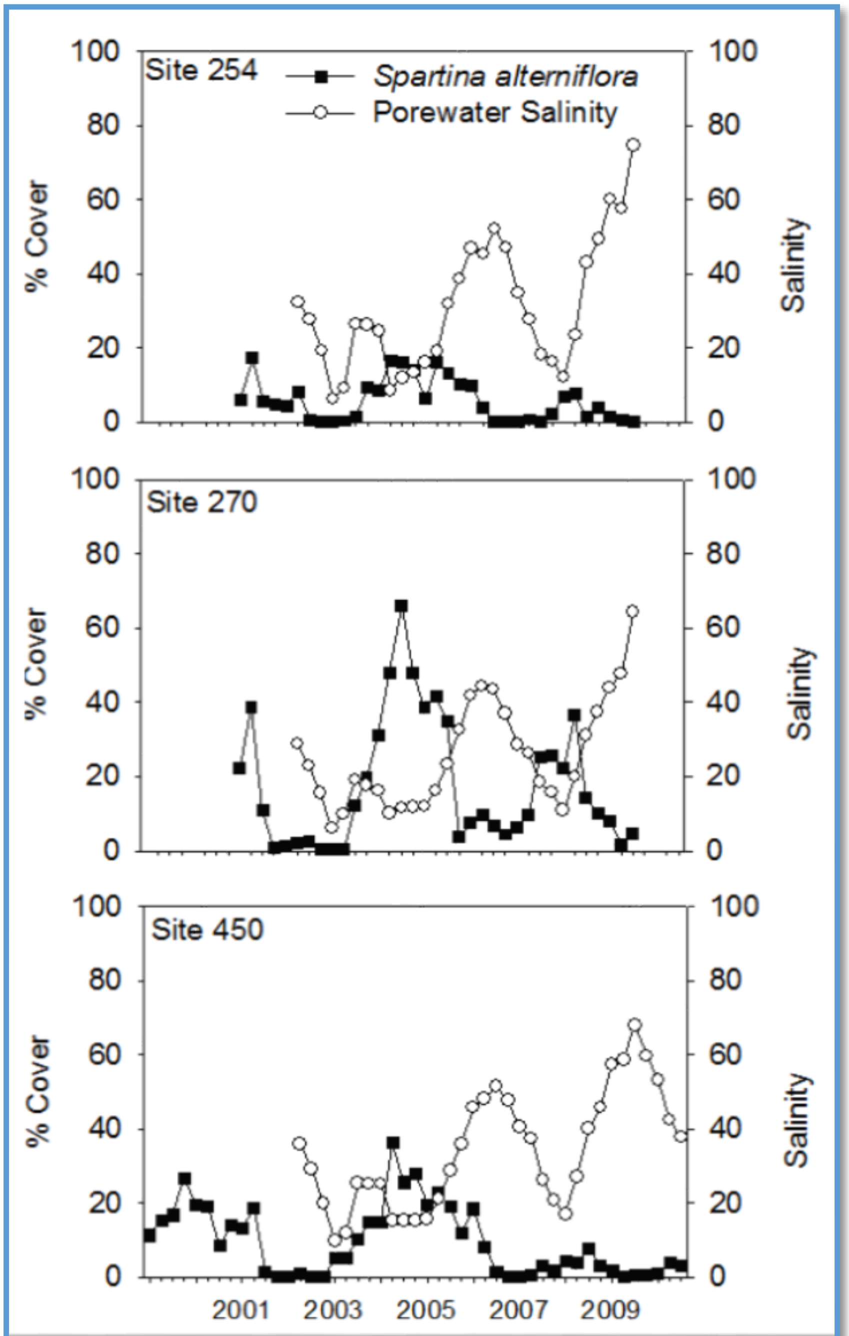


Figure 2.3.3-1: Porewater salinity (white circles) and percent cover of Spartina alterniflora (black squares) along the creek bank in the low marsh. Porewater salinities exceeding 25 result in declines of S. alterniflora abundance. From Stachelek and Dunton (2012).

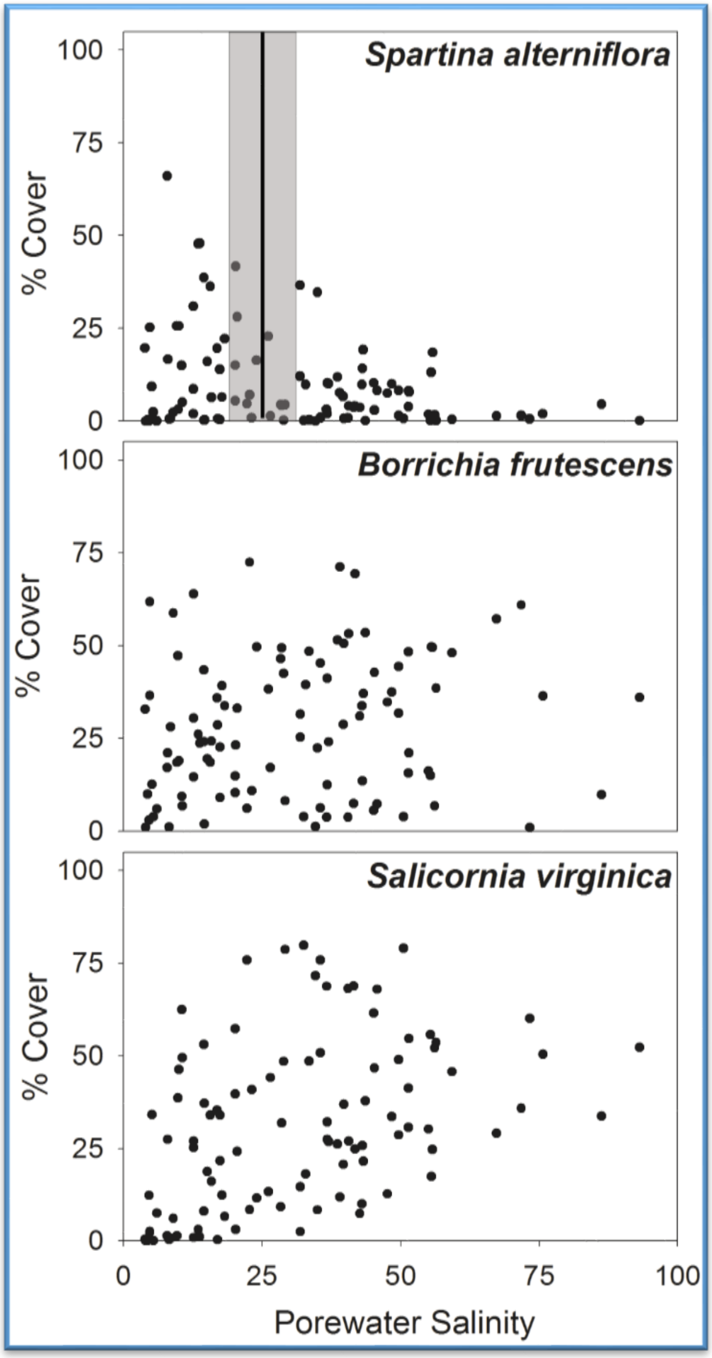


Figure 2.3.3-2: Percent cover of individual plant species (*S. alterniflora*, *B. frutescens*, and *S. virginica*) relative to variations in porewater salinity. The salinity tolerance (shaded box) of *S. alterniflora*, estimated at 25 ± 5, was estimated from empirical measurements and published literature values [*Webb* 1983; *Bertness* 1991]. From Stachelek and Dunton (2012).

The observed relationship between porewater salinity and freshwater inflow was investigated with respect to S. *alterniflora* abundance. An exponential decay fit to this relationship provided a means to estimate freshwater inflow corresponding to a given salinity target. This study determined that achieving a porewater salinity target of 25 required a Nueces River discharge of approximately 2.87 x 10^8 m^3y^{-1}. However, this value can be expressed as a range between 2.2 x 10^8 m^3y^{-1} and 3.7 x 10^8 m^3y^{-1} owing to variations in published salinity tolerance values for *S. alterniflora* varying between 20 – 30 (Webb 1983; Bertness 1991).

2.3.4 Vegetation Response to Freshwater Inflow

Freshwater inflow events impact the Nueces Estuary by flushing salts, delivering nutrients, and distributing sediments (BOR 2000). The most dramatic of these effects is the flushing of salts following large magnitude freshwater inflow events. For example, flooding in 2002 caused extensive freshening of Nueces Bay, dropping salinity values near standard seawater to values typical of freshwater and brackish systems (Figure 2.3.1-1). Two approaches have been used to assess the impact of freshwater inflow events on the Nueces Estuary. Early studies focused on the impact of individual hydrographic events in order to define flooding thresholds and flow regimes (Ward et al. 2002). Later studies aggregated hydrographic events into distinct hydroclimatic periods (Forbes and Dunton 2006; Montagna et al. 2009). Here we consider the latter approach in order to examine how permanent alterations in hydraulic regimes may affect long term (>10 years) variations in freshwater inflow and this impact the emergent plant community of the Nueces Delta.

Previous studies have shown that the emergent plant community is responsive to variations in salinity and freshwater inflow (BOR 2000; Alexander and Dunton 2002; Forbes and Dunton 2006). However, this study is unique in that it considers both the wettest period (2002 -2004) and the driest period (2008-2009) since reservoir construction. These results demonstrate that the vegetation community typical of drought periods is distinct from that of wet periods (Figure 2.3.2-2). In addition, communities observed during early droughts (1999-2001) reappeared during subsequent dry periods in 2005 and 2008 (Figure 2.3.2-1). These drought period communities were characterized by a high abundance of *S. virginica* and a low abundance of *S. alterniflora*. The time required for the reappearance of drought period assemblages was related to the magnitude of freshwater inflow events during the preceding wet period. High freshwater inflows during 2002-2004, the wettest period during this study, extended the time period between the reemergence of drought period vegetation communities. Furthermore, vegetation communities returned to a drought assemblage after only one year following moderate inflows in 2007 (Figure 2.3.2-1). Results are consistent with previous studies regarding the response of the plant community to salinity and freshwater inflow (Forbes and Dunton 2006).

2.3.5 Environmental Flow Needs for the Nueces Delta

One way in which environmental stress is expressed in the vegetation community is through zonation. Zonation is characterized by distinct banding or spatial separation of species depending on differing tolerance to environmental stress and interspecific competition for resources (Adams 1963; Pennings et al. 2005). Typically, this occurs in response to variations in inundation frequency corresponding with an elevation gradient (Rasser 2009). Zonation can be observed in the Nueces Delta under intermediate flooding disturbance (Figure 2.3.5-1). However, during extreme drought or flooding, zonation bands are dissolved and extensive bare areas are created (Alexander and Dunton 2002). Large magnitude events, such as floods, are known to cause wholesale reorganization of the vegetation community (Forbes and Dunton 2006). The NMDS analysis from this study confirms a consistent reorganization of the plant community following flood disturbances (Figure 2.3.3-2, above).

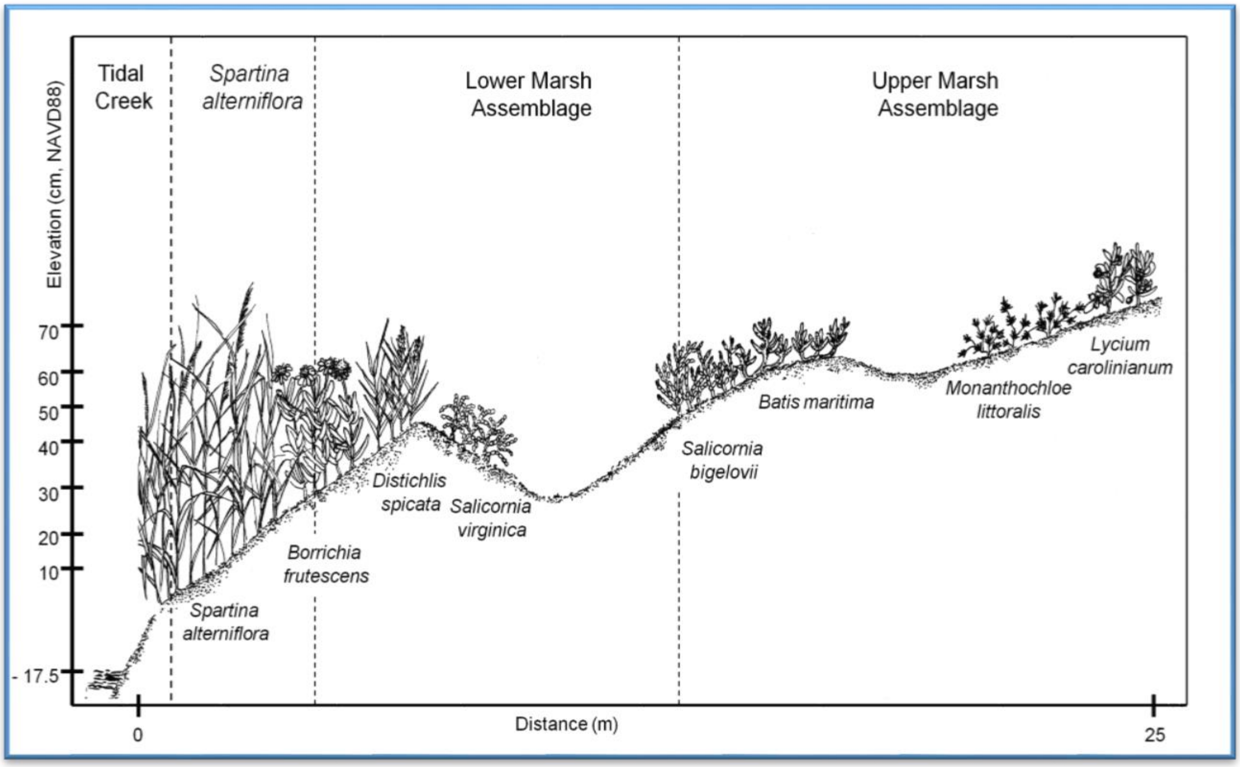


Figure 2.3.5-1: Zonation patterns of major marsh plant indicator species with respect to elevation in Nueces Delta and Nueces Bay (from Rasser et al., 2013)

This finding is important because the use of emergent vegetation as indicators of ecosystem condition is predicated on the assumption that community structure is predictable under a given set of hydroclimatic conditions. Vegetation communities, in the Nueces Delta follow a predictable trajectory. First, bare areas are created following large inflow events and initially colonized by stress intolerant species such as *S. alterniflora* and *Suaeda linearis*. Next, in the absence of freshwater inflow, these individuals were eventually replaced by the moderately stress tolerant *B. frutescens*. Finally, the onset of drought conditions encouraged the replacement of all other species by the stress tolerant *S. virginica* (Figure 2.3.2-1). The observation that *S. virginica* abundance increases during drought periods is consistent with a study by Forbes and Dunton (2006) that demonstrated the displacement *S. virginica* by *B. frutescens* following freshwater inflow events. In addition, a variety of studies determined that *S. virginica* is resilient to extreme environmental stress (Zedler 1983; Forbes and Dunton 2006; Rasser 2009).

The establishment of acceptable flow conditions (as part of an adaptive management plan) that serves to moderate large and unnatural extremes in salinity will help reduce physiological stresses that cause displacement or elimination of species over relatively short time scales. Results demonstrate that frequent freshwater inflow events are required for the maintenance of a persistent *S. alterniflora* creek bank habitat and to maintain a reasonably high diversity of plant species that imparts resilience to the overall marsh ecosystem. Increased vegetative stability will also provide a sound habitat for estuarine foundation species, especially *Spartina alterniflora*, which is preferred habitat for many estuarine dependent species at intermediate salinities (e.g. 18-25; Figure 2.3.5-2). Based on these studies, model runs for potential projects were based on achieving a maximum target salinity of 25 by providing inundation of freshwater for the length of one tidal cycle (6.2 hrs.) for a period of at least 30 days. Since vegetative cover responds optimally to lowered salinities during the spring and early summer, freshwater releases during these seasons are clearly most beneficial to the Nueces Deltaic marsh ecosystem.

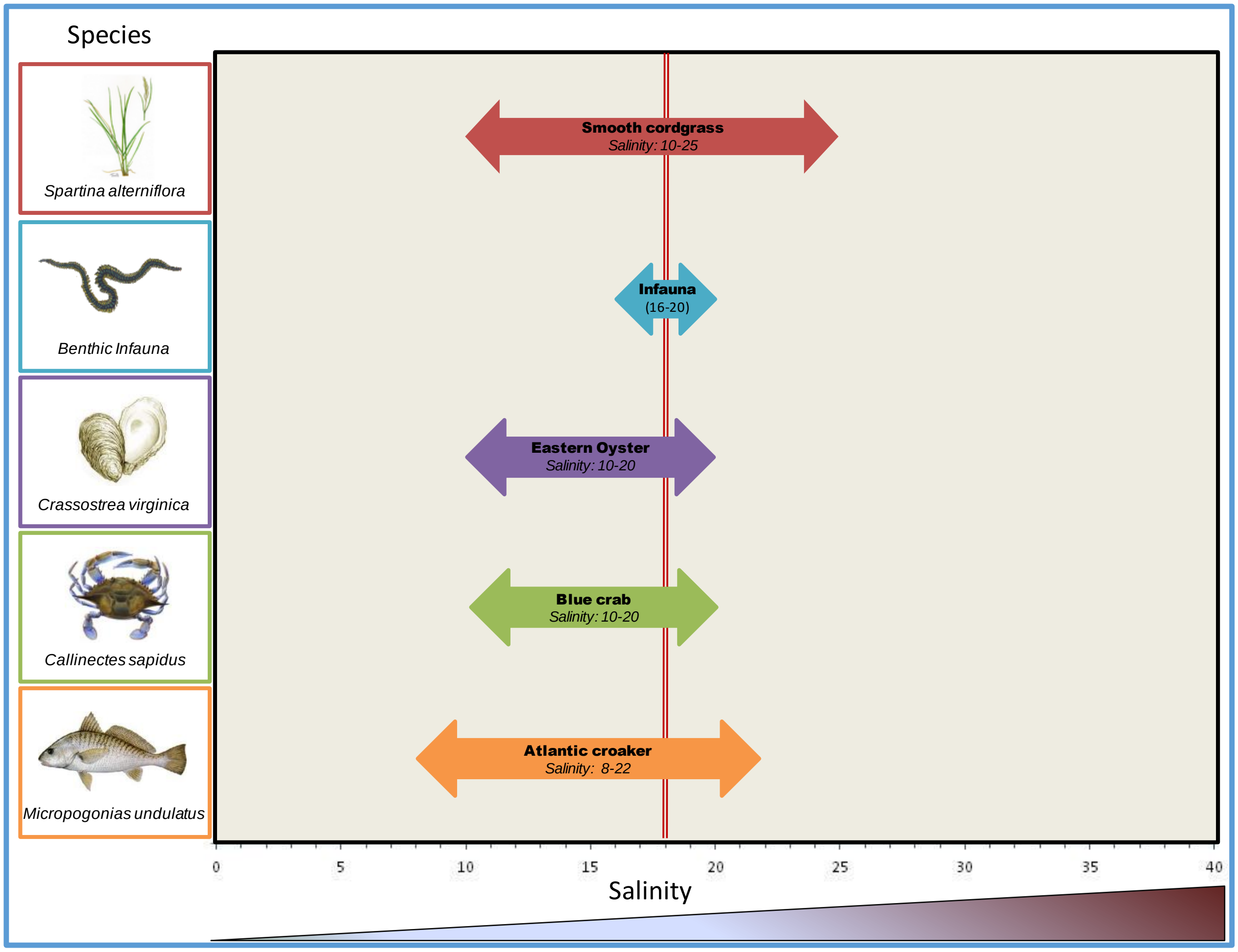


Figure 2.3.5-2: Indicator species profile showing salinity preferences in Nueces Delta and Nueces Bay (from BBEST, 2011)

3. Results and Discussion

3.1 Identification and evaluation of proposed projects

3.1.1 Initial set of projects proposed by project team

Based on the literature review and synthesis, plus the expert judgment of the project team, as expressed during a series of project team workshops, the following potential projects were identified for initial consideration: (*for more information on this process, see Section 7.2 - Appendix B for notes from these project team meetings*)

Table 3.1.1: Initial set of potential projects compiled by project team

Project #	Potential Project Title
1	***Upper Delta Nueces River to Rincon Bayou (RB) Diversion***
2	***Upper RB Diversion to high marsh/wetlands North of RB***
3	***East end of Upper RB control structure & diversion to South Lake area***
4	***Middle RB to South Lake Diversion***
5	***North Lake to South Lake system diversion***
6	***Lower Delta Nueces River Diversion***
7	***Diversion of Odem WWTP Discharge and Peters Swale Storm water***
8	***Restoration of Allison WWTP Discharge to South Lake***
Others:	***Nueces Delta Face/Nueces Bay Projects; Landform Modifications to create/improve habitat (not necessarily hydraulic modifications – i.e., modifying land surface elevations)***

Figures No. 3.1.1-1 through 3.1.1-8, below, provide maps of the general location of each of these initially proposed project concepts, with each map followed by a brief description of that proposed project.

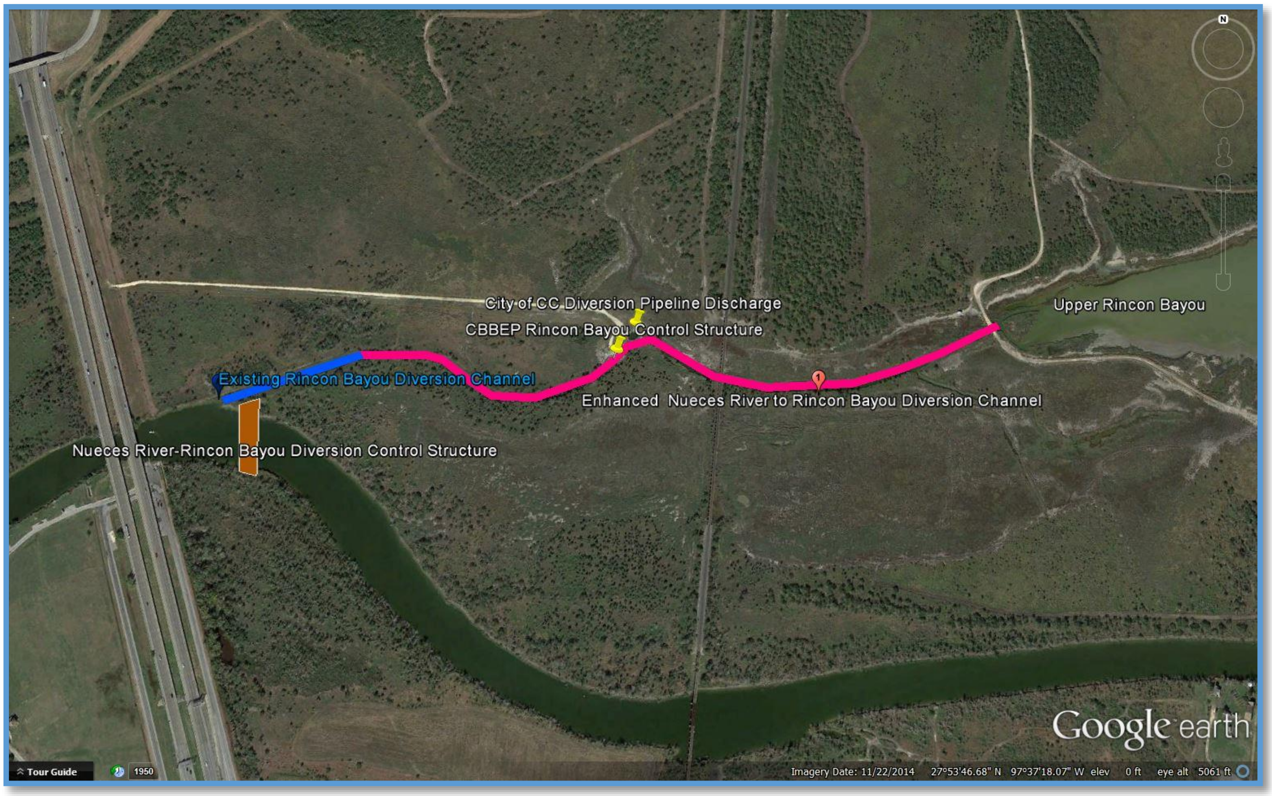


Figure 3.1.1-1: Project #1 -- Upper Delta Nueces River to Rincon Bayou Diversion.

This concept has been under consideration since the early planning studies on freshwater diversions and consists of a large weir structure within the channel of the Nueces River Tidal Segment, just below the Rincon Bayou Overflow Channel. The weir would be capable of regulating river surface elevations above that point such that the river level would exceed the overbanking threshold of the Rincon Bayou Overflow Channel and a large portion of the flow of the Nueces River Tidal Segment would be diverted through the overflow channel and into Rincon Bayou.

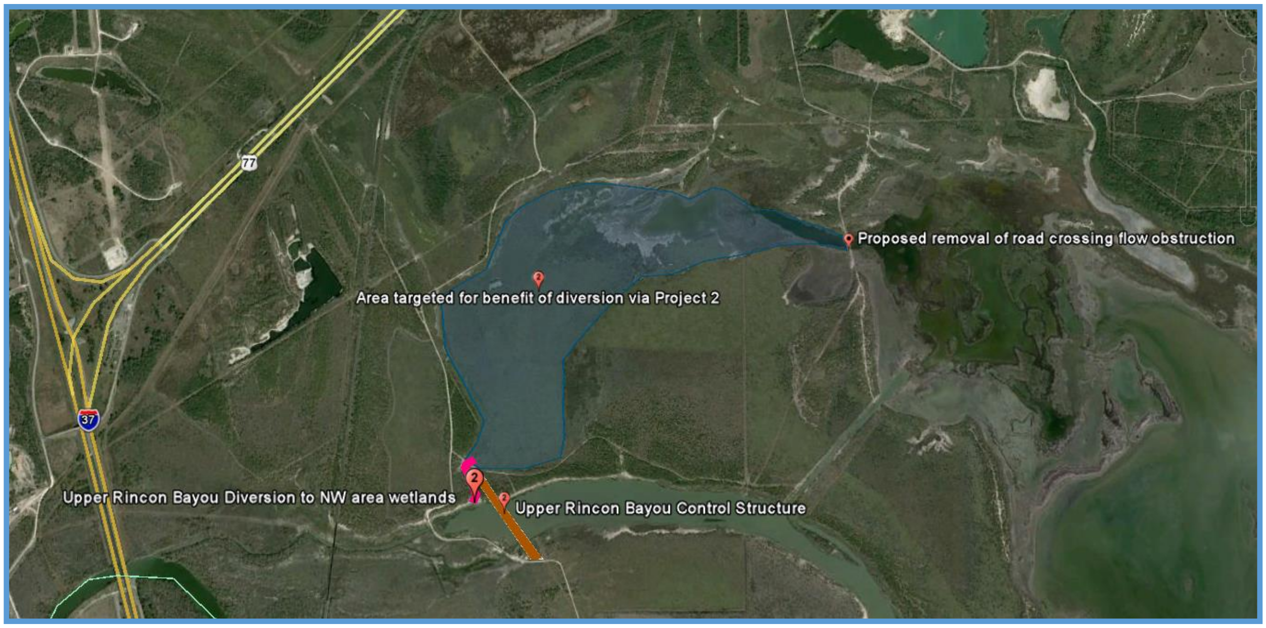


Figure 3.1.1-2: Project #2 -- Upper Rincon Bayou Diversion to High Marsh/Wetlands N. of Rincon Bayou

This proposed project was designed to increase diversions through an existing natural overflow channel connecting the west end of the Upper Rincon Bayou with an area to the north. Under flood flow conditions, water from Rincon Bayou will already flow through this channel and inundate several hundred acres of high marsh, then flow east, through a partially obstructed road culvert, into a wetlands area already connected to Rincon Bayou by the existing, but rarely functioning, Rincon Bayou Overflow Channel. By installing a water control structure just below the natural diversion point, and raising water surface elevations in the western most end of Upper Rincon Bayou, water would be a diverted to the north during low flow events which would not otherwise provide water to the high marsh and wetlands in this area.

Figure 3.1.1-3: Project #3 -- East end of Upper Rincon Bayou Diversion to South Lake Area

South Lake is a tidal lake connected to Upper Nueces Bay by a significant channel, but having no connection to the Rincon Bayou or the Nueces River Tidal Segment. South Lake is surrounded by a large area of wind tidal flats, inundated only at very high tide events. This proposed project was aimed at diverting water out of the eastern most end of Upper Rincon Bayou into the northwestern portion of the larger South Lake system, where it was anticipated that it would travel through the tidal flats and into South Lake, then out the channel to Upper Nueces Bay.

Figure 3.1.1-4: Project #4 -- Middle Rincon Bayou Diversion to South Lake Area

As an alternative to Project #3, this proposed project would divert water out of the Middle Rincon Bayou via a channel directly into South Lake.

Figure 3.1.1-5: Project #5 -- North Lake Diversion to South Lake System

This proposed project would divert water from the North Lake area of Rincon Bayou into a wetlands complex bordering the north-east side of the South Lake "system," east of the railroad tracks crossing the mid-Delta area. The area targeted for the water diverted, via a new channel, from Rincon Bayou also contains some bare wind tidal flats and is relatively removed from tidal event exchanges occurring through the main channel from Upper Nueces Bay into South Lake.

Figure 3.1.1-6: Project #6 -- Lower Nueces River Diversion into Lower Delta

In high flow events, some portion of the flow in the lower part of the Nueces River Tidal Segment naturally diverts through existing tidal channels into the lower Nueces Delta, and then into Upper Nueces Bay. This project would have lowered the banks of the Nueces River at the entry point into existing channels and created the opportunity for these diversion events to occur more frequently and at lower river flow stages.

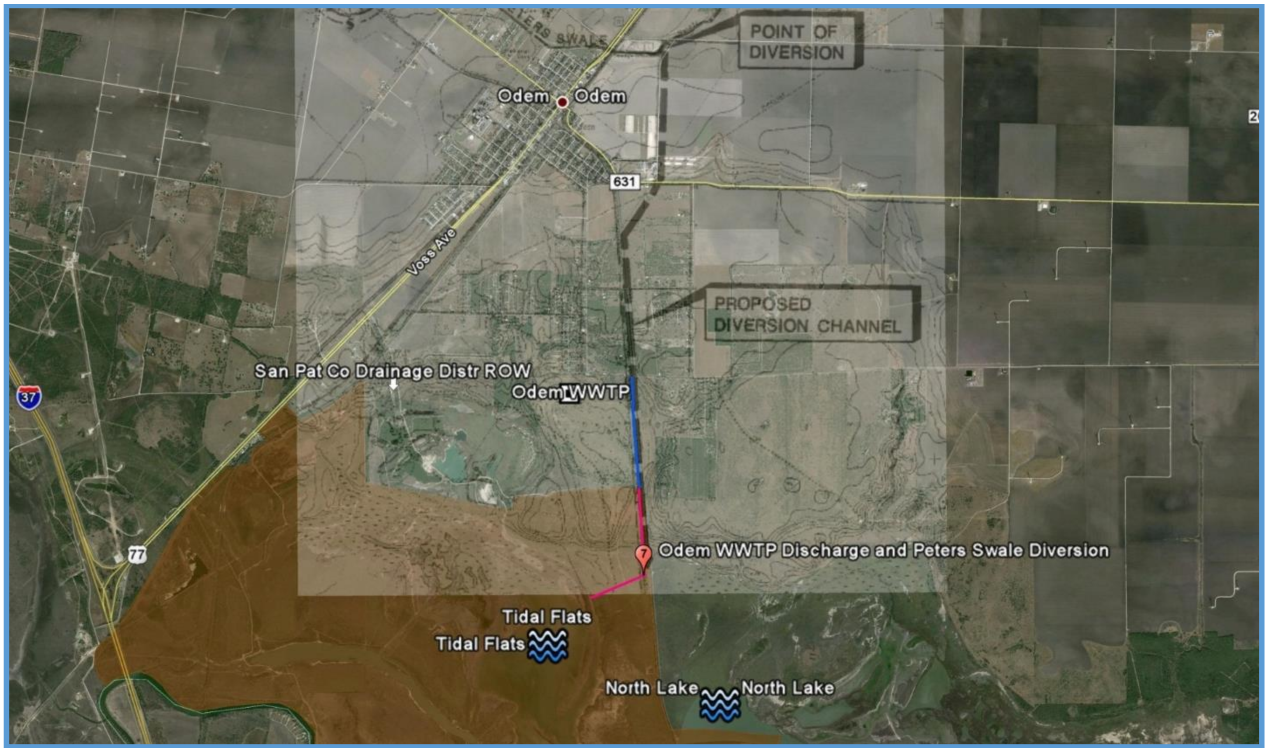


Figure 3.1.1-7: Project #7 -- Diversion of Odem WWTP Discharge & Peters Swale Storm water into Tidal Flats North of Rincon Bayou

This proposed project dates back to the 1993 report on Phase II of the Regional Wastewater Planning Study for the Nueces Estuary (HDR et al, 1993), which investigated "ways to more efficiently use river diversions and available wastewater effluent to meet estuarine needs." The Texas Water Development Board, under the Regional Wastewater Planning Grant program, partnered with a number of regional entities to fund this study which recommended several river and wastewater diversion demonstration projects and evaluated their potential impacts on the yield of the Choke Canyon/Lake Corpus Christi reservoir system. At the time of the study, the Odem Wastewater Treatment Plant (WWTP) was located on the northeast side of Odem, and the plant's effluent was discharged into Peters Swale, which was a storm water drainage channel discharging into Chiltipin Creek, and then ultimately into the Copano/Aransas Bay system. The idea was to divert both the wastewater effluent and any available storm water across the "basin" divide and into the Nueces Delta.

However, since the 1993 Phase II report was issued, the City of Odem constructed a new WWTP at a location south of Odem. The effluent from this new facility (estimated at an average flow of 0.25 MGD) now discharges into a storm water channel draining south, along the west side of the railroad track right-of-way crossing the middle of the Nueces Delta. The WWTP discharge does not, apparently, flow all the way to the wetlands areas fringing the tidal flats to the north of Rincon Bayou. The proposed project would, via either a channel or pipeline, convey the effluent across a high point between its current "terminus" and discharge this freshwater into the wetland areas, and also convey any available storm water discharges along the same route.

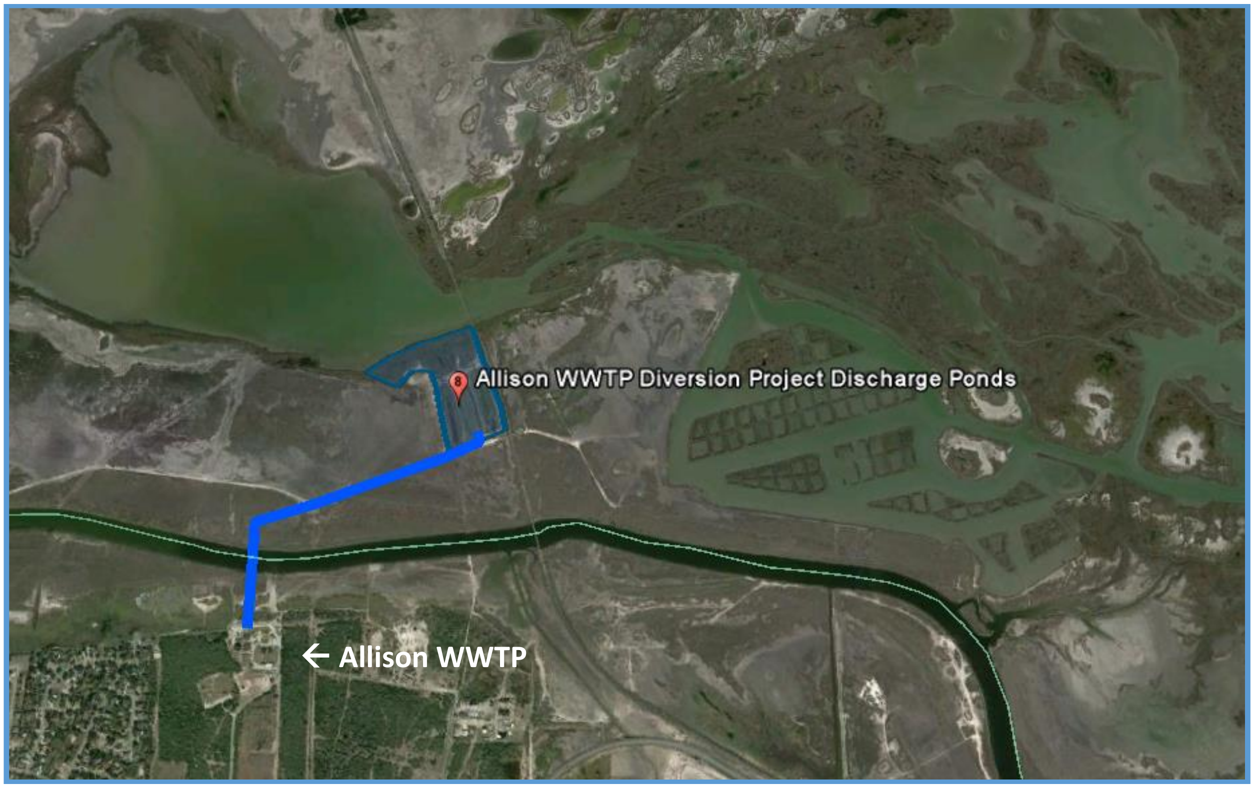


Figure 3.1.1-8: Project #8 -- Restoration of the Allison WWTP Discharge Diversion Demonstration Project

The Allison Wastewater Treatment Plant Discharge Diversion Demonstration Project was recommended in the 1993 Phase II Regional Wastewater Planning Study and later designed, permitted, constructed and operated by the City of Corpus Christi. The background and history of the project is documented in Section 2.1.4, above. While not technically a new project, the restoration of the original wastewater discharge into the project location on the south banks of South Lake in the Nueces Delta has been an issue since changes in the EPA/TCEQ permit conditions for ammonia (NH_3) caused the City to halt the discharge diversion demonstration project in 2010 in order to maintain compliance with the facility's NPDES permit.

Stakeholders supporting the resumption of this demonstration project have "lobbied" for exceptions to the Allison WWTP's NPDES permit conditions so the project could be resumed, but no headway has been made in the several years this effort has been underway.

Other Potential Projects Initially Proposed

The project team also considered, and included as a general category on the list of proposed projects, several other concepts which have been discussed over the years and which would involve landform and/or hydraulic modifications within the Nueces Delta/Bay system. These included, among others, the idea of the "beneficial use" of material dredged from the Corpus Christi Ship Channel and Inner Harbor to create landforms within the Upper Nueces Bay area in order to increase emergent marsh habitat and to reduce wind wave energy which contributes to the erosion of important wetlands along the face of the Nueces Delta.

3.1.2 Prioritization of Potential Projects: Role of Stakeholder "Charrettes"

The NEAC meeting on the afternoon of February 23, 2015, held at the "Choke Canyon Conference Room" in the City of Corpus Christi's Water Utilities Office, provided the first opportunity for the project team to hold a planning "*charrette,*" a collaborative session intended to facilitate consultation between stakeholders and the "design team" on initial elements of the proposed plan. On the evening of March 9, 2015, the project team conducted a second *charrette* in association with a CBBF public forum held at the Port of Corpus Christi's Congressman Solomon P. Ortiz International Center. **(*See Sect. 7.1 – Appendix A for copies of the slide presentations made at each of these meetings.*)**

Figure 3.1.2-1: Stakeholders participating in the project charrette at the Coastal Bend Bays Foundation's "Public Issues Forum" on March 3, 2015

After considering comments from stakeholders received during and subsequent to the two *charrettes*, and reviewing additional information which was provided during follow-up discussions between some stakeholders and the project team, the project team met to consider which of the potential project should be selected for additional modeling and analysis.

After further review of results of the initial modeling of six (6) of the eight (8) proposed potential projects, the project team determined that several of the projects appeared not to provide much additional benefit in terms of new acreages inundated or salinity reductions, and should therefore be eliminated. The results indicated that the projects proposed for the Middle Rincon Bayou area appeared to produce greater benefits than those proposed for the Upper Rincon Bayou area.

Additionally, of the two proposed wastewater diversion projects under consideration, it was noted that the Allison WWTP diversion demonstration project is already constructed and capable of delivering freshwater effluents to the Nueces Delta – if regulatory obstacles can be overcome -- but the proposed diversion of the Odem WWTP effluent would be a new source of freshwater available for a portion of the upper Nueces Delta which is often extremely hypersaline.

The project team also determined that the proposed projects involving large-scale land form modifications to the Upper Nueces Bay/Nueces Delta Face area would be difficult to evaluate on a level comparable to the potential hydraulic modifications which could be accomplished within the Middle Rincon Bayou area.

The project team therefore decided that the list of potential projects would be narrowed down to three projects for further analysis: two channels to divert water from Rincon Bayou into adjacent wetland areas, and a wastewater effluent and stormwater discharge diversion. (*See Table 3.1.2 and the map*, *Figure 3.1.2*, *below*.)

Table 3.1.2: List of Projects to be carried forward for further design and analysis

Project #	**Potential Project Title**
4	***Middle Rincon Bayou to South Lake Diversion***
5	***North Lake to South Lake System Diversion***
7	***Diversion of Odem WWTP Discharge and Peters Swale Storm water***

These three projects were carried forward for further conceptual design and additional modeling analysis.

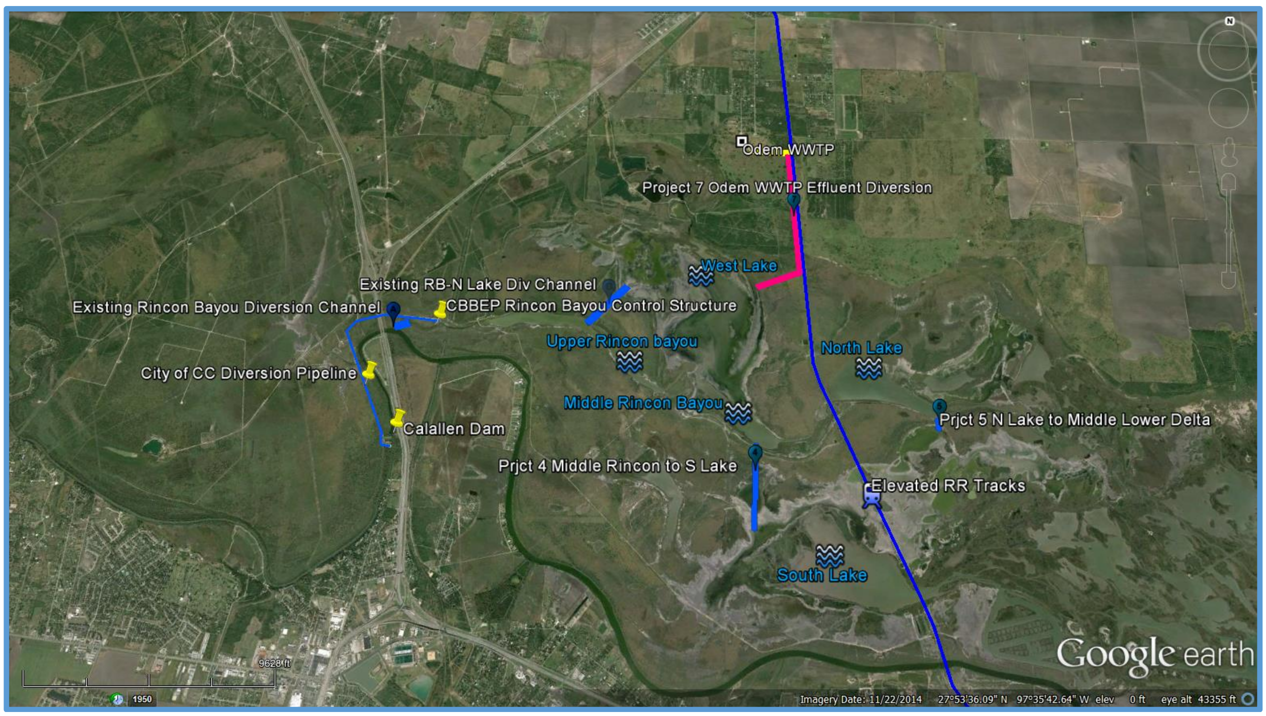


Figure 3.1.2-2: Location of the three potential projects subject to additional evaluation, including hydrodynamic modeling of the two proposed channel features

3.1.3 Using the Nueces Delta Hydrodynamic Model to quantify changes in the area of freshwater distribution, depth and duration of inundation, and achievement of salinity targets resulting from the two proposed channel

A series of NDHM runs were made in order to measure, as compared to the baseline (system as it is currently), the changes the installation of both of the two proposed diversion channels would make in several ecologically important parameters: the area of freshwater distribution, and the achievement of targets for the depth and duration of inundation, and salinity. Water was pumped from the Calallen Pool and discharged into Upper Rincon Bayou via the City of Corpus Christi's Diversion Pipeline. For all model runs:

- All pumping was assumed to be using only one of the two pumps available
- Model ran for a 30-day duration in each simulation
- The CBBEP Control Structure on Rincon Bayou above the pipeline discharge point would remain closed for the entire simulation period
- Volumes of 1,200 ac-ft. and 3,000 ac-ft. were modeled
- 1,200 ac-ft. represents drought period monthly target per the Agreed Order on FW Inflows
- 3,000 ac-ft. represents the maximum physical delivery capacity for one pump in a 30 day period
- The wind and tidal conditions were based upon TCOON data from August 7 through September 6, 2012
- The salinity boundary condition for Nueces Bay was set at a constant 35
- The salinity initial condition was 35 throughout the delta and bay
- Precipitation during the modeled period was neglected
- The models did not include temperature effects, evaporation, transpiration, or porewater exchanges that affect salinity.

Model runs were made comparing baseline (existing system) conditions to the conditions achieved with the addition of two channels, one connecting the middle Rincon with South Lake and the other connecting the downstream end of North Lake with the southern saltmarsh region.

Results from models were processed to find areas that obtain minimum depths of 1.0 cm for at least 6.2 hours, corresponding to a typical tidal flooding period. The data were analyzed for salinities less than 25 and less than 15, to see how different salinity levels are affected.

Figures below show the different periods of inundation for salinities less than 25 expected for 1,200 ac-ft. and 3,000 ac-ft., respectively <u>for the existing system</u>. Note that other areas are flooded in the delta, but do not show up in the figures as the salinities are higher than 25, the depths are smaller than 1 cm, or the duration of inundation is less than 6.2 hours.

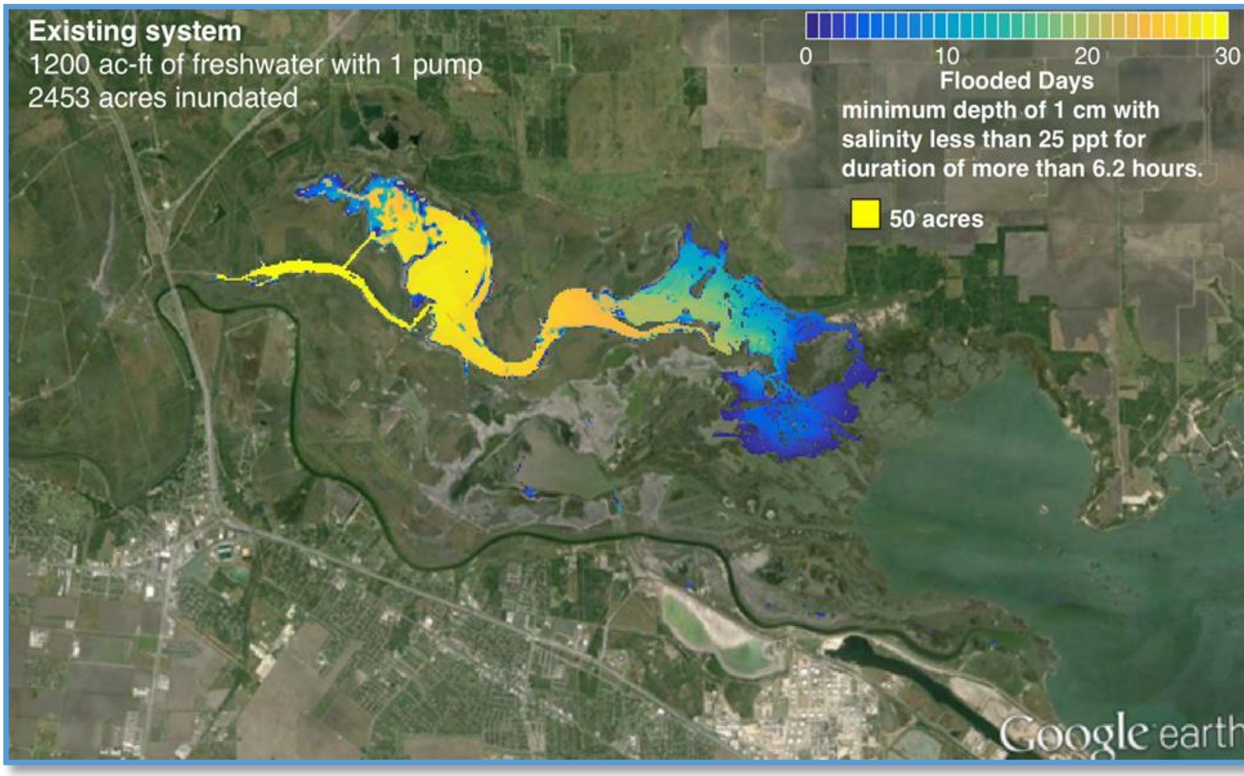


Figure 3.1.3-1: Baseline Condition 1 | 1,200 ac-ft. pumped

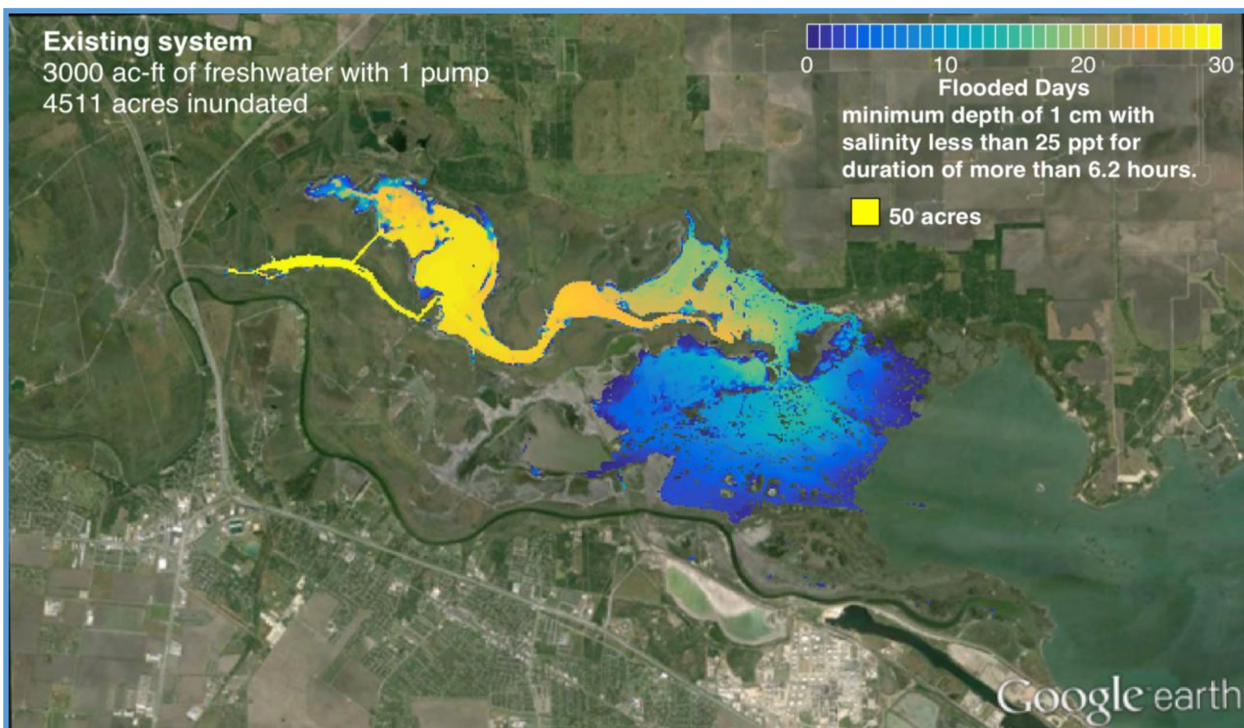


Figure 3.1.3-2: Baseline Condition 2 | 3,000 ac-ft. pumped

Similar figures (3.1.3-3 and 3.1.3-4) for the addition of the two channels illustrate the effects of Projects 4 and 5 are shown below.

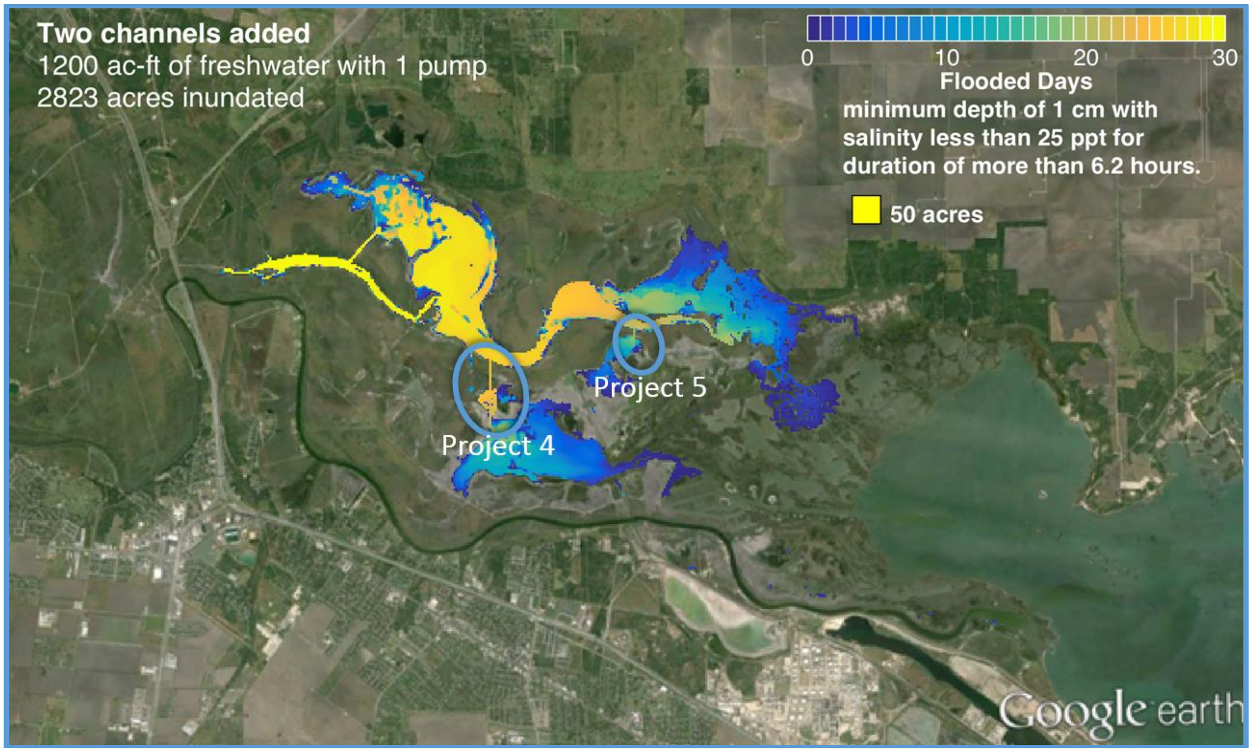


Figure 3.1.3-3: Modified System (Projects 4 & 5): 1,200 ac-ft. pumped

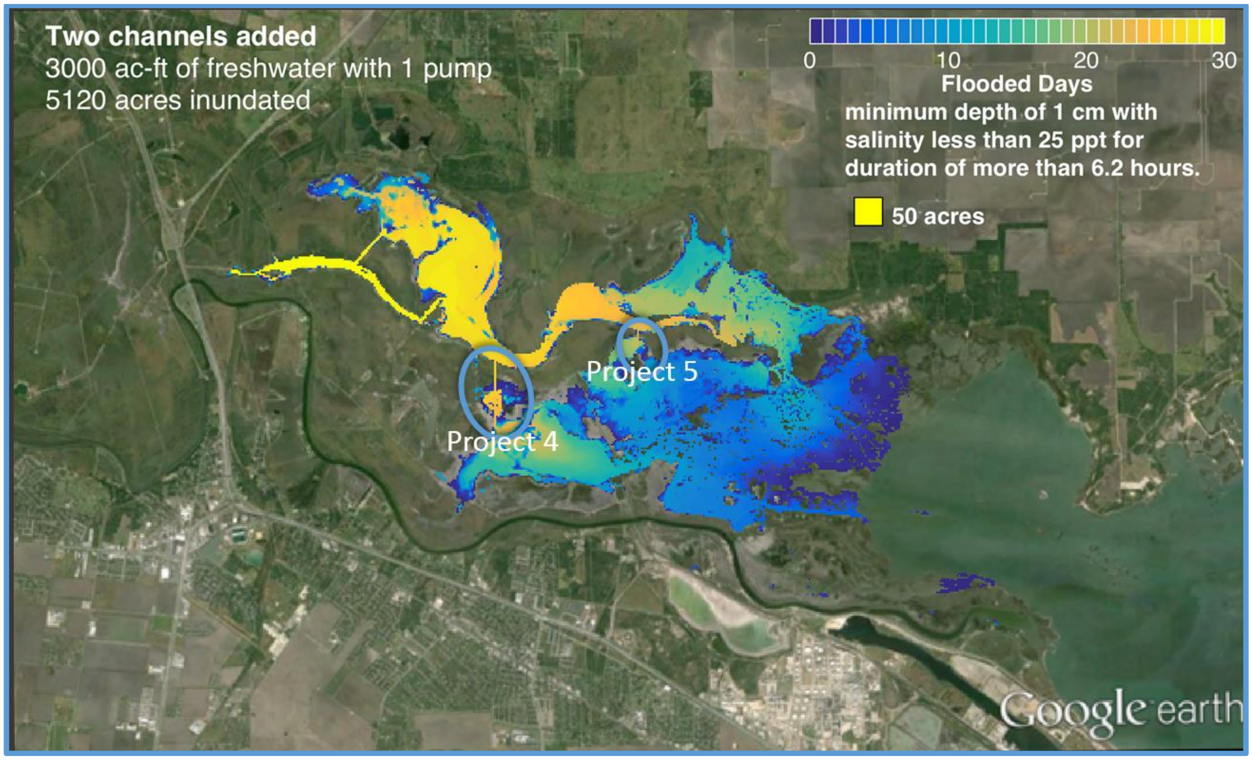
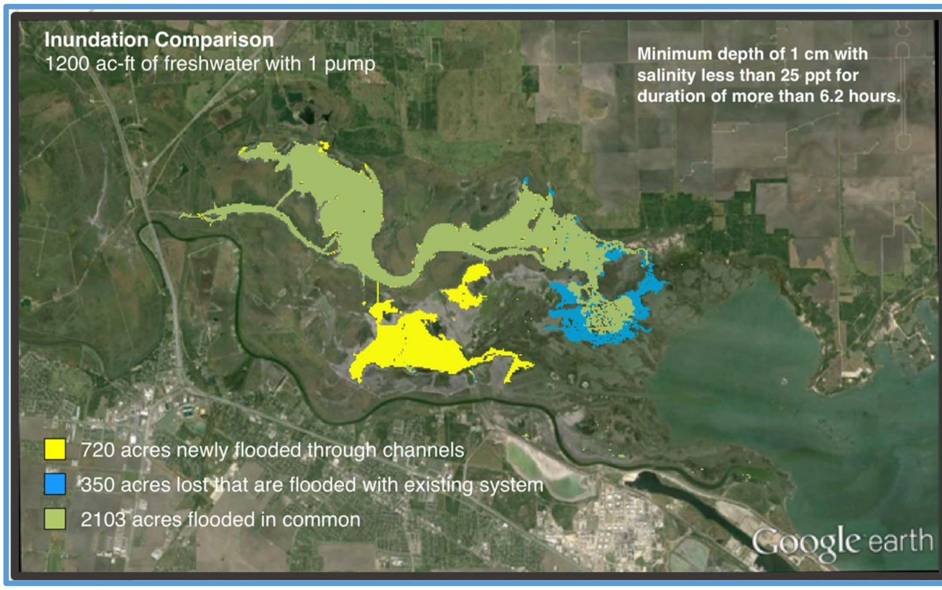


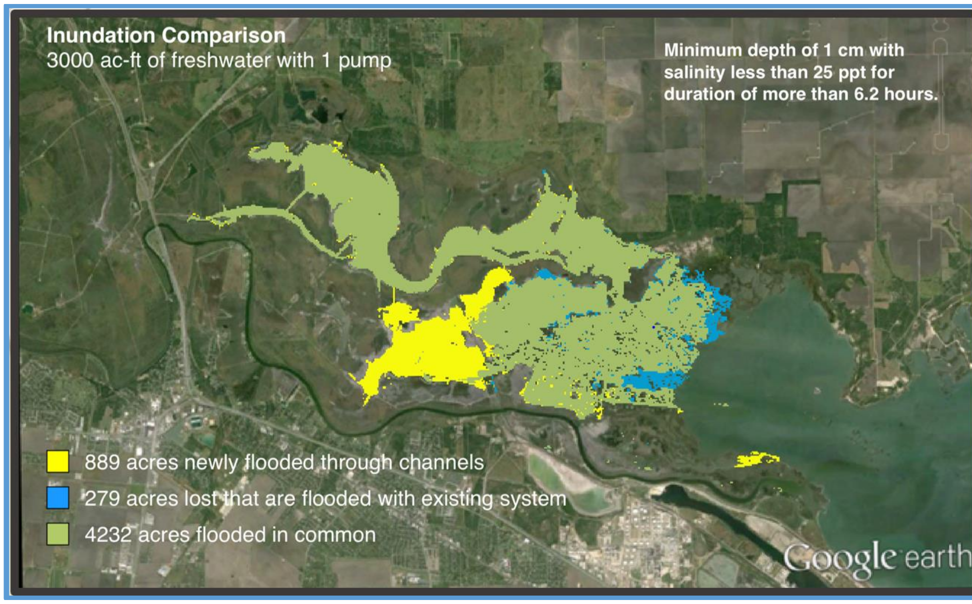
Figure 3.1.3-4: Modified System (Projects 4 & 5): 3,000 ac-ft. pumped

It is convenient to compare the overall inundation based on (1) common areas flooded both in the existing system and with the new channels, (2) new areas that would be flooded with the addition of the channels, and (3) areas that are flooded in the existing system, but are lost with addition of the new channels. These are shown below for salinities below 25.



New acres:	720 ac
Lost acres:	350 ac
Acres in common with Existing System:	2,103 ac
Net Addition:	370 ac

Figure 3.1.3-5: Modified System (Projects 4 & 5): 1,200 ac-ft. pumped Inundation Comparison with Baseline - for areas with salinity less than 25.



New acres:	889 ac
Lost acres:	279 ac
Acres in common with Existing System:	4,323 ac
Net Addition:	610 ac

Figure 3.1.3-6: Modified System (Projects 4 & 5): 3,000 ac-ft. pumped Inundation Comparison with Baseline - for areas with salinity less than 25.

For salinities lower than 25 there is a substantial improvement of acreage covered with the addition of the channels. These are in the range of 13%-15% increase in acreage inundated at 25 or less. However, when looking at inundation for lower salinities cutoffs, a different story emerges. At both 1,200 and 3,000 ac-ft. of pumping, the area with salinities lower than 15 is actually reduced by inclusion of the new channels, as shown below (Figures 3.1.3-7 and 3.1.3-8). Here we see 13% and 4% reductions, in the 1,200 ac-ft and 3,000 ac-ft. cases, respectively.

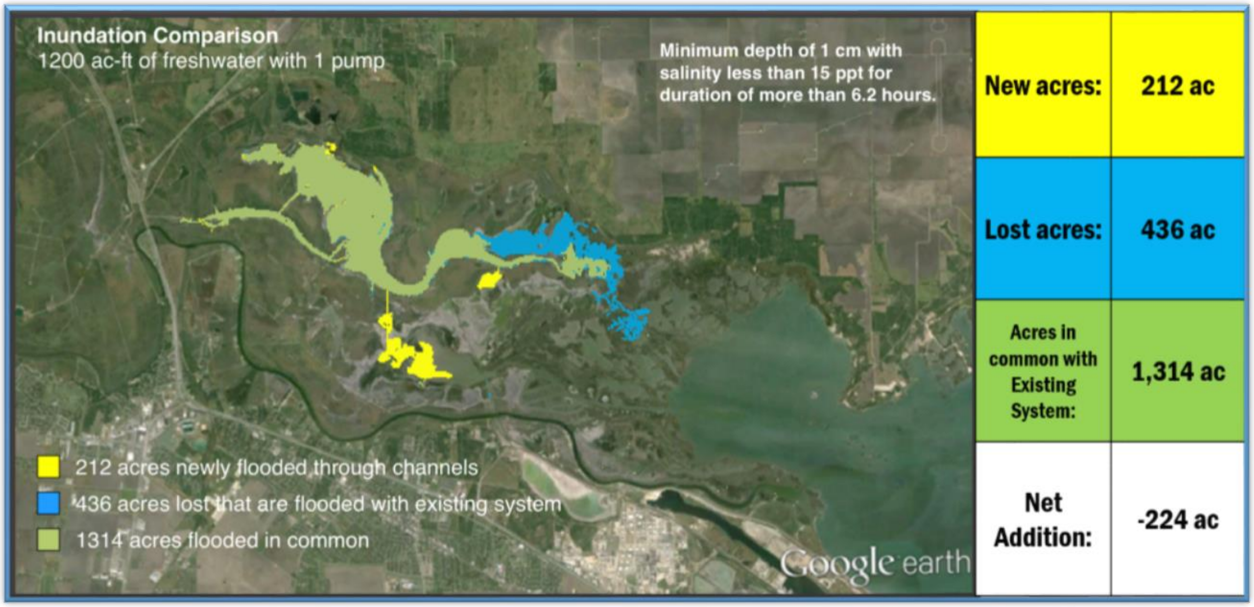


Figure 3.1.3-7: Modified System (Projects 4 & 5): 1,200 ac-ft. pumped Inundation Comparison with Baseline - for areas with salinity less than 15.

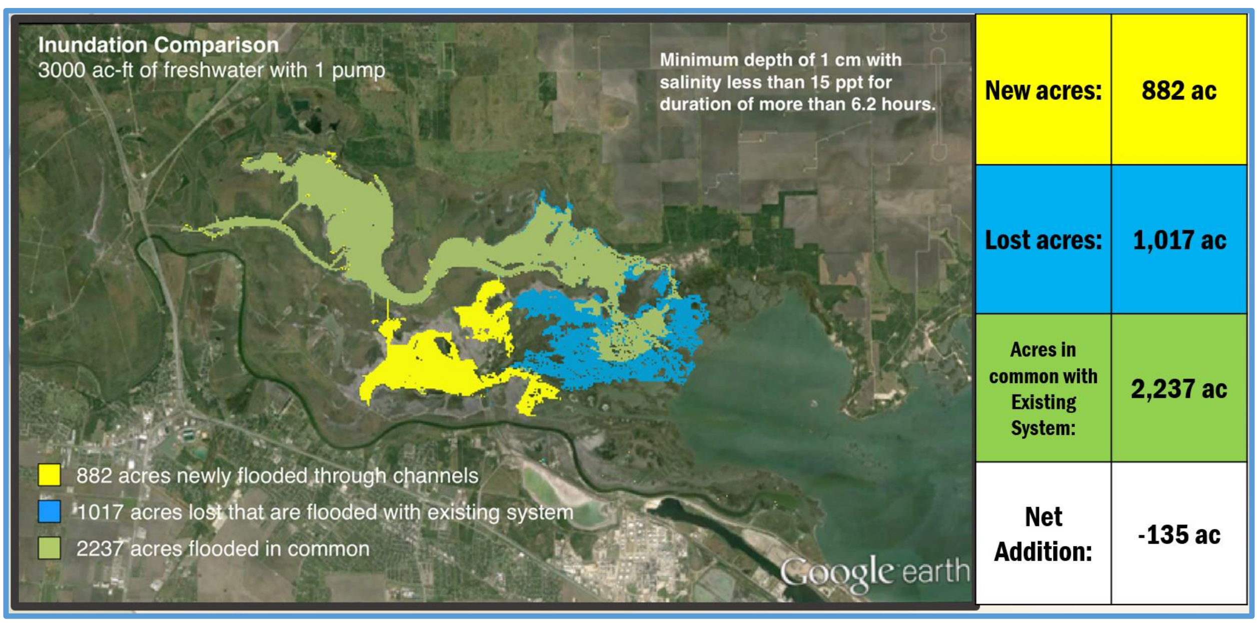


Figure 3.1.3-8: Modified System (Projects 4 & 5): | 3,000 ac-ft. pumped Inundation Comparison with Baseline - for areas with salinity less than 15.

We can also look at salinities lower than 20, where the comparison provides a 7% reduction at 1,200 ac-ft. (Figure 3.1.3-9), but a 7% increase at 3,000 ac-ft. (Figure 3.1.3-10).

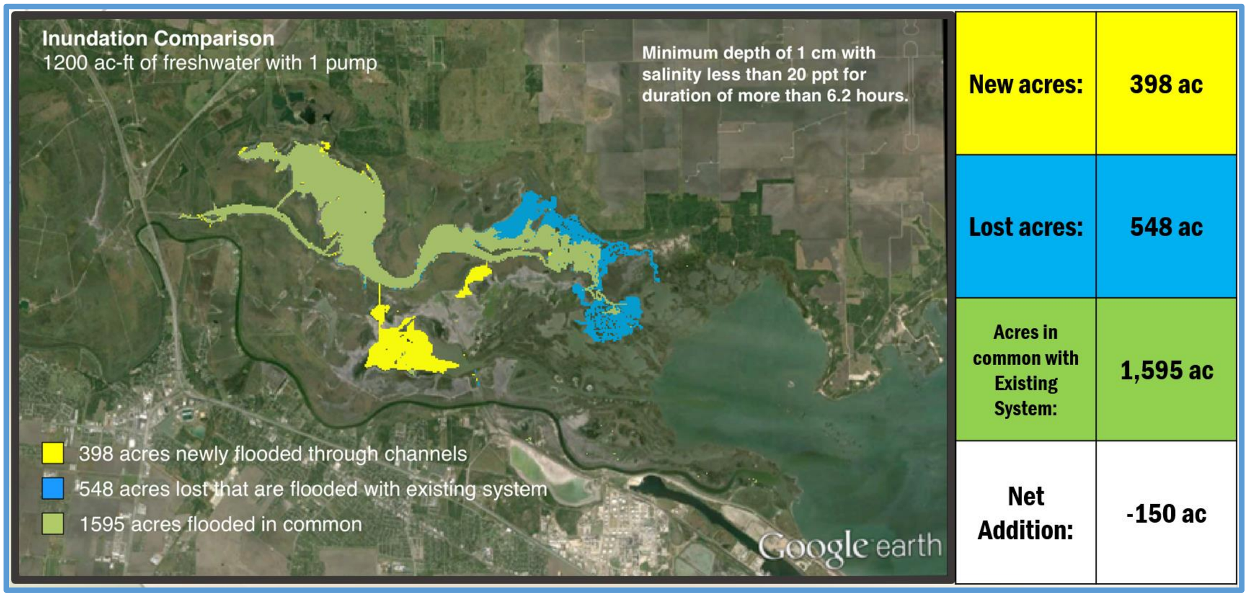


Figure 3.1.3-9: Modified System (Projects 4 & 5): | 1,200 ac-ft. pumped Inundation Comparison with Baseline - for areas with salinity less than 20.

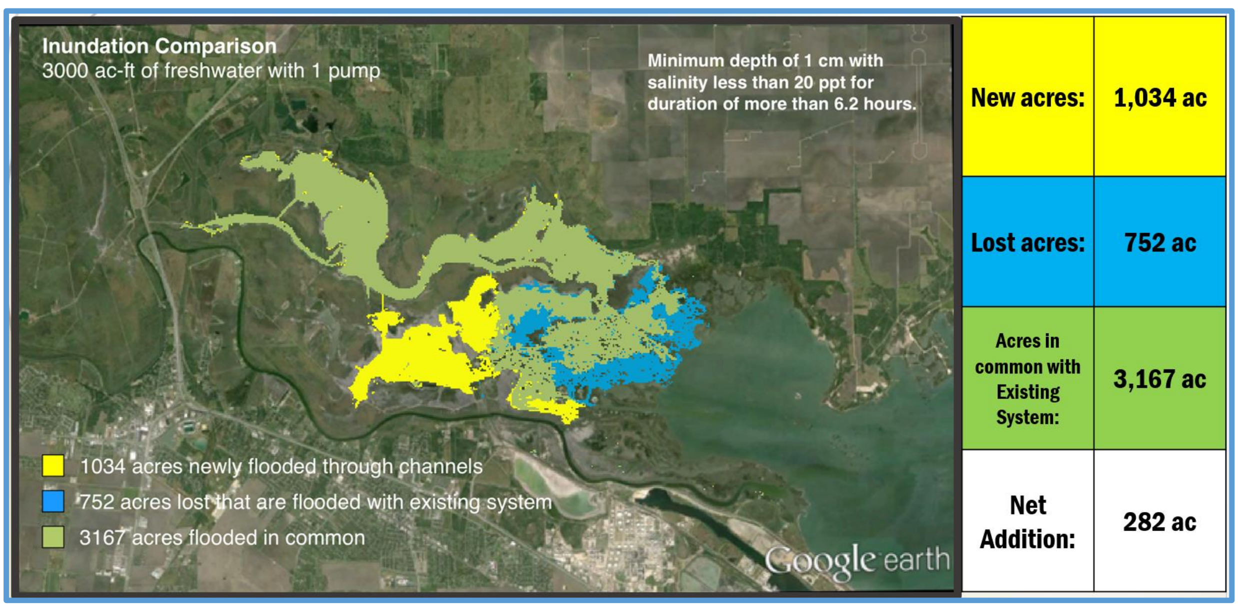


Figure 3.1.3-10: Modified System (Projects 4 & 5): 3,000 ac-ft. pumped Inundation Comparison with Baseline - for areas with salinity less than 20.

The simple inclusion of the channels is effective in increasing the area flooded with 20-25 salinity, but at the expense of reducing some of areas that with salinities less than 15 (Table 3.1.3).

Table 3.1.3: Modified System (Projects 4 & 5) | Summary of Results for Varying Salinity Criteria and Volumes Pumped

Salinity Criteria:	< 25		< 20		< 15	
Ac-ft pumped:	1,200	3,000	1,200	3,000	1,200	3,000
New Acres:	720	889	398	1,034	212	882
Lost Acres:	350	279	548	752	436	1,017
Acres in Common w/ Existing System:	2,103	4,323	1,595	3,167	1,314	2,237
Net Addition:	370	610	-150	282	-224	-135

Evaluating Real-World Salinity Effects

In the modeling studies discussed above, the inflow salinities were fixed at 35 for Nueces Bay and 0 for the Rincon Pipeline inflow with initial conditions of 35 throughout. Thus, all the modeled freshwater is entirely from the pumping system and not from either initial conditions or precipitation. Thus, another way to interpret the model results is in terms of dilution of the background values rather than salinity per se; i.e. salinities less than 25 corresponds to dilutions of at least 29%, less than 20 are dilutions of at least 43%, and less than 15 are dilutions of at least 57%.

These dilutions can be used to help evaluate the effects of missing transpiration and evaporation data. For example, if evaporation/transpiration causes the salinity throughout the delta to rise to 40 (loss of 12.5% of the freshwater), then the 29%, 43% and 57% dilutions in the model (i.e. the 25, 20, and 15 criteria in Table 3.1.3) would correspond to 28, 23, and 17 salinities. Thus, we can extend the present modeling to provide some insight as to how the system would be affected by salinities higher than used herein.

The model results above are also only applicable to the tested conditions – i.e. the higher secular tides typically seen in August of each year, which are similar to higher tides in April and May (see Ward, 1997, Fig. 2-15). The highest tides (late September and October) and the lowest tides (January and July) can be expected to have different behaviors. A further confounding factor is the wind, which substantially affects the upstream propagation of salt water. During summer the winds are reliably from the south by southeast, but tend to be northerly during winter months, which alters the interaction between wind and tide.

The modeling work herein is a preliminary screening tool to evaluate whether any projects *could* have an impact; i.e. if none of the projects substantially affected the freshwater distribution, this would have shown up clearly in the model results. However, proving a project is beneficial under the tested conditions cannot be simply extrapolated to other conditions. Evaluating which projects would have a greater impact on a year-round basis requires further study.

In Li and Hodges (2015) companion study, simulations were conducted (without any of the potential projects), over a wide range of wind, tide, and freshwater pumping conditions. These simulations revealed complexity in the relationships between these variables that could not be reduced to simple rules. There appears to be a critical dependency on whether the freshwater is being pumped on the rising limb of the secular tide, or the declining limb. The effect of the wind was clearly important, but varied in ways that could not be reduced to simple relationships from the simulations conducted. We believe that the timing of wind shifts relative to the timing of the freshwater pumping and secular tidal slope might play an important role. The key message is that the behaviors illustrated for the August case (herein) cannot be extrapolated to predictions of behavior in other months. Indeed, as the secular tide has annual variability (approx. 30 cm for August in Ward 1997, Fig. 2-15), the results of the simulations for August 2012 might not be applicable to years with substantially different tidal behavior.

Validation results indicate that the NDHM tends to underpredict long-term salinities affected by evaporation, transpiration, and porewater fluxes occurring within the delta, which is consistent with the model lacking algorithms for these phenomena. The model correctly predicts shorter-term salinities that are controlled by salt transport from the boundaries rather than in situ processes. The salinity patterns presented herein are best considered as screening tools to evaluate the differences between the baseline and the projects to better understand which projects have the most potential. To fully evaluate the annual performance of any project requires simulations for a range of typical conditions in the delta. *We would therefore caution against using the model results herein as the sole arbiter of which projects should be implemented.*

3.1.4 Evaluation of the Odem WWTP effluent discharge diversion into wetlands in the Nueces Delta West Lake area

The average daily flow of treated wastewater effluent currently being discharged by the Odem, Wastewater Treatment Plant (Odem WWTP) was included in the preliminary modeling along with the two pumping scenarios for pipeline deliveries into the Rincon Bayou. However, results of these initial model runs revealed that the effect of the 250,000 gallons per day (0.76 ac-ft/d; 0.25 MGD) diversion of the Odem WWTP effluent into West Lake could not be discerned in the model results (measured changes in area, depth and duration of inundation, and salinity) because of the much larger volumes of freshwater modeled as being pumped into Rincon Bayou and diverted through the two proposed diversion channels in a thirty (30) day period – 1,200 ac-ft (~13 MGD) or 3,000 ac-ft (~33 MGD).

Further evaluation of the diversion of the Odem WWTP effluent discharge relied on informed professional judgment, utilizing information gathered from the monitoring of the City of Corpus Christi’s Allison WWTP Effluent Discharge Diversion Demonstration Project. Alexander and Dunton (2006) and Hill et al (2011)) documented measurable increases in vegetative coverage and biomass, benthic diversity and community structure associated with the discharge of an average of 2.0 MGD of Allison WWTP effluent into the demonstration site as compared to a control site not receiving the effluent discharge. The effluent discharge into the three cells at the demonstration project site produced significant ecological benefits, particularly, as these ponds received a constant freshwater source during times of drought, which provided a refuge for birds and other wildlife.

Utilizing this information, the project team determined that diverting, on a regular basis, even the relatively small amount of effluent available from the Odem WWTP discharge into a suitable wetlands site within the West Lake area of the Nueces Delta would produce a net increase in the productivity and ecological value of the target wetlands.

3.2 Conceptual design, implementation issues and cost estimates

3.2.1 Conceptual design of proposed freshwater diversion facilities

3.2.1.1 Conceptual design challenges common to all projects

There are several conceptual design challenges that are common to all of the projects. These challenges are addressed here together and are then subsequently detailed in the sections addressing the individual projects.

Each of the projects is in a remote location. This presents several challenges to the conceptual design. The first challenge is access for construction and operation. There are no existing public or private roadways allowing access to the proposed project locations. In addition, the project locations include wetlands and low uplands with unconsolidated and under-consolidated soils. Options available to access the project locations include constructing access roadways that can be traversed by conventional terrestrial vehicles, utilizing low earth pressure terrestrial or amphibious vehicles to reach the project location from existing available roadways, or utilizing a combination of aquatic, amphibious and terrestrial vehicles to reach the project location from existing navigable waterways. All of these options significantly affect project implementation costs. Constructing roadways to access the project locations will be difficult and expensive due to the long distances from existing roadways to the project locations, unfavorable soil conditions and permitting issues (wetlands and floodplain). Accessing the project locations using other types of vehicles (low earth pressure terrestrial/amphibious or aquatic/amphibious/terrestrial) significantly increases travel time and decreases payload capacity per trip, significantly increases the time (and therefore cost) of construction.

A second challenge is the availability of electrical power. Given the remote location of each project, the extension of electrical power would be difficult and expensive. For the basis of the conceptual design, electrical power for construction and operation of the proposed projects will be provided using mobile sources (e.g. converted vehicle power, mobile generators, etc.)

A third challenge is inundation. Given that all of the projects are located within a riverine and estuarine floodplain, they will experience periodic inundation from stream overbank flow or coastal tide surge. To address this challenge, all of the project elements must either be designed to withstand the inundation or be elevated above the inundation. This condition may restrict the ability of the projects to dispose of excess soil (i.e. “spoil”) in the proximity of the project and may require that any excess soil be removed outside of the floodplain area.

A fourth challenge is an exposed environment. All of the project locations are subject to wind, sun and both fresh and salt water exposures. To address this challenge, all of the project elements must be designed with materials that are resistant (to the extent feasible) to these exposures.

A final challenge is security. Given the remote locations, it is impractical for the projects to be manned. It may also be difficult to secure the projects with fencing or other access controls. Administrative controls (e.g. "No Trespassing" signage, etc.) may not prevent unauthorized access. To address this challenge, the project elements must either be unattractive targets for theft or vandalism or should be sufficiently robust to survive reasonably anticipated access.

3.2.1.2 Projects 4 -- Middle Rincon Bayou to South Lake Diversion -- and 5 -- North Lake (Rincon Bayou) to South Lake Diversion

The modeling of Project 4, the Middle Rincon Bayou to South Lake Diversion Channel, and Project 5, the North Lake (Rincon Bayou) to Middle Lower Delta Area Diversion Channel determined that these projects should be further considered for conceptual design. The next step was to refine the information used in the macro scale hydrodynamic modeling regarding the location and dimensions of the channels which would convey water out of Rincon Bayou and into the targeted receiving areas. Where possible, the refined conceptual design would minimize construction scope (and therefore costs) and conform to micro scale features such as localized topography and morphology. For conceptual design purposes, the preliminary alignments developed for the macro scale hydrodynamic model were superimposed onto available aerial and topographic mapping, and where appropriate, micro scale alternatives locations were considered. Information on the widths and depths of the existing natural and constructed features was obtained from available documentation. Where necessary, supplemental information on the dimensions of the existing natural channels and proposed constructed channels were determined using the measurement tools available within the Google Earth program.

Figure 3.2.1-1 Measurements of the width of Rincon Bayou – at two locations along the natural channel and the Rincon Bayou Overflow Channel

As illustrated in Figure 3.2.1-1, above, measurements of the width of Rincon Bayou at two locations where the natural channel is the narrowest indicates that it ranges from approximately 30 to 40 ft at a point between the discharge for the City of CC Diversion Pipeline and the road crossing at the W end of Upper Rincon Bayou to approximately 80 ft in the natural channel between Upper Rincon Bayou and Middle Rincon Bayou. Figure 3.2.1-2, below, illustrates cross section profiles of Rincon Bayou made just upstream of the Diversion Pipeline discharge point, indicating the relative channel depth (4 to 5 ft) at these points.

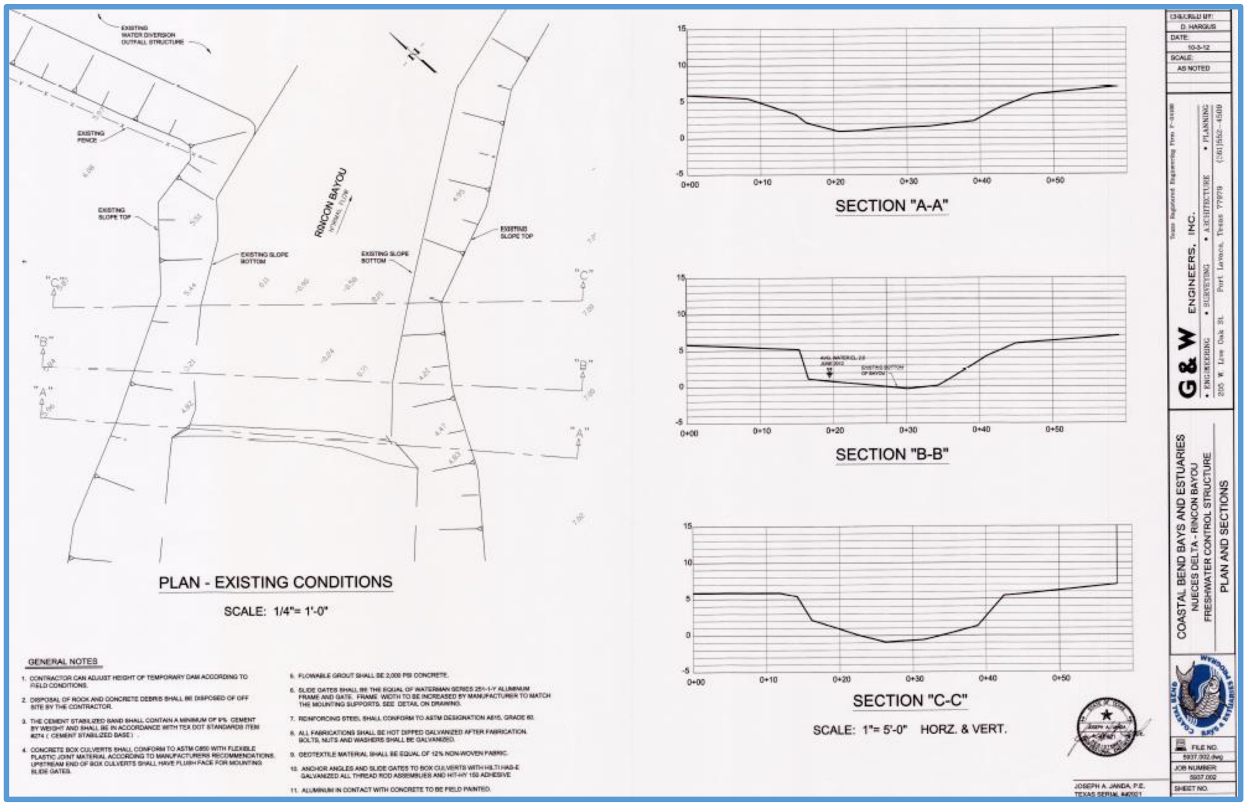


Figure 3.2.1-2 Cross-Sections and measurements of the width of Rincon Bayou prepared in association with the installation of the CBBEP water control structure (*illustration courtesy of CBBEP*)

At these widths and depths, Rincon Bayou downstream of the Diversion Pipeline discharge is capable of containing within its banks the full volume of the water discharged by the pipeline at the modeled pumping rate of 111 ac-ft/day.

Additional conceptual design information comes from the Rincon Bayou Overflow Channel, constructed by the U.S. Bureau of Reclamation as part of their Rincon Bayou Demonstration Project. The project report notes that the dimensions of the channel were *"approximately 610 m long and 30 m wide, with a bottom elevation of 1.22 m (4.0 ft) msl on the upstream (south) end and 0.91 m (3.0 ft) msl on the downstream (north) end."* (Bureau of Reclamation, 2000) This total 30 m (98 ft) channel width includes some side slopes, so the somewhat narrower bottom width is probably in the range of 60 to 80 ft.

While the natural channel along reaches of Rincon Bayou may provide an indication that a channel in the range of 30 to 40 ft in width can convey volumes of flows in the modeled range, the Rincon Bayou Overflow Channel is a good example of a man-made diversion channel which has been permitted and constructed within the Nueces Delta and will therefore be used as a conceptual design for the two channels which would be associated with the proposed Projects 4 and 5. Figure 3.2.1-3, below, illustrates a cross-section of this conceptual design. The actual depth will vary with the topography through which the channel is excavated, with the target bottom elevation being approximately mean sea level (msl), or 0.0 (NAVD88).

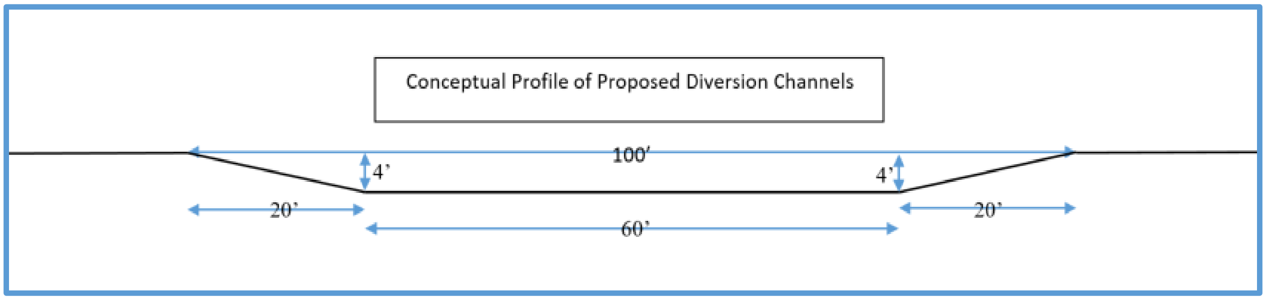


Figure 3.2.1-3 Conceptual cross-section profile of a diversion channel

The general locations of the diversion channels used in the hydrodynamic modeling of Projects 4 and 5 are shown in Figures 3.2.1-4 below, and 3.2.1-5, next page, which also illustrate the inundation effects of pumping 1,200 ac-ft and 3,000 ac-ft via the Diversion Pipeline over a 30-day period. A more detailed view of the proposed layout of the two diversion channels, and possible alternatives, is shown in Figure 3.2.1-6, next page.

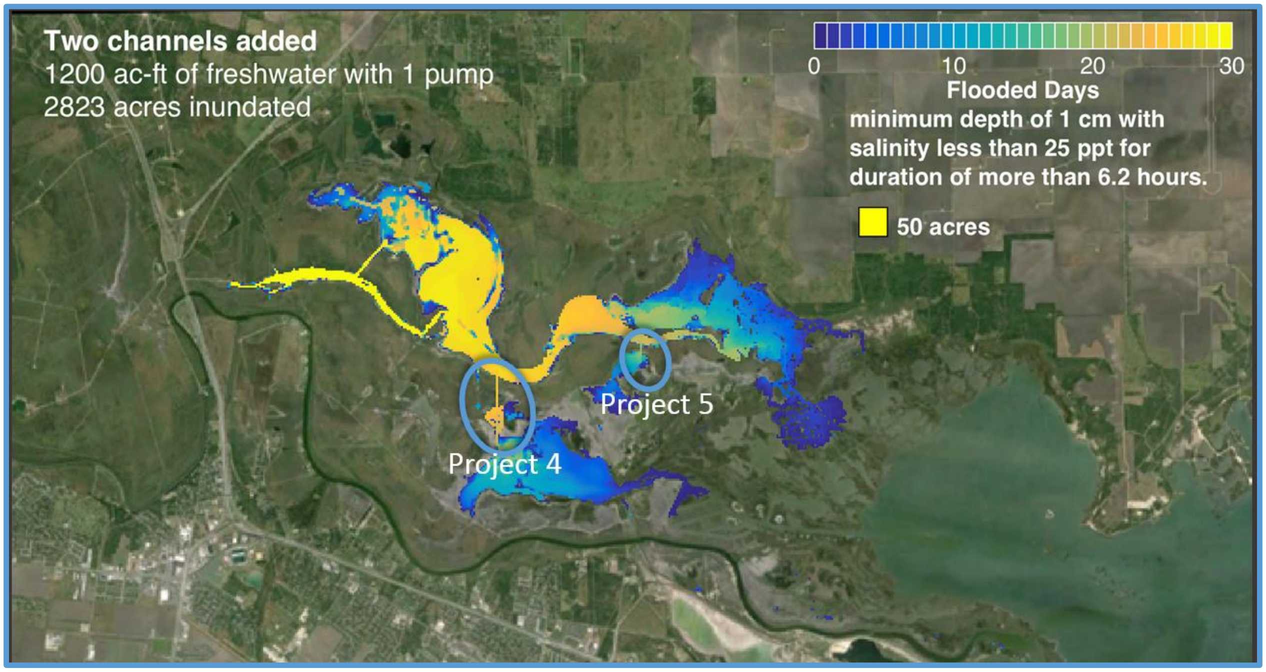


Figure 3.2.1-4 Projects 4 and 5: Areas inundated with 1,200 ac-ft pumping over 30 days

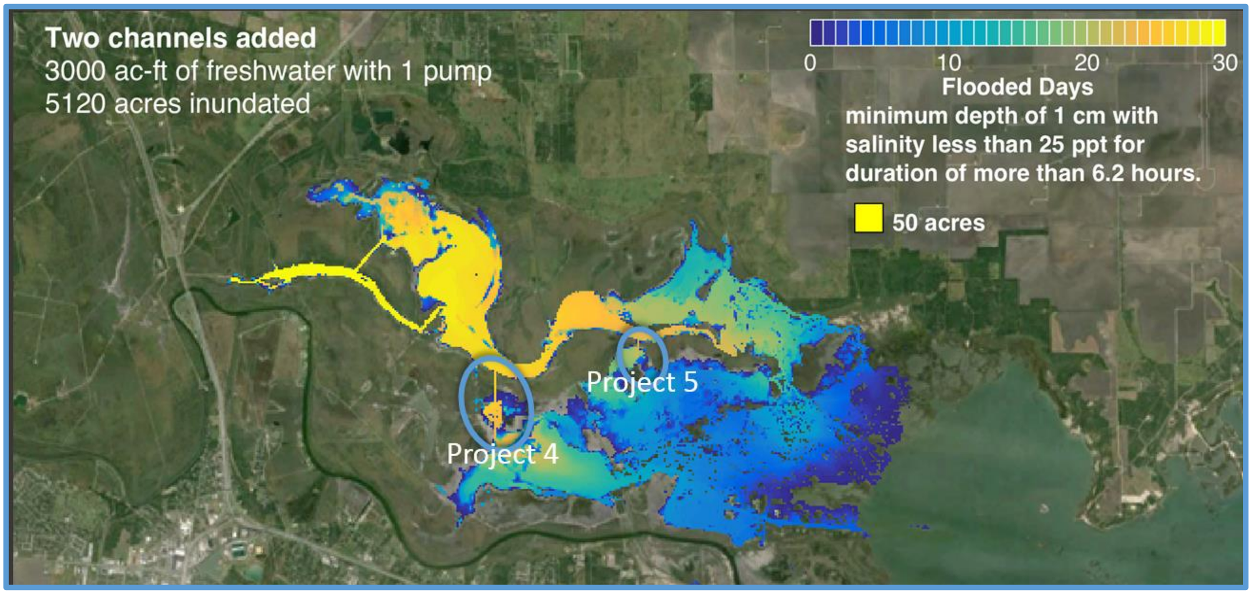


Figure 3.2.1-5 Projects 4 and 5: Areas inundated with 3,000 ac-ft pumping over 30 days

Figure 3.2.1-6 Projects 4 and 5: Proposed diversion channels, as modeled and alternate locations

The diversion channel modeled for Project 4 was approximately 3,600 ft long. Using the width identified in the conceptual profile (Figure 3.2.1-3) of 100 ft wide would yield a total surface area of approximately 360,000 ft^2, or 8.26 acres. The alternate diversion channel alignment for Project 4 (reflected on Figure 3.2.1-6) would be shorter (2,600 ft), and using the same width of 100 ft, would cover approximately 260,000 ft^2 or 5.97 acres.

A review of the available topographic mapping indicates that both the modeled and the alternative alignments for Project 4 will require excavation of approximately 1.5 to 4.0 ft of soil to construct the channel. For the conceptual design, an average excavation depth of 3 ft was used across the width of the channel section. This will require the excavation of approximately 1,080,000 cubic feet (ft^3) or 40,000 cubic yards (yd^3) of soil for the modeled alignment and approximately 780,000 ft^3 or 29,000 yd^3 of soil for the alternative alignment.

The diversion channel modeled for Project 5 was approximately 500 ft long and 100 ft wide, for a total area of 50,000 ft^2, or 1.15 acres. An alternate channel alignment for Project 5 would be slightly shorter (450 ft), and at a width of 100 ft would cover approximately 45,000 ft^2 or 1.03 acres.

A review of the available topographic mapping indicates that both the modeled and the alternative alignments for Project 5 will require excavation of approximately 1.5 to 4.0 ft of soil to construct the channel. For the conceptual design, an average excavation depth of 3 ft was used across the width of the channel section. This will require the excavation of approximately 150,000 ft^3 or 5,500 yd^3 of soil for the modeled alignment and approximately 135,000 ft^3 or 5,000 yd^3 of soil for the alternative alignment.

The conceptual design includes a water flow control device incorporated into each channel at the diversion point in order to allow greater opportunity to manage the water level in Rincon Bayou during the diversions and to prevent "backflow" into the Rincon Bayou during higher tide events. These water flow control devices would be constructed on the North end of each channel, on the South side of Rincon Bayou, in an area of higher elevation dividing Rincon Bayou from the tidal flats to the south. The devices used in the conceptual design were inflatable or water-filled "bladder dams," fabricated from elastomeric membranes. These devices were selected for the conceptual design because they are low-profile and the height of the bladder can be varied to control the depth of water behind the device and therefore the depth of the water column overflowing the device. These devices were also selected because of their relative ease of construction and operation. The devices are pre-fabricated and can be delivered to the installation site in a deflated condition. Once at the site, the devices can be installed using portable anchors and cables. The devices can be filled, and then subsequently controlled, using a portable pump. The devices would be placed across the bottom of the channel at the diversion point, with the ends extending onto the higher ground outside the bed of the channel, for a total length of approximately 150 feet. Examples of the proposed water flow control devices are shown in Figures 3.2.1-7 and 3.2.1-8, below, and Figure 3.2.1-9. Figures 3.2.1-10 and 3.2.1-11 show where control structures would be located on the channels.

Figure 3.2.1-7 Water filled bladder dam
(Photo: *http://www.damitdams.com/images/portfolio/rivercrossing/IMG_4435.jpg*)

Figure 3.2.1-8 Inflatable bladder dam (Photo: *http://ca.water.usgs.gov/user_projects/sonoma/sonomapics.html*)

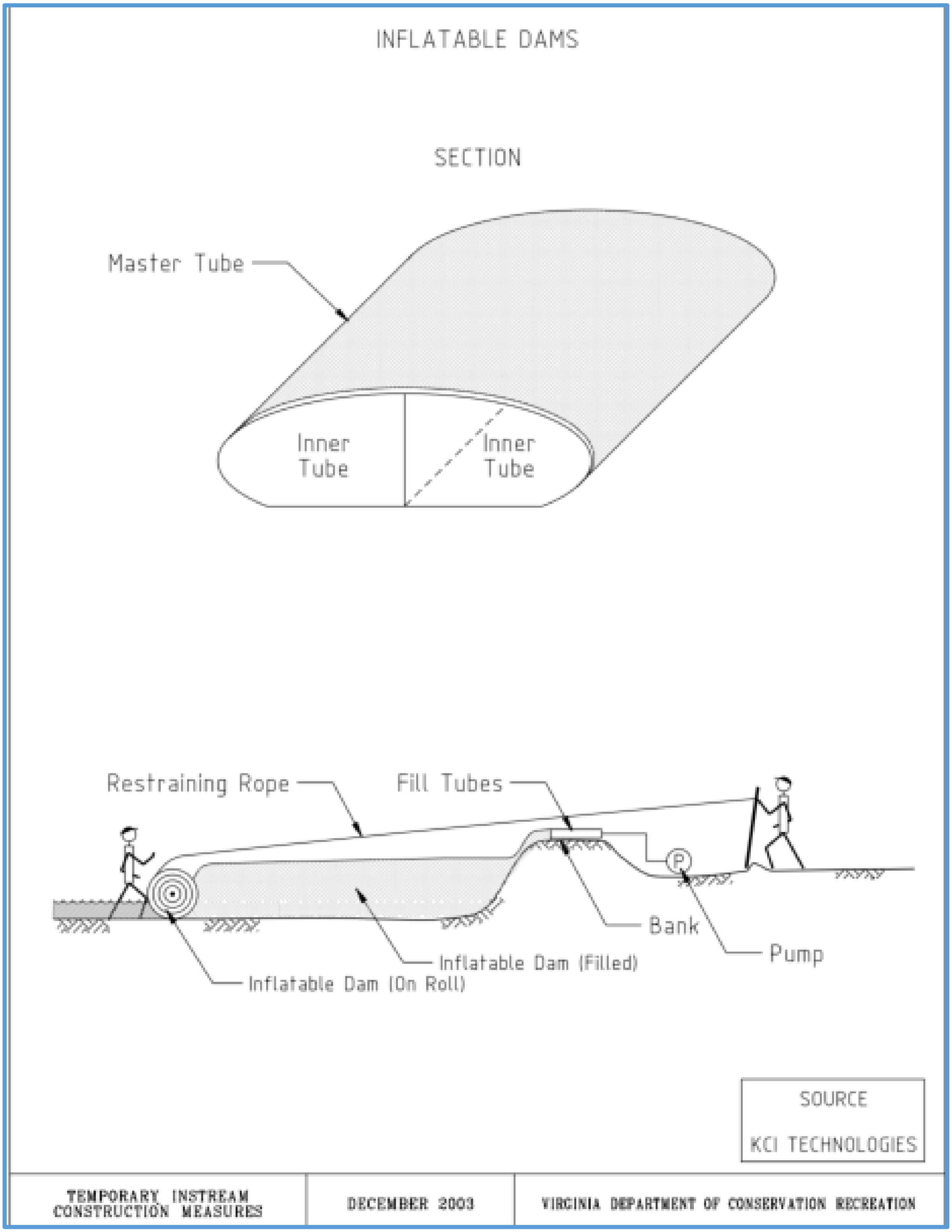


Figure 3.2.1-9 Example of deploying an inflatable barrier in the field

(Source: *http://www.deq.virginia.gov/Portals/0/DEQ/Water/Publications/BMPGuide.pdf*)

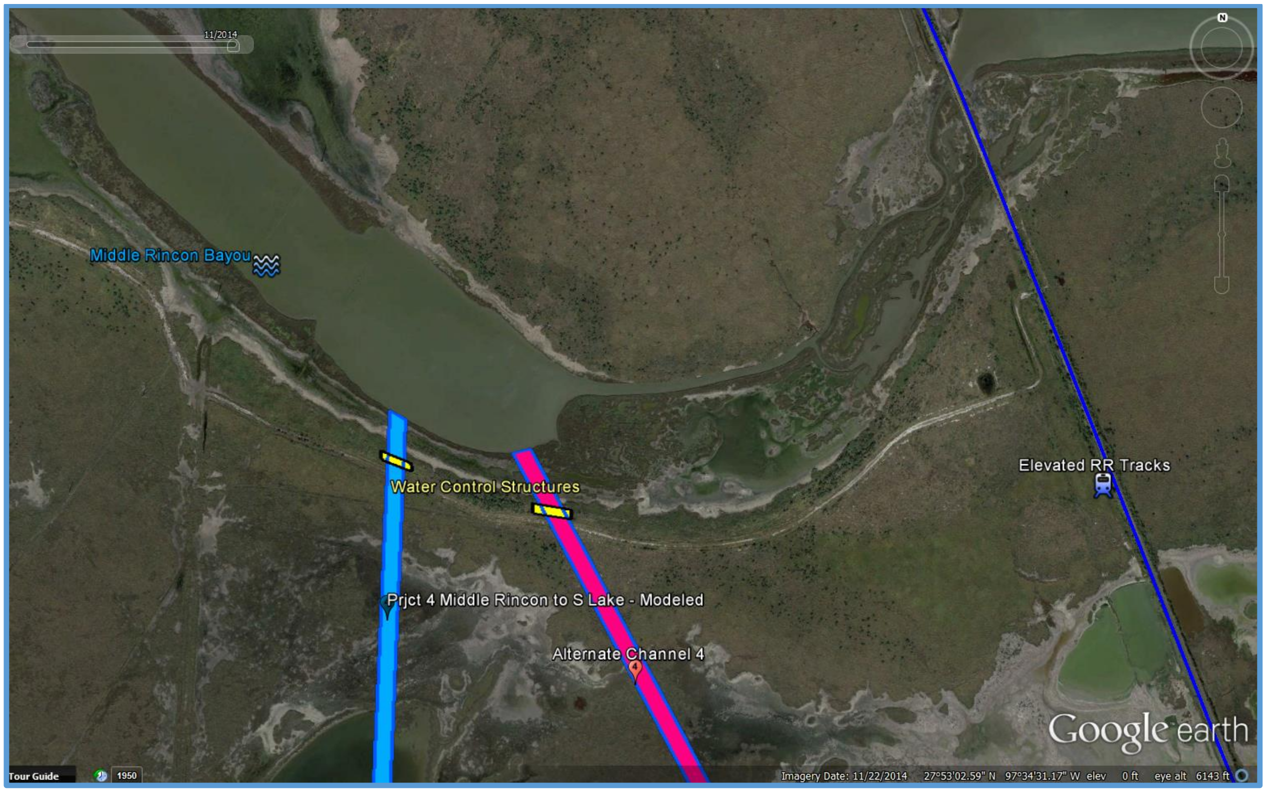


Figure 3.2.1-10 Proposed location of water control structure - Project 4 modeled channel and alternate

Figure 3.2.1-11 Proposed location of water control structure - Project 5 modeled channel and alternate

3.2.1.2 Project 7: Odem WWTP Effluent Discharge Diversion Pipeline

Figure 3.2.1-12, below, shows the proposed diversion of the existing effluent discharge from the Odem WWTP to an area of intertidal wetlands directly south of the plant site. Currently, the effluent is piped to a discharge point on an open stormwater drainage channel due east of the plant. The effluent then flows south through the drainage channel, which runs immediately adjacent to the railroad tracks crossing the middle of the Nueces Delta. Infiltration and evaporation losses generally consume the discharged effluent so that it generally does not flow past a point about 3,000 feet down the discharge point in the drainage channel.

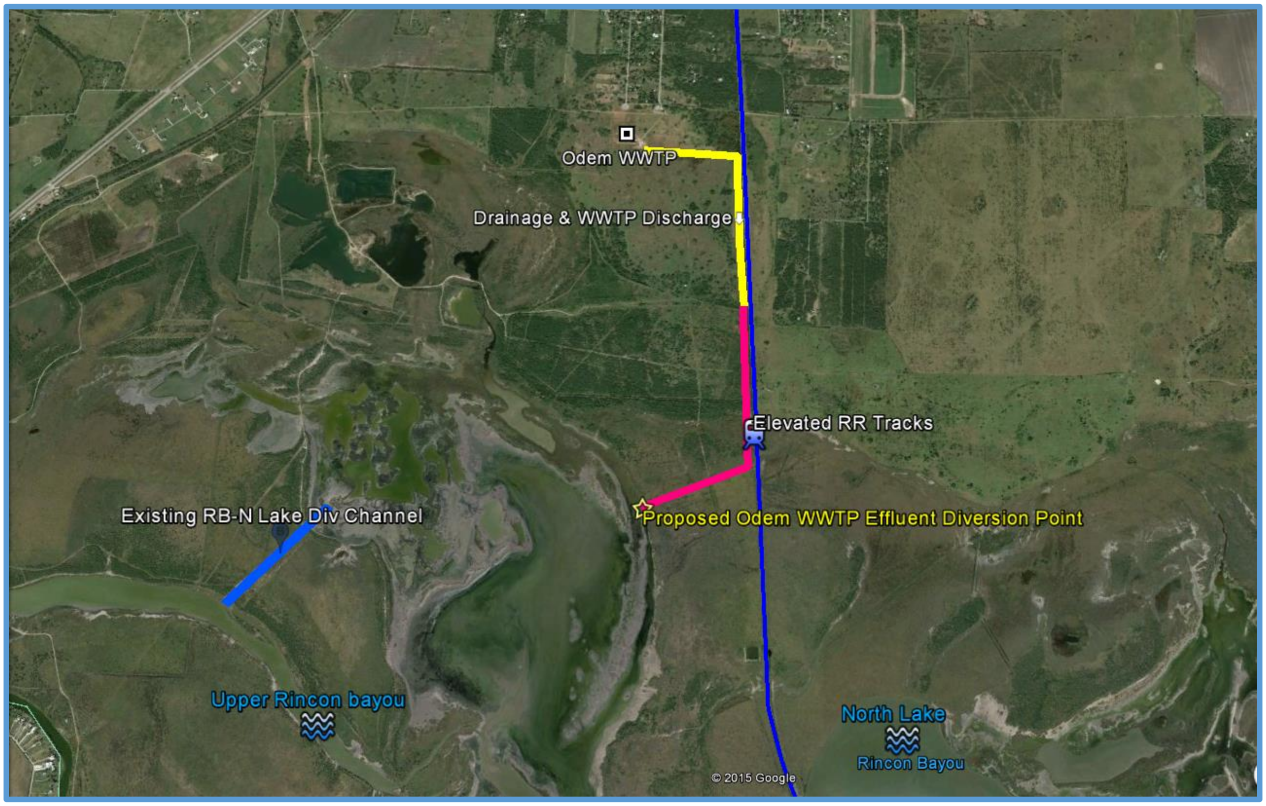


Figure 3.2.1-12 Pipeline (in pink) extending existing Odem WWTP effluent discharge (yellow) to wetlands area

Simply extending the drainage channel to the desired wetlands location would result in additional opportunities for infiltration and evaporation losses and would not likely increase the amount of water available. The conceptual design for project (Project 7) involves diverting the effluent from the existing drainage channel (where most of the effluent flow is still available) and conveying that flow in a pipeline to the desired discharge point. To accomplish this, a capture and diversion structure would be installed across the existing drainage channel, approximately 8,000 ft of gravity diversion pipeline would be installed, and a discharge structure would be installed at the target discharge point. Figure 3.2.1-13, below, illustrates this configuration.

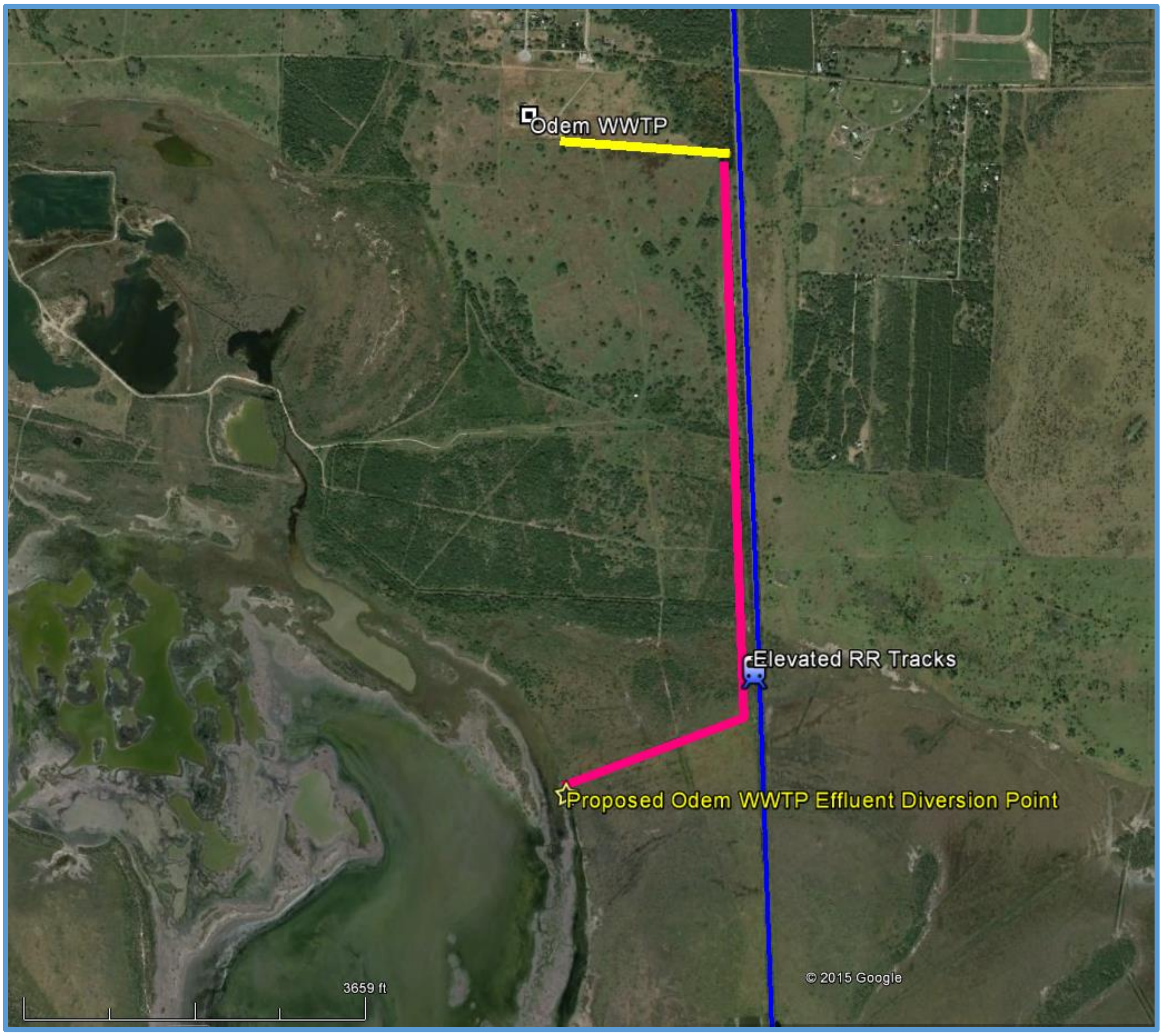


Figure 3.2.1-13 Configuration of new pipeline to convey Odem WWT effluent to delta wetlands location

The pipeline capacity should be large enough to accommodate the current discharge volume and additional volumes as the Odem area grows and effluent volumes increase. If economical, additional capacity could be designed into the line to convey stormwater runoff which is available periodically in the drainage channel into which the Odem WWTP effluent is discharged and from which it would be captured and conveyed in the pipeline.

3.2.2 Construction, Permitting/Regulatory, and Implementation Issues

3.2.2.1 General

The preferred project options were evaluated with regard to construction, permitting/regulatory, environmental, and other implementation considerations. This analysis was performed based on the conceptual design; additional analysis will be required as the actual design of the projects is refined.

First, the land and water features in the proposed project area, as well as habitat and natural resources potentially influenced by alternative construction activities, were identified to determine the type of permits and issues required for project implementation. The Nueces River Delta area contains numerous existing alterations to the natural environment, including caliche roadways to oil/gas production well sites, railroads, power lines, pipeline and drainage easements. The more upland areas of the estuary-delta are used for cattle grazing. Local, state and federal regulatory permit programs were reviewed, including interviews with key permitting authorities.

Since land ownership, or landowner approvals (i.e., easements) will be required for property access and construction activities, these property access issues and options were evaluated and key landowners identified. Coordination with the CBBEP has been ongoing since they are the primary landowner involved with the diversion channel options, and are a key potential project sponsor and supporter.

The following potential local, state and federal permits and implementation considerations were addressed:

<u>Permitting/Regulatory Programs</u>

1. U.S. Army Corps of Engineers (USACE) Wetlands (Section 404) and Navigable Waterways (Sections 9 and 10) Permits.
2. Texas Commission on Environmental Quality (TCEQ) Section 401 Water Quality Certification
3. Texas Commission on Environmental Quality Water Rights Permit Review (to determine if the installation of water control structures in Rincon Bayou would require a new water rights permit for the diversion and “storage” of unappropriated state waters – existing water rights (i.e., City of Corpus Christi’s permits) would not be included in this review)
4. Texas General Land Office (TXGLO) Coastal Lease
5. TCEQ and U.S. Environmental Protection Agency (USEPA) Wastewater Discharge Permit Amendment (Odem WWTP Discharge Permit effluent related option)
6. Odem WWTP Reclaimed Water Beneficial Reuse Authorization
7. TCEQ Construction Site Stormwater Permit
8. San Patricio County Drainage District Permit

Other Implementation Considerations

1. Property Access, Use Authorization, Easements and Approvals
2. Analysis of Potential Environmental Impacts and Environmental Clearance

Threatened and Endangered Species

3. Historic and Cultural Resources
4. Essential Fish Habitat
5. Migratory Bird Treaty Act Compliance Program

Projects 4 and 5, involving the excavation of the diversion channels and placement of the water control devices in regulated wetlands (i.e. much of the delta), may require a USACE Permit, a TCEQ Water Rights Permit review, and a TCEQ Construction Site Stormwater Permit. USACE permitting requirements for the basic construction could likely be satisfied using one of several Nationwide permits, including Nationwide Permit No. 7 (Outfall Structures and Associated Intake Structures) or Nationwide Permit No. 27 (Aquatic Habitat Restoration, Establishment and Enhancement Activities). There are also other implementation considerations, studies, environmental regulatory compliance, and mitigative measures which may be triggered by the respective permits, regulatory reviews, property access approvals, and coordination with funding authorities.

The remote location of the preferred projects could require more involved alternative access options, including roadway improvements for construction access by heavier equipment, marsh/amphibious equipment access through regulated wetlands, and the use of temporary board matts could be extensive. In this situation, the alternative access and construction issues generate more involved permitting, added cost considerations, and the need for more comprehensive project development and analysis.

Permitting and implementation issues similar to those identified for Projects 4 and 5 would also be expected for Project 7 (the Odem WWTP effluent diversion project). This project is expected to involve coordination with the City of Odem, possible minor amendments to the Odem WWTP discharge permits, an easement from the San Patricio County Drainage District, as well as easements/permits for crossing oil/gas pipelines.

3.2.2.2 Construction Considerations

Projects 4 and 5 are generally described in Section 3.2.1.2 and include various amounts of excavation and the installation of water flow control devices.

The material to be excavated is primarily soils and vegetation associated with tidally influenced wetlands (aqueous, sediment, hydric soils, wetland plants, etc.), which would be hauled offsite to an upland site for final disposition. Projects 4 and 5 require approximately 34,000 to 46,000 cubic yards of material to be mechanically excavated. Construction equipment would most likely include wide-track marsh buggies and long reach excavators (amphibious), with dump trucks used to haul the excavated material offsite. Existing caliche roadways would likely require improvement to sustain the heavy equipment and material transport traffic. There would likely be substantial temporary use of board mats to access certain construction areas.

Water control structures would involve two (2) bladder dams, each approximately 150 feet long and 4 ft. in diameter, which would be inflated using portable pumps. The bladder dams are placed across the constructed diversion channels with the ends extending onto the higher ground outside the constructed bed of the diversion channel. The ground surface area covered by un-inflated bladder dam can be twice as wide as the inflated height (approximately 4ft.) For example, each 150 ft long and 4 ft high bladder dam, when fully deflated, would occupy an area 8 ft. wide for a total area of 1,200 ft^2. The combined area covered by two (2) inflated bladder dams would be approximately 2,400 ft^2 (0.055acres). The majority of the area covered would consist of excavated channel bottom, but some small areas of higher marsh or wetlands outside the channel could also be displaced.

Construction access would be along primarily unimproved roadways utilized for the ranching and oil/gas production well sites. These roadways only provide limited access to the project site. The roadways are in major disrepair and are occasionally flooded, and may therefore not support the heavier excavation equipment and hauling trucks required. As a result, substantial roadway improvements, use of wide track equipment and submersible marsh equipment and use of temporary board mats can be expected in order to provide for adequate project site access.

The substantial cost of improving construction access along existing ranch roads and paths and use of specialized equipment will trigger the need to evaluate alternative construction access approaches, such as incorporating access along/within Rincon Bayou using amphibious marsh equipment and small work barges.

3.2.2.3 Permitting

The construction sites for the preferred options are primarily along the immediate Rincon Bayou, South Lake, North Lake, and Upper West Lake area of the Nueces Delta. The more direct impacts of the preferred options will be located in and between these construction sites. The preferred options will also indirectly benefit habitat and aquatic resources throughout the delta depending on the freshwater pumping volume, release season, and combined benefits of project options. The three recommended projects are located in San Patricio County, Texas within the Nueces River Delta among Rincon Bayou relict river channels and adjacent uplands.

According to the Texas Parks and Wildlife Department’s Ecological Mapping Systems of Texas (EMST), predominant vegetation types in this area include Gulf Coast: Salty Prairie, Coastal: Salt and Brackish High Tidal Marsh, Coastal: Salt and Brackish Low Tidal Marsh, Coastal: Sea Ox-eye Daisy Flats, and Coastal: Tidal Flats. Typical dominant species in these habitat types may include Gulf cordgrass (*Spartina spartinae*), marshhay cordgrass (*Spartina patens*), smooth cordgrass (*Spartina alterniflora*), three-square bulrush (*Schoenoplectus robustus*), saltgrass (*Distichlis spicata*), and sea ox-eye daisy (*Borrichia frutescens*).

Portions of Project 7 (Odem WWTP Discharge Diversion Pipeline) are also located in upland habitats mapped by the EMST as Gulf Coast: Coastal Prairie, Coastal Bend: Floodplain Live Oak Forest, Native Invasive: Baccharis Shrubland, and Native Invasive: Huisache Woodland or Shrubland vegetation types. Upland vegetation in these habitats may include a variety of exotic or native grasses, such as Kleberg bluestem (*Dichanthium annulatum*), King Ranch bluestem (*Bothriochloa ischaemum*), or little bluestem (*Schizachyrium scoparium*). Other upland plants that are typical for these vegetation types include live oak (*Quercus virginiana*), sugar hackberry (*Celtis laevigata*), baccharis (*Baccharis neglecta*), honey mesquite (*Prosopis glandulosa*), huisache (*Acacia farnesiana*), granjeno (*Celtis pallida*), and Texas prickly pear (*Opuntia lindheimeri*).

The primary permits and authorizations expected for the proposed projects (Project No. 4 – Middle Rincon Bayou to South Lake Diversion, Project No. 5 – North Lake to South Lake Diversion and the Odem WWTP effluent diversion project) include:

- **USACE Permitting** -- The diversion channel/bladder dam alternative construction approaches, described above, could determine the type of USACE permits required, particularly whether the USACE-Nationwide Permit No. 27 is applicable, or whether a full USACE Individual Permit might be required. The Odem WWTP effluent diversion would also potentially involve an outfall structure (USACE Nationwide Permit No. 7) and portions of a pipeline (USACE Nationwide Permit No. 12) in regulated wetlands.
  - USACE Nationwide Permit (NWP) No. 27 -- Aquatic Habitat Restoration, Establishment, and Enhancement Activities: Activities in Waters of the United States associated with the rehabilitation or enhancement of tidal wetlands and tidal open waters can qualify for NWP No. 27 provided these activities result in a net increase in aquatic resource functions and services. There are no binding enhancement agreements expected with a recognized federal agency since the CBBEP is the landowner and is expected to provide project authorization. It is expected that Pre-Construction Notification (PCN) would be required and would likely trigger some coordination with the state and federal joint agencies (i.e., TPWD, USFWS, TCEQ, EPA, NMFS, and TxGLO). An aquatic resource functions and services analysis is expected to show applicability of NWP No. 27. In addition the combination of recommended options could also influence the applicable permits.
  - USACE Nationwide Permit No. 7 for Outfall Structures and Associated Intake Structures. This permit will involve pre-construction notification to the USACE and a wetlands delineation.
  - USACE Nationwide Permit No. 12 for Utility Line Activities. This permit also can involve permitting of the access roads.
  - USACE Individual Permit: Should a NWP No. 27 not be applicable, based on the nature of the site access and construction activities or other issues, then the more involved Individual Permit (IP) would be required. The IP would require a more involved public and agency coordination process which could significantly influence the construction approach, timeline, and cost. The likelihood of an IP being triggered could center on the issue of the proposed project being able to demonstrate a "net increase in aquatic resource functions and services". Therefore, the application for a NWP No. 27 would likely include a more comprehensive analysis of anticipated

improvements in aquatic resource functions and services, as well as pre-project coordination with the USACE and joint agencies. The vegetation response and environmental flow needs for the Nueces Delta discussed in this report, and ecological benefits of moderating extremes in salinity would likely need to be addressed in further detail.

This pre-project coordination would then determine NWP No. 27 applicability under the preferred construction approach and alternatives, and likewise what construction approach might trigger the need for an IP. Should an IP with the USACE be required there is also certification from the TCEQ required under Section 401 of the Clean Water Act and in accordance with Title 30, Texas Administrative Code Section 279.1-13. It is anticipated that the work involved with constructing the diversion channels would be executed in a way to comply with Texas Water Quality standards and therefore TCEQ certification would be expected. The USACE permit process also involves a determination that the project is in the public interest.

- **TCEQ Water Rights Permit** Review -- The TCEQ regulates the diversion, impoundment, and use of state owned surface waters under its water rights permitting program. In Texas, "state water" is defined by TCEQ rules as:

  > "The water of the ordinary flow, underflow, and tides of every flowing, underflow, and tides of every flowing river, natural stream, and lake, and of every bay or arm of the Gulf of Mexico, and the Stormwater, floodwater, and rainwater of every river, natural stream, and water course in the state." (TCEQ, Subchapter A, Definitions and Applicability, Section 297.1 and 297.2)

  TCEQ rules also define a watercourse as:

  > "A definite channel of a stream, in which water flows within a defined bed and banks, originating from a definite source or sources. (The water may flow continuously or intermittently, and if the latter with some degree of regularity, depending on the characteristics of the sources.)" (Ibid.)

  However, in practice, defining a "watercourse" and "bed and banks" can be subjective and requires coordination with the TCEQ as to what actions can trigger what level of water rights permitting.

  The TCEQ defines a dam as:

  > "Any artificial structure, together with any appurtenant works, which impounds or stores water." (Ibid.)

  A water right is required to impound, store, *divert*, *convey*, take or otherwise use state water and the TCEQ requires that a person obtain a water rights permit before using such water. Even temporary structures such as the proposed bladder dams could be considered "diversion dams" since they *divert* and *convey* water by gravity. There are various types of water rights permits and/or exemptions depending on the use of such waters. Various issues influence the applicability of water rights regulations and exemptions including design and operating conditions, aquatic resource, wildlife and endangered species, impoundment direction and quantities (acre-feet of water). The City of Corpus Christi water rights permit for the Choke Canyon/Lake Corpus Christi reservoir system requires certain freshwater inflows to the Nueces Estuary that are to be measured at the Saltwater Barrier Dam and Rincon Bayou Diversion Pipeline. These locations are upstream of the recommended diversion channels and bladder dams and a water rights review associated with the City water rights permit could be applicable.

Since the Rincon Bayou project area includes relict river channels, most of which are under tidal influence, and the water within those channels is considered unappropriated "state waters," it could be determined that the proposed diversion channels and bladder dams would "*impound, divert and convey*" those waters, and a State Water Rights Permit "review" would be required. Preliminary communication with the TCEQ has further indicated a strong expectation that projects such as the proposed diversion channels would be subject to the jurisdiction of the TCEQ Water Rights permitting program. Additional coordination with the TCEQ is required to fully determine the applicability of these regulations with respect to the installation of water control structures and whether this would require a new water rights permit for the diversion and "storage" of water in Rincon Bayou, and how various design approaches, operating conditions, and landform modifications might trigger permitting or exemption. Existing water rights (i.e., City of Corpus Christi's permits) would not be subject to this review. The significance of TCEQ water rights permitting combined with the applicability of USACE Nationwide or Individual Permits can have a major effect on the selection of the preferred landform modification approach and costs. As a result, there should be continued and more involved Cost/Benefit Analysis, agency coordination, and alternative permitting analysis to select the most preferred landform modification project for implementation.

- **TCEQ Construction Site Stormwater Permit --** A construction project must comply with TCEQ's Texas Pollutant Discharge Elimination System (TPDES) Construction General Permit (CGP) if an area greater than 1 acre is disturbed during construction. Stormwater Pollution Prevention Program (SW3P) would be required and implemented and a construction site notice would be posted on the construction site. A Notice of Intent (NOI) would also be required to be submitted if the project disturbed greater than 5 acres. The diversion projects involve greater than 5 acres and would be expected to require a NOI and SW3P.

  A Stormwater Pollution Prevention Plan (SW3P) would be prepared before construction and followed during construction. Pollution from Stormwater would be minimized through adherence to measures in the project's SW3P. Table 3.2.2.3, below, lists erosion control measures available for this project.

Table 3.2.2.3 Construction Site Stormwater Pollution Prevention Plan Best Management Practices

CEQ-Water Quality Permit BMP* Category	BMPs Available for Use
Erosion Control	Temporary Vegetation/Mats/Mulch/Sod
Sedimentation Control	Silt Fences/Hay Bale Dikes/Rock Berm
Post Construction TSS** Control	Detention/Retention Ponds/Booms/Sediment Traps

*BMP - Best Management Practices **TSS - Total Suspended Solids

If any of the proposed project area is located within the boundaries of the City of Corpus Christi (the City), construction activities would require coordination with the City since the City holds a Texas Pollutant Discharge Elimination System *Municipal Separate Storm Sewer System (MS4)* permit. Under Section 401 of the Clean Water Act, the regulated entity holding a MS4 permit is responsible for assuring that construction activities within its jurisdictional area comply with local building code regulations and certain Best Management Practices (BMPs) to assure stormwater quality.

- **Texas General Land Office Coastal Lease and Texas Coastal Management Program (TCMP)** -- The proposed project areas are within the TCMP area boundaries. If located within those boundaries, projects requiring a USACE permit may be required to show consistency with the TCMP goals and policies, in accordance with the regulations of the Coastal Coordination Council, and would not be allowed to have a direct and significant adverse effect on the Coastal Natural Resource Area (CNRA's), as identified in 31 TAC Chapter 501.31.

  Structures and work within submerged lands owned by the TxGLO can require a coastal lease. The TxGLO maps of state-owned submerged lands and interviews with TxGLO staff have indicated the project area is not within these areas and a Coastal Lease is therefore not required.

3.2.2.4 Other Implementation Considerations

In addition to the primary permits and authorizations listed above, the following other implementation issues must also be considered during project planning:

- **Property Access, Use Authorization, Easements, and Approvals** – Since the proposed project areas are largely within the Nueces Delta Reserve properties owned by the CBBEP, this project has involved extensive coordination and cooperation with, and assistance from, CBBEP staff. These communications indicate that CBBEP will require the eventual project sponsor to get a project authorization, and access agreement, from CBBEP. All project area access options will be evaluated for alternatives and acquisition of easements or approvals.

- **Analysis of Potential Environmental Impacts and Environmental Clearance --** Since a landform modification project in the Nueces Delta wetlands and estuary will involve USACE permits, possibly a Water Rights Permit Review, and since the area is within an "estuary of national significance" (CBBEP, 1998), certain types of project funding can trigger environmental assessment and clearance by the funding authority. Therefore, project planning should involve a review of potential environmental impacts. The USACE Nationwide Permit program also involves a range of conditions which must be met to qualify for NWP authorization – i.e., avoidance of migratory bird breeding areas, minimizing adverse effects from impoundments, minimizing impacts to aquatic resources, minimizing the substantial disruption of aquatic life movements, avoiding harm to or take of threatened or endangered species, and a range of other conditions. The Water Rights Permitting process can also involve an analysis of environmental impacts. There is also a range of state and federal environmental grants which may be available to help fund project implementation. Most state and federal grant programs involve the need for an environmental assessment which generally follows the National Environmental Policy Act (NEPA) type assessment of alternatives, and conformance to the Council of Environmental Quality (CEQ) guidelines. Therefore, the analysis of project options should be expected also to include a more comprehensive environmental assessment review generally consistent with a NEPA assessment of alternatives before project implementation. Some of the key permit conditions, regulatory issues, and environmental assessment factors which can influence continued project development and implementations are further discussed in this section.

- **Migratory Bird Treaty Act Compliance Program --** The Migratory Bird Treaty Act (MBTA) of 1918 is a federal law (16 USC 703-712) administered by the U.S. Fish and Wildlife Service (50 CFR Parts 10, 14, 20 and 21). This act protects 1,027 species of birds, making it unlawful to "take" migratory birds. Under the MBTA, "take" means to pursue, hunt, shoot, wound, kill, trap, capture, or collect any such bird covered by the MBTA, or to attempt those activities. "Migratory birds" include most native birds in the United States that migrate as well as some of those that do not. If a project inadvertently destroys active nests or causes physical harm to birds, this constitutes a violation of the MBTA.

  The MBTA Compliance Program will identify steps to avoid impacts to protected birds during project construction. The Compliance Program will include incorporating best management practices to protect birds from harm as well as a nesting bird survey to be conducted within two weeks prior to beginning work in the project area. Peak bird nesting in this area is from February through September. Based upon results of the nesting bird survey, the program will identify available time periods and/or work areas which will not impact nesting birds within the project site. Providing professional environmental oversight will ensure optimal construction schedules that are also MBTA compliant.

- **Threatened and Endangered Species** – According to the USFWS, TPWD, and the National Marine Fisheries Service (NMFS), San Patricio County has a total of 52 Federal and State-listed threatened, endangered, and/or rare species. Based upon aerial imagery and vegetation types mapped by the EMST for the Nueces River Delta area (see Section 3.2.3.2), several listed species could potentially occur in or near the recommended project areas. Although the Federal and State-listed endangered whooping crane winters almost exclusively in the coastal areas of nearby Aransas, Refugio, and Calhoun counties, it is possible that the whooping crane could utilize marshes in the project areas for feeding or resting. The Sprague's pipit is a Federal candidate and State-listed rare species which could be present in coastal grasslands during the winter months. Impacts to the whooping crane and Sprague's pipit are not expected due to their ability to avoid project construction sites and due to their non-breeding status while present in this region.

Although suitable tidal flat habitat is available for the Federally-listed threatened piping plover and red knot, these shorebirds are typically found on beaches and bay shores and would not be expected to occur in the project areas which are over two miles inland from the Nueces Bay shoreline. Other Federally-listed endangered and threatened species which are known to occur in nearby Nueces Bay but which would not be expected within the project areas include the West Indian manatee and five species of sea turtles. These species would be restricted from access to project areas by shallow and variable water depths between the project areas and Nueces Bay.

State-listed species which could potentially occur in the recommended project areas include the brown pelican, reddish egret, snowy plover, sooty tern, white-faced ibis, white-tailed hawk, wood stork, American eel, opossum pipefish, and Texas diamondback terrapin. The Texas diamondback terrapin is known to nest in coastal marshes of the Nueces Delta. Coordination with local terrapin researchers will be conducted prior to initiating work in these areas during the spring terrapin nesting season. State-listed species which could potentially occur in Project 7 uplands include the sheep frog, black-spotted newt, South Texas siren, peregrine falcon, plains spotted skunk, Texas scarlet snake, Texas tortoise, Texas indigo snake, spot-tailed earless lizard, and timber rattlesnake. Best Management Practices established by TPWD for amphibians, reptiles, and fish will be followed to avoid impacts to these species. Four State-listed rare plants could potentially occur in the Project 7 area; coastal gay-feather, plains gumweed, three flower broomweed, and Welder machaeranthera. Impacts to protected nesting birds will be avoided in all locations (see MBTA Compliance Program above).

- **Historic and Cultural Resources** – A review of the Texas Historical Commission's Texas Historic Sites Atlas database indicated that no historic resources are located within the immediate project areas. The closest mapped resource is Meansville Cemetery located approximately 0.5 miles east of the proposed site of the Odem WWTP diversion project. However, due to the high probability that Nueces Bay contains archaeological resources, consultation with the State Historic Preservation Officer (SHPO) would likely be requested during project planning.

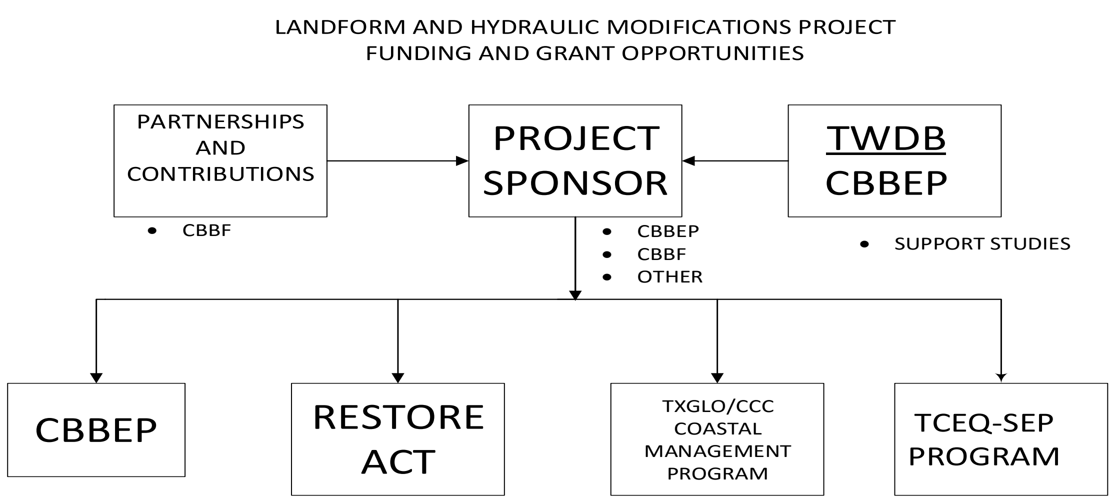
- **Essential Fish Habitat –** Much of the Nueces River Delta is mapped as Essential Fish Habitat (EFH); therefore, coordination with the NMFS will likely be necessary for the recommended projects. In addition, consultation with NMFS would be triggered for any construction work in tidal waters subject to a USACE Individual Permit (IP).

3.2.2.5 Funding and Grants

The purpose of the project is to provide a natural resource or ecological benefit which also includes benefits to the public and the users and stakeholders of the Nueces Bay Corpus Christi bay systems. The preferred projects are also located on lands owned by a non-profit conservation group – the CBBEP. As a result there are a number of grants which can be applicable to the land form modification project. Provided in the below flow chart, Table 3.2.2.5, is a listing of some of the more applicable grant programs also listed as follows:

- Coastal Bend Bays and Estuaries Program
- RESTORE Act
- Texas Coastal Management Program (funded by National Oceanic and Atmospheric Administration –NOAA).
- Texas Commission on Environmental Quality (TCEQ) Supplemental Environmental Administration – NOAA)
- Texas Water Development Board

Table 3.2.2.5 Funding and Grant Opportunities Flowchart



3.2.2.6 "System Operations" Approach

The Nueces Delta is no longer operates as a "natural" system in terms of freshwater inflows. This is due, in large part, to the impacts on the timing and volume of water entering the Nueces River Tidal Segment and the Nueces Delta resulting from the development of two major reservoirs "upstream" within the Nueces Basin. However, it also due to the extensive modifications which have already occurred within its bounds. These changes have taken place over many years and for many reasons – "better access," "better drainage," "reclamation" of lands for agricultural use, oil and gas development, construction of pipelines, powerlines and rail lines, and, in the more recent years, as part of habitat and ecosystem conservation activities, including efforts to provide better access to and distribution of available freshwater inflows.

As indicated previously, efforts to restore the Nueces Delta to a "more natural" system in terms of hydrologic and ecosystem functions originated in a series of planning studies which began in the 1970's and have continued up to present time. As a result of extensive scientific investigation and documentation of the problems caused by the historic alterations in inflows and hydrology within the Nueces Delta, support increased for some of the proposals made as a result of these studies, and by the early 2000's a number of the "modifications" proposed in these planning studies had come to fruition: the Nueces River Overflow Channel connecting the Tidal Segment of the Nueces River to the uppermost portion of Rincon Bayou, opening up two-way flow between the two; the Rincon Bayou Overflow Channel connecting the main body of the Rincon Bayou to the West Lake area to its north; the Allison WWTP Effluent Diversion Demonstration Project; and the Diversion Pipeline from Calallen Pool to the upper Rincon Bayou. Less well known, but also important, were smaller scale projects, including repairing, replacing or removing blocked culverts at several road crossings within the Delta's system of natural channels.

More recently, a water control structure was put into place on the Rincon Bayou just "upstream" of the Diversion Pipeline outfall structure (see Figure 3.2.2.6, below). This control structure is designed to prevent water being discharged into Rincon Bayou through the Diversion Pipeline from traveling "upstream" and discharging into the Nueces River Tidal Segment instead of flowing "downstream" in the Rincon Bayou, through the Nueces Delta and into Upper Nueces Bay.

Figure 3.2.2.6 Water Control Structure on Upper Rincon Bayou – view to East, from upstream to downstream; Diversion Pipeline outfall in background, on left, downstream side of water control structure *(Photo courtesy of Coastal Bend Bays and Estuaries Program)*

If the two diversion channels recommended in this study, with their associated water control structures, could be added to the existing facilities already moving water -- to a limited extent -- within the Rincon Bayou and adjacent wetland area, the development and implementation of an integrated, "systems operations" approach to freshwater inflow management within the Nueces Delta is a very real possibility.

This systems operations approach, already envisioned in the SMART Inflow Management planning work conducted by the Coastal Bend Bays and Estuaries Program and the City of Corpus Christi, would utilize real-time monitoring and measurement to inform decisions on when, where and how much fresh water inflow is needed to maximize the benefits of the freshwater inflows, in terms of the ecological health of the Nueces Delta, and the yield of the regional water supply system.

The installation of the two proposed diversion channels and water control structures, combined with the already existing infrastructure (i.e., the Diversion Pipeline and the upper Rincon Bayou water control structure) would provide a much improved ability to maximize the benefits of often limited amounts of freshwater inflow by increasing the areal extent and duration of the freshwater inundation of critical wetland areas now only receiving intermittent, unpredictable freshwater inundation. The hydrodynamic modeling work conducted in this study showed significant improvements in this regard with only the two channels having been put in place, without the water control structures. The inclusion of a water control structure (i.e., bladder dam) on each of these channels affords a much greater degree of control over the timing and volume of water being diverted from Rincon Bayou into the adjacent wetlands, and some degree of control over the influx and redistribution of higher salinity water from Upper Nueces Bay as it is pushed “inland” via Rincon Bayou during high tide events.

The development of a systems management protocol for the various freshwater inflow diversion scenarios which might be possible via a combination of the pumped delivery of freshwater from the Calallen Pool into the Rincon Bayou and the operation of “downstream” control structures associated with the proposed diversion channels, will require additional hydrodynamic modeling. Historical data from stream gages and monitoring stations within the Nueces Delta could be used to create any number of scenarios which, since they could potentially occur again in the future, can be used to formulate model inputs. Modeled results could then be used to inform a process of developing operational “rules” for a systems management program for freshwater inflows.

3.2.3 Cost estimates

Cost estimating methods were based on planning level cost information and developed to closely resemble the planning level cost estimates prepared for water management strategies evaluated and presented in the Senate Bill 1 Regional Water Plans. The major categories are Capital Costs and Additional Project Costs, the sum of which is the Total Project Costs; from this number the annual debt service is determined, then added to annual operations and maintenance costs (O&M), and any other annual expenses, to develop a Total Annual Cost number.

The following two project description summaries present the anticipated project construction elements used to develop the Capital, Additional and Total Annual Project Costs for the proposed projects.

3.2.3.1 Proposed Projects 4 -- Middle Rincon Bayou to South Lake Diversion Channel -- and 5 -- North Lake (Rincon Bayou) to Middle Lower Delta Diversion Channel

These two proposed diversion channels, shown in Figure 3.2.2-1, below, will include excavation of: Project 4 -- a 3,600 ft. long by 100 ft. wide channel (8.26 acres), and Project 5 -- a 500 ft. long by 100 ft. wide channel (1.15 acres). These channels are expected to be approximately 1.5 to 3.0 feet deep. Alternate channel locations and lengths (Project 4: 2,600 ft. and Project 5: 450 ft.) were also included in the project recommendations.

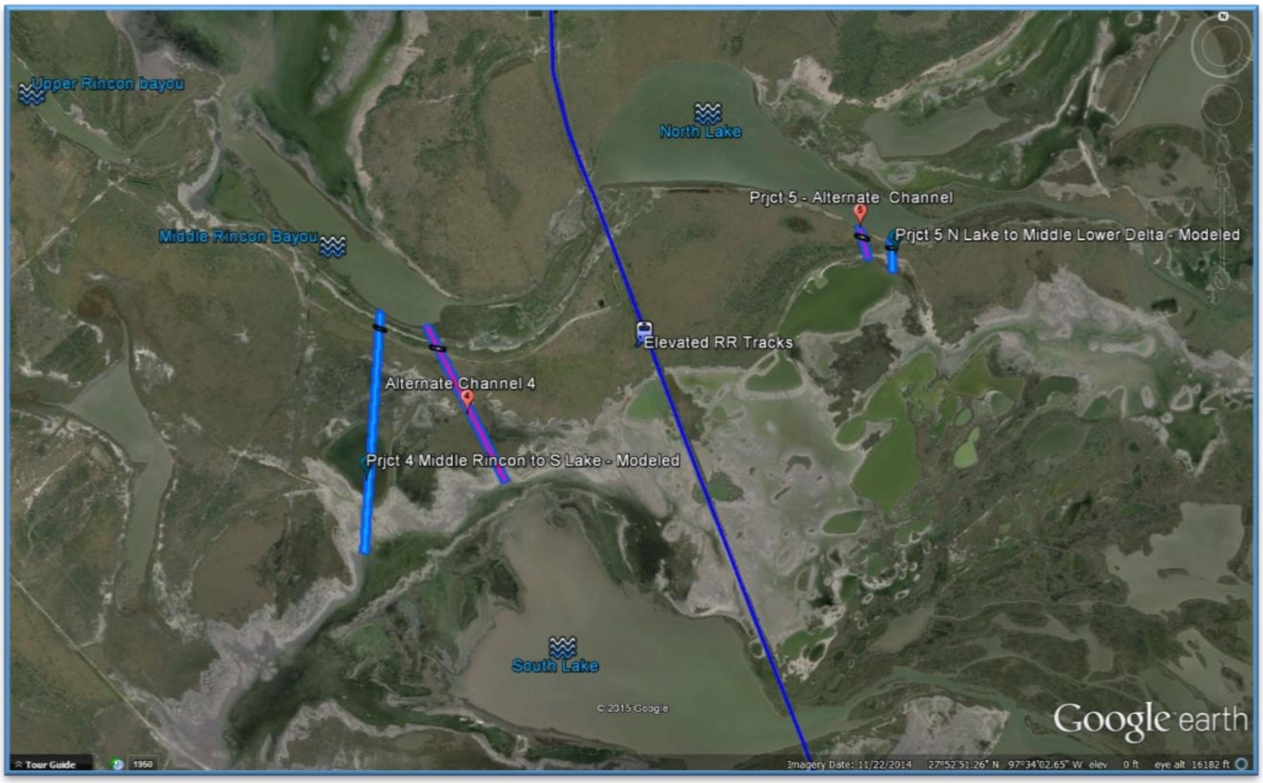


Figure 3.2.3.1 Locations of proposed projects 4 and 5 -- Rincon Bayou Diversion Channels

These two proposed diversion channels will require the excavation of soils and vegetation associated with tidally influenced wetlands (aqueous, sediment, hydric soils, wetland plants, etc.), which would be hauled well offsite to an upland storage site. A total of approximately 46,000 cubic yards of material is expected to be mechanically excavated for the two channels at the primary locations, and a total of approximately 34,000 cubic yards of material if the construction occurred at the alternate locations.

Construction equipment would include wide-track marsh buggy and long reach excavators (amphibious), and dump trucks for hauling semi-solid marsh sediments. Existing caliche roadways would likely require improvements to maintain the roadway for heavier equipment and material transport to the upland site. There would likely be substantial use of temporary board mats to access certain construction areas.

Water control structures would involve two (2) approximately 150 feet long and approximate 4 ft. diameter bladder dams that would be expanded using submersible pumps. These "bladder dams" are inflatable water-filled with variable heights that utilize submersible water pumps and solar powered level controls. The bladder dams are placed across the constructed diversion channels with the ends extending onto the higher ground outside the constructed bed of the diversion channel. Water level and flow measurement devices would be installed in association with these water control structures.

Construction access would be along primarily unimproved roadways which only provide limited access to the project site. The roadways are in major disrepair and are occasionally flooded, and may therefore not support the heavier excavation equipment and hauling trucks required. As a result, substantial roadway improvements, use of wide track equipment and submersible marsh equipment and use of temporary board mats can be expected in order to provide for adequate project site access.

3.2.3.2 Project 7 -- Odem WWTP Effluent Discharge Diversion Pipeline

The construction of the Odem WWTP effluent diversion pipeline and outfall is expected to involve the installation of a concrete effluent capture and diversion structure, approximately 8,000 feet of 16-inch diameter PVC pipe, and a concrete discharge outfall and apron at the terminus of that pipeline. A similar discharge outfall, constructed on the Rincon Bayou in association with the City of Corpus Christi's Freshwater Diversion Pipeline, is illustrated in Figure 3.2.2-2, below. A flow meter would be installed at the discharge point in order to measure the total monthly volume of effluent diverted into the Nueces Delta. This information can then be correlated with the changes in ecological conditions within the area affected by the diversions.

Figure 3.2.3.2 Concrete Outfall for City of Corpus Christi's Freshwater Diversion Pipeline to Rincon Bayou

3.2.3.3 Project Cost Estimates

Table 3.2.3.3, next page, presents planning level cost estimates prepared for the two proposed Rincon Bayou Diversion Channel projects, for both the primary and alternate locations, and for the proposed Odem WWTP Effluent Diversion project.

Table 3.2.3.3 Cost Estimates for Proposed Projects

Nueces Delta Landform Modifications Project **Recommended Projects -- Cost Estimates**	**Diversion Channels (Combined Projects 4&5) As Modeled**	**Diversion Channels (Combined Projects 4&5) Alternate Channels**	**Odem WWTP Diversion**	**Notes:**
Capital Costs				
Combined Projects 4 & 5, as modeled:				*Total of 4,100 linear ft. of 100 ft. wide channel;*
Channel Excavation	$ 920,000			*Total Excavation: 46,000 cu yds @ $20/cu yd; all inclusive*
Bladder Dams	$ 90,000			*2 @ 150' x 48" dia, installed*
Board Mat Roadway	$ 155,350			*750' x 16' x 8" -- rental for 5 mos.*
Flow and water level measurement instruments	$ 60,000			*3 flow meters purchased; 2 installed; 1 backup meter*
Combined Projects 4 & 5, alternate channels:				*Total of 3,050 linear ft. of 100 ft. wide channel;*
Channel Excavation		$ 680,000		*Total Excavation: 34,000 cu yds @ $20/cu yd; all inclusive*
Bladder Dams		$ 90,000		*2 @ 150' x 48" dia, installed*
Board Mat Roadway		$ 155,350		*750' x 16' x 8" -- rental for 5 mos.*
Flow and water level measurement instruments		$ 60,000		*3 flow meters purchased; 2 installed; 1 backup meter*
Odem WWTP Diversion:				
Effluent Capture and Diversion Structure			$ 35,000	*Box structure and connection to pipeline*
Effluent Diversion Pipeline			$ 760,000	*8,000 ft of 16" diaPVC pipe, gravity flow, installed*
Outfall Structure			$ 75,000	*Concrete outfall and apron*
Board Mat Roadway			$ 136,600	*1,500' x 16' x 8" -- rental for 2 mos.*
Flow measurement instruments			$ 40,000	*2 flow meters purchased; 1 installed; 1 backup meter*
Total Capital Costs	**$ 1,225,350**	**$ 985,350**	**$ 1,046,600**	
Additional Project Costs:				
Airboat Transportation	$ 90,000	$ 90,000		*1 airboat for 150 days @ $600/day*
Contingencies (15% *of total capital costs*)	$ 183,803	$ 147,803	$ 156,990	
Legal and ROW Acquisition (10% of total capital costs)	$ 122,535	$ 98,535	$ 104,660	
Engineering, Surveying, Environmental, Etc (20%)	$ 245,070	$ 197,070	$ 209,320	
Subtotal Addit Project Costs	***$ 641,408***	***$ 533,408***	***$ 470,970***	
Interest During Construction (1 yr)	$ 102,672	$ 83,532	$ 83,466	*(Total Capital Cost + Subtotal Addit Project Cost) x 5.5%*
Total Additional Project Costs:	**$ 744,079**	**$ 616,939**	**$ 554,436**	
Total Project Costs	**$ 1,969,429**	**$ 1,602,289**	**$ 1,601,036**	
Annual Costs				
Amount Financed	***$ 1,969,429***	***$ 1,602,289***	***$ 1,601,036***	
Annual Debt Service (5.5% for 20 yrs)	$ 164,800	$ 134,100	$ 134,000	*http://agstar.com/loans/Pages/LoanAmortizationCalc.aspx*
Annual O&M	$ 26,000	$ 26,000	$ 26,000	*Every other week inspection and maintenance visit*
Annual Ecological Monitoring Expenses	$ 48,000	$ 48,000	$ 24,000	*Monthly field sampling in affected areas of Delta*
Total Annual Cost	**$ 238,800**	**$ 208,100**	**$ 184,000**	

3.3 Development of Parameters for Additional Modeling of Proposed System of Landform Modifications

Field validation of the NDHM with data collected by TWDB (Schoenbaechler et al., 2014) was conducted in parallel to the present study (Li and Hodges, 2015). The validation results demonstrate that the model provides accurate modeling of water surface levels over a full year of simulation. Salinity modeling is quite good for the first 30-60 days of simulation, but over longer time scales the model is biased towards predicting lower salinities. This result is consistent with the known deficiencies of the present model, which does *not* include: (i) evaporation, and (ii) transpiration and exchanges with porewater salinity. Both of these processes will produce hyper-saline waters in the upper delta, so the inability of the model to accurately capture the development of hypersalinity over multi-month time scales is not surprising.

Li and Hodges (2015) also examined the relationships between the secular tidal elevation, wind direction, wind speed, and the pumping schema on the flooded acreage using wind and tide data from 2010-2014. They were expecting to see increased inundation area with higher secular tides and strong SE winds. Although there is no doubt that SE winds help retain water in the Nueces Delta, and higher tides lead to greater flooding, the effectiveness of the flooding (i.e. in covered acres per ac-ft. of freshwater pumped into the system) did not have the expected clear-cut results that would provide direct guidance for pumping operations. It is hypothesized that one of the critical issues in the effectiveness of pumping is the relationship between the timing of the pump operations and either a rising secular tide or a change in wind directions and speed.

Finally, the salinity transport analysis of the NDHM results by Li and Hodges (2015) showed that the model representation of narrow channels allows excessively high flow rates, which could result in overestimate of freshwater transport into the lower estuary. This effect appears to be caused by the coarser model grid (30 x 30 m) used in the present NDHM, compared to the finer grid (15 x 15 m) used in the earlier version (Ryan and Hodges, 2011). Unfortunately, the coarser grid is necessary to keep the model computational costs low enough to be able to run simulations 15 faster than real time (e.g. 1 month simulated in 2 days of computer time).

Thus, there are three critical needs for improving and additional modeling with the NDHM: (1) investigation of the flow/channel-width/drag relationship in the model to better represent flux rates through the narrow channels, (2) addition of models for evaporation, vegetation cover, transpiration, and porewater exchanges, and (3) more detailed analyses of the relationships between pumping rates, and the changes in tidal elevations and changes in wind conditions that affect the freshwater inundation. These modeling efforts should be undertaken with additional studies of any planned projects to provide improved insight into operating the system to maximize the effectiveness of freshwater pumping.

4 Conclusions and Recommendations

Evaluation of conceptual designs for several potential landform and hydraulic modifications in the Nueces Delta revealed that two new channels diverting water from Rincon Bayou could inundate and lower salinities in often dry areas to the south of the main channel, as compared to existing conditions, although, in some cases, at the expense of some areas which were inundated before the new channels were included in the model.

Our results are based on making consistent flow conditions a high priority in any adaptive management plan. Regular inundation events will serve to moderate the extremes in salinity and disturbance regimes that cause plant species displacements over relatively short time scales. Increased vegetative stability will also provide a sound foundation for estuarine dependent species, especially if salinity levels are maintained at a target of 25 (Figure 2.3.5-2) as recommended by BBEST (2011). Based on these studies, model runs for potential projects were based on achieving a target salinity of 25 by providing inundation of freshwater for the length of one tidal cycle (6.2 hrs.) for a period of at least 30 days. Since vegetative cover responds optimally to lowered salinities during the spring and early summer, freshwater releases during these seasons are clearly most beneficial to the Nueces Deltaic marsh ecosystem.

Although comprehensive indicators of health and sustainability for marsh ecosystems of the Gulf of Mexico are not yet available, the rich database of knowledge for the Nueces Delta provides an opportunity to identify indicators that can be used to evaluate the various alternatives presented here. One quantitative measure of plant condition and persistence are in situ measures of carbon sequestration. Other in situ biologic indicators include measures of trophic structure, diversity, and biomass or density of estuarine dependent species (Figure 2.3.5-2). For each indicator, we must identify the specific thresholds that allow ranking of changes in ecological integrity and ecosystem services of each ecosystem at both site and regional levels.

The “Expert Team” approach, drawing on, in a series of workshop meetings, the professional experience and knowledge of scientists with many years of time working in the Nueces Delta/Estuary system, greatly contributed to process of developing the initial set of potential projects and, later, refining the design of the projects selected for further evaluation. This process also demonstrated the value of using the easily accessible ***Google Earth***/***Google Earth Pro*** (© Google) mapping platform as a tool for the exchange of ideas and the visualization of preliminary project designs during the Project Team workshops.

The two *charrettes* held to inform stakeholders about the study’s background, goals and initial results, and to elicit comments and advice on the initially proposed projects, proved less valuable than anticipated. These *charrettes* (one held at a meeting of the NEAC and the other at a “Bays Forum” held by the Coastal Bend Bays Foundation) were intended to generate more of an in-depth, back-and-forth discussion than actually resulted. It may simply be that these two settings selected for that purpose were not really the best venue for allowing that level of information sharing and discussion. Given the success of the Project Team workshops, which included some experts not actually on the project team, perhaps a better method of gathering the desired input from stakeholders would be to identify and invite additional individuals/stakeholders with known interest and expertise to one or more Project Team workshops designated for that purpose.

The recently developed Nueces Delta Hydrodynamic Model proved to be extremely useful in the preliminary evaluation of project alternatives and the quantification of impacts associated with selected configurations of limited hydraulic modifications. However, prior to implementing construction of any project, we recommend additional model refinements and further modeling studies to better understand the performance of the proposed projects, and select alternatives, over a wider range of conditions.

At a minimum, the 18 environmental forcing scenarios of Li and Hodges (2015) for the baseline (no project) delta model should be tested with viable projects to better understand the range of likely behaviors. We further recommend that the model be run for typical wet/dry/moderate years. The results of these model runs can be used to produce monthly inundation maps and a measure of changed inundation for the projects.

More consideration should be given to the importance of over-banking events. The Nueces Marsh should not be defined as the water and banks along the Rincon Bayou. There are countless natural tidal creeks that traverse the lower Delta, serving as critical tributaries to the greater marsh habitat and providing a mechanism for horizontal exchange of ground waters that moderate porewater hypersalinity. Additional work should address the relationship between these tidal creek tributaries, the character and health of the adjacent vegetation and surrounding habitat, and the variations in pore water salinities in these “deep” marsh areas. The hydrological connections between tidal creek tributaries and the benefit (if any) of non-over banking water releases to the greater marsh are poorly understood.

There also remains uncertainty as to the best pump operating strategy to maximize freshwater inundation. It is recommended that a follow-on investigation of Li and Hodges (2015) be conducted to elucidate how the timing of pumping, tidal behavior (rising/falling limb of secular tide), and wind shifts alter the inundated area. This information would also assist in assessing the benefits of a “systems management/operations” concept for coordinating the pumping of required Pass-Thru flows into Rincon Bayou with the operation of the water control structures which would be associated with the proposed diversion channels.

Additional recommended follow-on activities include site visits, surveys and assessments at the potential project sites. This information would assist in verification of the NDHM, aid in the development of operational strategies for maximizing the benefit of freshwater pumped into Rincon Bayou, and provide for refinement of project permitting and construction plans.

5 Acknowledgements

The Project Team would like to thank the members of the Nueces River and Corpus Christi and Baffin Bays Basin and Bay Expert Science Team (Nueces BBEST) and the Nueces River and Corpus Christi and Baffin Bays Basin and Bay Area Stakeholder Committee (Nueces BBASC), for all their time and energy spent in the development of recommendations for environmental flow standards for the Nueces River Basin and Corpus Christi and Baffin Bays and for the recommendations in the Nueces BBASC Adaptive Management Work Plan, including the recommendation to "Explore Landform Modifications to Nueces Bay and Nueces Delta."

The Project Team would also like to especially thank several individuals who freely provided the benefits of their years of experience working in, and for, the Nueces Delta/Bay system. Their personal knowledge of the history and outcomes of previous efforts to better manage freshwater inflows to the Nueces Estuary helped steer the project in the right direction at certain critical junctures. Those providing this "on the ground and in the field" expertise includes: Jake Herring (CBBEP), Jace Tunnell (formerly with CBBEP, now with the Mission-Aransas NERR), Paul Carangelo (Port of Corpus Christi Authority), Rick Kalke (Harte Research Institute, TAMUCC), Rocky Freund (Nueces River Authority) and Brent Clayton (City of Corpus Christi).

The Project Team also extends its appreciation to the members of the Nueces Estuary Advisory Council and attendees at the Coastal Bend Bays Foundation's "Bay Forum" for their participation in the two project *charrettes*.

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7 Appendices

7.1 Appendix A - Presentations made to NEAC and CBBF *charrettes*

7.2 Appendix B – Notes from project team workshop meetings

7.3 Appendix C – Bibliography

7.1 Appendix A: Presentations made to NEAC and CBBF *charrettes*

These materials can be viewed via the following DropBox link:
https://www.dropbox.com/sh/1fbhng4wkv7w5rt/AADi5_t0ZmRNzDyL31uMBRFka?dl=0

7.2 Appendix B: Summary of Project Team Workgroup Meetings

The Nueces Delta Landform Modification Project Team had a total of 12 meetings that included nine working meetings to develop conceptual designs for the landform recommendations and two *charrettes* to discuss and present the conceptual design products with stakeholders. This Appendix gives the meeting summaries of the Team's design process and stakeholder involvement.

1/28/2015
Time: 10:00-11:20
Nueces Delta Landform Modifications Project Team
"Phone Conference to Develop Project Ideas"

Participants

Dave Sullivan (DS)
Erin Hill (EH)
James Dodson (JD)
Brien Nicolau (BN)
Ben Hodges (BH)
George Ward (GW)
Ken Dunton (KD)

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1. JD- emailed a map of the Delta segregated into four segments. (see attachment).
2. GW- Suggested diverting Nueces River into the Rincon Bayou at the ROC.
3. JD- Suggested connecting river to the southeast corner of delta across from the Viola Turning Basin.
    a. Also using an inflatable dam

    -Also suggested the use of drainage from the northern part of delta (Odem area).
4. BH- Suggested connecting the river at or near the mitigation site (actually just east of NDMP) north of Viola Turning Basin.
    a. Also suggested making land modifications for better use of RBP water and create a cut to South Lake.
5. BN- Get an updated map of the CBBEP property. Erin sent an email to Jake 1/28/2015.
6. KD- Suggested push water through the "ROC" to revive the northern tidal flats.

    BH- Stated just digging a trench won't do it, need a control structure.
7. KD- Fresh water stays in the channel and does nothing to the pore water salinity.
8. EH- RBP flows need to be more spatial and not channelized dominantly.
9. BH- Suggested the little channel north in Central Rincon could deliver water to the northern tidal flats. Would need a control structure, weir and gates.

    KD- Stated anything we can do to put water on the mud flats and into the vegetated areas and keep most of the flow out of the channels.
10. JD-Further research is needed on these ideas (i.e. property owners etc.).
11. BH-Suggested a break/cut through between North and South Lakes. This would flush the Rincon and create a flow through the ponds and flats (sheet flow?).
12. KD-Asked James to collect all ideas, email final project ideas to group. Get property map from CBBEP and past and present habitat enhancement projects CBBEP has in the delta (Erin emailed Jake both questions 1/28/2015).
13. DS- Suggested Gum Hollow and all options need to be explored.
14. JD and DS- Need to include CBBEP, Jake Herring, with this project. Also, take projects to next CBBEP HLRT meeting tomorrow 1/29/2015. Kara with Neismith is to attend this meeting.

14. BN- Has begun conversation with TCEQ about possible CMP funds to help with project costs.

2/5/2015
Time: 0900h-1100h

NEI Meeting/ Phone Conference "Project Development"

<u>Attendees</u>

James Dodson
Mary Kay Skoruppa
Ken Dunton
Ben Hodges
Paul Carangelo
Erin Hill
Jake Herring
George Ward

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1. Upper Delta Nueces River Diversion
    a. This would include a control structure/dam in the river proper near the current diversion channel
    b. A notched structure
    c. Make the existing diversion channel larger
    d. Do not want to back up the river past the Calallen Diversion Dam
    e. NOC is at 0.0 MSL
    f. CBBEP installed a diversion dam structure to keep RBP water from going back to the Nueces River proper.
    g. **Questions:**
        i. What is the max flow for the CBBEP structure?
        ii. Need the engineering plans and cost from CBBEP for structure?
        iii. Need to define "benefits"?
        iv. Need to define "negatives"?

2. Upper Rincon Bayou Diversion to Northwest part of delta (wetlands)
    a. Use this diversion during RBP pumping events
    b. Use a weir to control flow to marsh and tidal flats
    c. **Questions:**
        i. How much upstream flooding is needed to have water flood into this area?

3. Proposed Removal of Road Crossing
    a. This is a flow obstruction
    b. Lots of junk in this area of the delta that needs to be cleaned up
    c. Install culverts (couple 100k)
    d. This area needs to have a road access for CBBEP's Master Plan

4. East End of Upper Rincon Bayou Diversion into South Lake
5. North Lake to South Lake Diversion
6. Middle Rincon Bayou to South Lake Diversion
    a. **Questions**:
        i. Need to know what kind of flow we want to achieve? Moderate flow?

ii. George will provide flow regimes
iii. David Lozano with the city runs the RBP pumps
iv. Ben will run model to determine if 1 diversion in this area will suffice or if a combination of diversions are needed.

7. Lower Delta Nueces River Diversion to COE Mitigation Site
    a. Bulldozer could expand this connection
    b. Note: this area is commercially fished for crabs
    c. One suggestion was to fill the Delta Access Channel (DAC) to Mitigation Site. It is not a natural channel
    d. Ken stated the emergent vegetation in this channel is the most productive in the delta. Ken does not want this channel altered and suggests the projects focus on the upper delta

8. Delta Face Protection/ Water Control Project
    a. Ben will model Nueces Bay hydrodynamics

9. Allison WWTP Diversion Project Ponds
    a. Keep in presentation
    b. Issue is meeting the 4 mg/L NH_4 limit

10. Peripheral Sources of Freshwater for the Delta
    a. Odem?

Next meeting 2/19/2015 @ 1000h

2/19/2015

Time: 10:00-11:10

Nueces Delta Landform Modifications Project Team
"Phone Conference to Refine and Finalize Landform Modification Recommendation Ideas for NEAC meeting and CBBF meeting"

Participants

Paul Carangelo (PC)
Kara Thompson (KT)
Erin Hill (EH)
James Dodson (JD)
Brien Nicolau (BN)
Ben Hodges (BH)
George Ward (GW)
Ken Dunton (KD)

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4. This phone conference call was to refine and better detail the landform recommendation ideas the group decided on to present at the NEAC meeting this Monday 2/23/2015, and CBBF meeting on 3/9/2015.
5. James discussed the format of the NEAC presentation and went through each slide. The presentation is not complete at this point.
6. Ben discussed in detail his models he ran for Case 1 through Case 5 (See attached Agenda):
    i. Case 1- BASELINE
        1. Normal flow of RBP without diversions. He did not discuss this model.
    ii. Case 2: DIVERSION TO NORTHWEST FLATS OF DELTA
        1. Effective in getting water to the northwest flats of the delta
        2. Needs a bigger structure on Rincon so no backflow will occur to river proper
    iii. Case 3: DIVERSION FROM UPPER RINCON TO SOUTH LAKE
        1. Problem with this scenario is the water is pushed through the existing diversion
        2. This would need an additional structure to block the existing diversion
    iv. Case4: DIVERSION FROM MIDDLE RINCON TO SOUTH LAKE
        1. Definitely would need a control structure
        2. This requires a lot of water to back up in the northwestern flats before flow begins to South Lake.
        3. VERY INTERESTING SCENARIO
    v. Case 5: DIVERSION FROM NORTH LAKE TO SOUTH LAKE
        1. This scenario does not have an effect unless under high tides
7. RECOMMENDATIONS THAT WILL BE PRESENTED TO NEAC AND CBBF
    a. Project 1: Upper Delta Nueces River to Rincon Bayou Diversion
    b. Project 2: Upper Rincon Bayou Diversion to High Marsh/Wetlands North of Rincon Bayou (Case 2).
    c. Project 3: East End of Upper Rincon Bayou Control Structure & Diversion to South Lake

d. Project 4: Middle Rincon Bayou to South Lake Diversion
e. Project 5: North Lake to South Lake Diversion
f. Project 6: Lower Delta Nueces River Diversion
g. Project 7: Diversion of Odem WWTP Discharge and Peters Swale Stormwater
h. Project 8: Restoration of Allison WWTP Discharge to South Lake
i. Other(s): Conceptual Nueces Delta Face/Upper Nueces Bay Projects

8. It was decided to keep Project 1 to stimulate conversation at the NEAC meeting.
9. PC- suggested to add an additional Project that involves intentional creation of habitat. (Paul, did I get this right?)
10. The Landform Team, those that will be attending the NEAC meeting 2/23/2015, will meet Monday 2/23/2015 at 1100 hr. at CCS for lunch. We will also meet with Dr. Zimba about his recent CMP funded project in the delta dealing with freshwater connectivity between the marsh and bay.

E-mail from James Dodson, re: 2-19-15 MEETING AGENDA

Here is my suggested agenda for tomorrow's project team conf call:

1. **Complete descriptions and preliminary evaluations of potential projects we'd like to carry forward and present at the NEAC and CBBF meetings**

   Last Thursday I sent out the Dropbox link below, which should open a spreadsheet with the drafts of the project description worksheets:
   https://www.dropbox.com/s/dg0cwj9og80gbfx/Nueces%20Delta%20Landform%20Mod%20Project%20Description%20Worksheets.xls?dl=0

   I hope we can go through each of these and discuss whether to carry it forward and, if we do, try to fill in the blanks (they all have a lot). So, if you get a chance to look them over before the conf call and develop your own list of those you think should be carried forward, it will go much faster. Also, if you do fill in some of the blanks on those, and can send me your revisions today, I'll post the changes up for everyone to access before the meeting.

2. **Determine format/presenters for presentation of potential projects to stakeholders at NEAC and CBBF meetings.**

Monday's NEAC meeting is just around the corner. I'll work on a first draft of a Powerpoint today and try to get it out before tomorrow's meeting so we can go over it. Please let me know if you will be able to attend the NEAC meeting – that will help determine who will be presenting different parts of this.

In that regard, my first thoughts are:

- I will introduce the background for the project, the project approach, and the project team
- Given the experience Brien, Erin, Ken and George have had with the history of projects in the Delta over the past 25 years, I'd hope several of you will speak to that
- Since Ben will be there and presenting on his other project, I'd like him to show one or two of his award winning YouTube clips (see attached copy of links to Ben's videos), and explain what we're looking at them to do in the way of helping us screen options.
- I'll go through the description of each of the projects we're going to put on the table (using the maps and information in the worksheets)

3. **Review project work plan/schedule and project administration (i.e., billing)**
4. **Other business**

E-mail from Ben Hodges to Project Team 2-16-15:

Hi All

Some preliminary model work: I've uploaded animations to YouTube as that's the easiest way to stream them without overloading mailboxes. These are all based on 23 days of pumping with 1 pump, with no wind, or tide and an initial water surface elevation of 0.2 m.

Baseline: http://youtu.be/mu7mFINgBsg
One issue is that the relative fluxes out of the Upper Rincon Bayou through the main channel and through the overflow have not been calibrated, so the balance as to the relative fluxes in each is not necessarily correct.

Case 2: http://youtu.be/qqRLGAO93yY
Similar to baseline, but added blocking both downstream of pipeline and upstream of pipeline. We had not previously discussed an upstream blocking feature, but this proved necessary to prevent back flow into the main channel of the Nueces River. It takes a fair bit of flow retention in the upper Rincon to make this work, but it seems effective in flushing the northwestern flats.

Case 3 http://youtu.be/gjAfNBXFwcQ
Channel from Upper Rincon to South Lake. This channel is essentially useless at the low water elevations in these simulations. To get significant action we would need a control structure at the outlet of the Upper Rincon as well. However, it is also possible that wind and tide would provide some flushing here. I will set up some additional simulations.

Case 4 http://youtu.be/42J50DflGAE
Channel from Middle Rincon to South Lake with a blocking structure in the Middle Rincon. This requires a significant backup of water in the northwestern flats before you get flushing into the South Lake. However, it does appear to eventually flush the South Lake region.

Case 5 http://youtu.be/kKO0IEUFGjY
Channel from North Lake to South Lake without any blocking structures. At the low water levels and without wind and tide, this has essentially no effect.

2/23/2015
Time: 1:30 pm-5:00 pm

NEAC Meeting, Water Utilities Building

Purpose: "Charrette for Presenting Landform Modification Recommendation Ideas to the NEAC"

Nueces Delta Landform Modifications Project Team

Participants from the NDLM group

Paul Carangelo (PC)
Kara Thompson (KT)
Erin Hill (EH)
James Dodson (JD)
Brien Nicolau (BN)
Ben Hodges (BH)

Under each Project number will include NEAC's comments along with Ben Hodges' model information, those that apply, he provided to the NDLM group.

> Some preliminary model work: I've uploaded animations to YouTube as that's the easiest way to stream them without overloading mailboxes. These are all based on 23 days of pumping with 1 pump, with no wind, or tide and an initial water surface elevation of 0.2 m.
> Baseline: http://youtu.be/mu7mFINgBsg
> One issue is that the relative fluxes out of the Upper Rincon Bayou through the main channel and through the overflow have not been calibrated, so the balance as to the relative fluxes in each is not necessarily correct.

Recommendation 1: "Upper Delta Nueces River to Rincon Bayou Diversion" (George Ward)

Comments:

1. Are you assuming all the agencies will be on board with these recommendations? No assumptions were made with any of these recommendations
2. What is the elevation needed for water to move down the NOC? Not sure, I do not have the LIDAR data with me
3. Who owns the land? CBBEP
4. Do you know the CFS needed for flow to run through the Rincon Bayou? No
5. Will there be problems with damaging the highway? I don't think so, this area already floods during high inflow times.

Recommendation 2: http://youtu.be/qqRLGAO93yY
"Upper Rincon Bayou Diversion to High Marsh/Wetlands North of Rincon Bayou"

"Similar to baseline, but added blocking both downstream of pipeline and upstream of pipeline. We had not previously discussed an upstream blocking feature, but this proved necessary to prevent back flow into the main channel of the Nueces River. It takes a fair bit of flow retention in the upper Rincon to make this work, but it seems effective in flushing the northwestern flats."

Comments:

1. How many pumps and how many days? 1 pump for 23 days
2. The first movie showed RBP baseline water movement with no tide or wind
3. Second movie showed RBP flow with wind and tide.
4. Group would like to see wind vectors on the movies

5. What will the water depth be in the wetland/flat area when the water pushes up into that area? Probably 3''-4'' a sheet flow.
6. Is this CBBEP property? Yes

Recommendation 3: http://youtu.be/gjAfNBXFwcQ

"East End of Upper Rincon Bayou Control Structure & Diversion to South Lake Area"

Channel from Upper Rincon to South Lake. This channel is essentially useless at the low water elevations in these simulations. To get significant action we would need a control structure at the outlet of the Upper Rincon as well. However, it is also possible that wind and tide would provide some flushing here. I will set up some additional simulations.

Comments: None

Recommendation 4: http://youtu.be/42J50DflGAE

"Middle Rincon Bayou to South Lake Diversion"

Channel from Middle Rincon to South Lake with a blocking structure in the Middle Rincon. This requires a significant backup of water in the northwestern flats before you get flushing into the South Lake. However, it does appear to eventually flush the South Lake region.

Comments:

1. How will you construct the channel based on elevation? Will the depth of the channel be the same as Rincon at the start and where the channel ends will the depth be that of South Lake?
2. There were two blue lines that broke through to South Lake that was shown in the movie, what is this area? Yes, the larger blue channel is a natural depression located at the power lines. The build channel will not be dug in this area for scouring and potential damage to the power lines.

Recommendation 5: http://youtu.be/kKO0IEUFGjY

"North Lake to South Lake System Diversion"

Channel from North Lake to South Lake without any blocking structures. At the low water levels and without wind and tide, this has essentially no effect.

Comments: None

Recommendation 6: "Lower Delta Nueces River Diversion"

Comments:

1. How will water get into this area? Only Overbanking
2. Discussed the existing small channel that connects the Nueces River to the DAC. This has been connected since John Adam's days in the Mitigation Site.

Recommendation7: "Diversion of Odem WWTP Discharge and Peters Swale Stormwater"

Comments:

1. What is the discharge of WWTP? Not huge ~0.2 MGD

Recommendation 8: "Restoration of the Allison WWTP Discharge to South Lake"

Comments:

1. What is the ammonia limit? 4 mg/L

2. Jace Tunnell commented on the permitting issues and that Flint Hills is taking Allison effluent for reuse.
3. NEAC mention the City will be building a consolidated plant at/near the Greenwood Plant resulting in the closing of Allison WWTP in the future.
4. Paul Carangelo brought up the idea again of getting a permit to pump effluent water directly from the Nueces River to the Allison ponds/cells.

Recommendation 9: "Other Recommendations- Conceptual Nueces Delta Face/Nueces Bay Projects"

Comments:

1. Place dredge material in south part of Nueces Bay to create new marsh
2. John Adams commented the earliest modification to Nueces Bay was in the 1920's.
3. Idea> Place a dam at the Nueces Bay Causeway
4. Idea> Place/Make a dam at the rails road bridge in the delta
5. Question: How much does the railroad (dam/berm part) affect flow in the delta? A lot. The railroad bridge really affects the flow. Need to look at the model to understand it more thoroughly. Overall, it is the elevation in the delta that affects flow.
6. Model shows clearly three zones based on salt.
    a. Rincon> Fresh (RBP)
    b. Middle Delta> Salt Flat
    c. Lower Delta (south lake area)> Salt water

3/9/2015
Time: 5:30 pm-7:00 pm

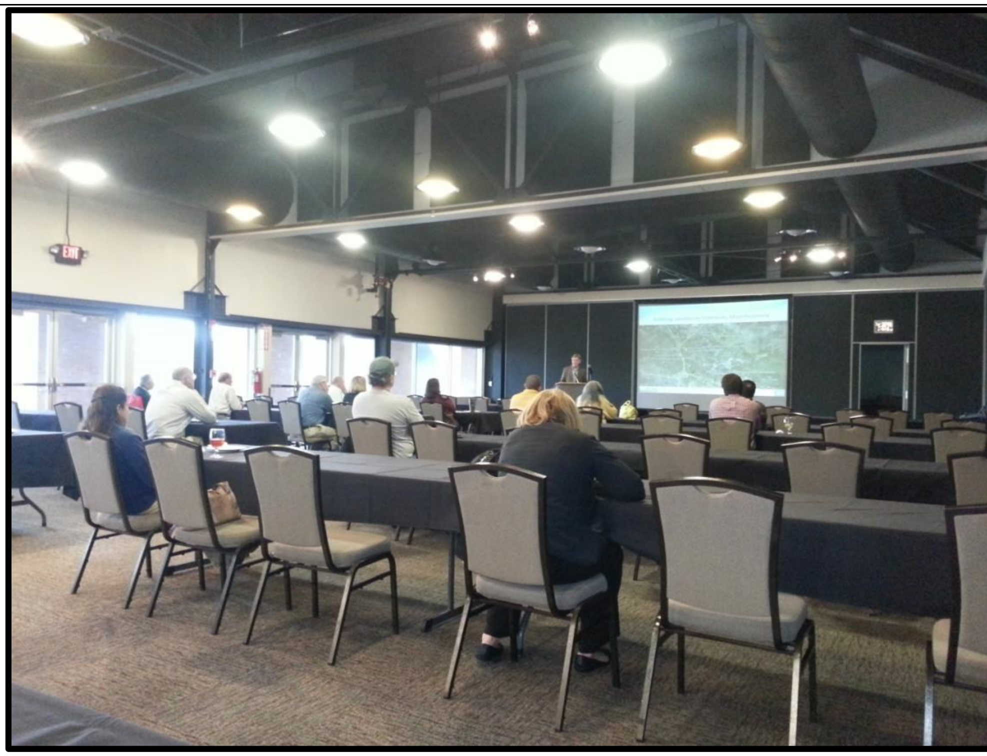
CBBF Forum Meeting, Ortiz Center

Purpose: "Charrette for Presenting Landform Modification Recommendation Ideas"

Nueces Delta Landform Modifications Project Team

Participants from the NDLM group

James Dodson (JD)-presenter
Kara Thompson (KT)
Erin Hill (EH)



Under each Project number will include CBBF Forum attendee.

Recommendation 1: "Upper Delta Nueces River to Rincon Bayou Diversion" (George Ward)

Comments:

1. How far do you want the salinity gradient to extend? Once the gradient is defined the water swashes around via tide and wind.

Recommendation 2: "Upper Rincon Bayou Diversion to High Marsh/Wetlands North of Rincon Bayou"

Comments:

1. Are all models independent? Yes
2. Do you have a model of the ideal salinity gradient and how it will be achieved? We are trying to figure it out with using these independent scenario models using the RBP to solve this

Recommendation 3: "East End of Upper Rincon Bayou Control Structure & Diversion to South Lake

Area"

Comments:

1. How many acres are you trying to impact? 200 acres? We are trying to maximize surface area of any freshwater available to the delta.

Recommendation 4: "Middle Rincon Bayou to South Lake Diversion"

Comments: None

Recommendation 5 "North Lake to South Lake System Diversion"

Comments: None

Recommendation 6: "Lower Delta Nueces River Diversion"
Comments: None

Recommendation7: "Diversion of Odem WWTP Discharge and Peters Swale Stormwater"

Comments: None

Recommendation 8: "Restoration of the Allison WWTP Discharge to South Lake"

Comments: None

Recommendation 9: "Other Recommendations- Conceptual Nueces Delta Face/Nueces Bay Projects"

Comments:

1. More information on oyster reefs.

General Comments

- Who are the stakeholders?
  - NEAC was given this presentation and we will also be presenting this to BBASC
- Before Wesley Seale and Choke Canyon was marsh hypersaline?
  - It was much fresher-refer to the BBASC reports-
  - James described the 1990 process of the Agreed Order and mandated water releases from LCC to the Nueces Estuary
- What was the overall cost of this project
  - $95,000
- What will be the overall cost to finish the project to include item lines 5 and 6?
- Was this done in all river systems in Texas?
  - Yes, it was the Senate Bill 3 process.
- Will all the projects come together for evaluation?
  - Most of the issues addressed in each basin were specific to their system
- Who owns the delta

        - The majority is owned by the CBBEP but there are still private land owners.
    - SLR was discussed and is factored in this process to make the delta more resilient
    - Desalination questions? Will it make the delta more salty?

3/25/2015
Time: 1:30-3:30

Nueces Delta Landform Modifications Project Team
"Landform Modification Recommendation Ideas meeting"

Participants

Kara Thompson (KT)
Erin Hill (EH)
James Dodson (JD)
Jake Herring (JH)
Ben Hodges (BH)
George Ward (GW)
Ken Dunton (KD)
Grant Jackson (GJ)

Meeting Notes

- Group decided to come up with a system-based approach using all models.
- The use of rubber dams/ aqua dams was discussed and is currently being explored to use as a dam structure for diverting freshwater flow
- Rubber dams are not permanent structures and can be moved if the flow from the land modification does not match the model
- CBBEP used the aqua dams during the RBP dam construction
- Lester Contracting did the aqua dam work for CBBEP
- Need to define delta acreage that will be affected by flow from the modification
- Ben commented his model will be able to define the acreage that receives flow from the modification
- Ben commented he needs to adjust channel depths in models and look at different scenarios
- Discussion on the RBP pumping events are more efficient during high tides
- Jake made a suggestion to replace culverts at the first Rincon Bayou crossing on the Preserve with box culverts. This may reduce flooding in the area when modifications are made to divert flow to the northern flats of the delta (near 77).
- Grant-Don't forget about Odem WWTP discharge for the North area, the plant has an elevation advantage
- Melanie and Paul worked on the Odem WWTP permit
- Need to talk with Rick Kalke about HRI's stations and ask him to join us on the delta tour
- Group decided on a delta tour to ground truth the areas of interest
- Tour will be either 4/13/2015 or 4/17/2015 need to wait for the delta to dry out
- Jake will send the tour map
- Question: Have the models changed from Ben's first set of movies he sent before the NEAC meeting? Yes
- Question: What are the channel depths in the models? Channel depths vary model to model
- As of 3/2015 the CBBEP owns ~8700 acres of the delta

Approximate <u>areas</u> and <u>lengths</u> based on Google Earth imagery

Delta	~14,000 acres
Northern marsh/flat area	~945 acres
South Lake	~250 acres
North Lake	~125 acres
Mitigations Site	~190 acres
Nueces Bay	~16,720 acres

Length of Nueces River from Labonte Park	~11 miles
Length of Rincon Bayou from NOC to Nueces Bay	~9.28 miles
Length of Delta Access Channel from RR bridge to Nueces Bay	~3 miles

04/14/2015
Time: 10:00-11:10

Nueces Delta Landform Modifications Project Team

“Phone Conference”

Participants

Kara Thompson (KT)

Erin Hill (EH)
James Dodson (JD)
George Ward (GW)
Jake Herring (JH)
Dave Sullivan (DS)

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1. This phone conference call was to make arrangements for Nueces Delta Site Visit and discuss and review project schedule and work products.

2. Jake gave an update to the Delta roads. With our heavy rains this morning there are roads that are under water. Prior to this morning's storm the roads were starting to dry out. The RBP started yesterday, 4/13/2015, and is still pumping water.

3. James suggested June is too late to make a delta site visit and recommends the visit be sooner. Doodle Poll results currently show Friday, May 15, 2015 as the tentative date for the visit. James still wants to hear back from Ken before finalizing this date.

4. James discussed Erin and his visit with Rick Kalke.

5. James discussed project timeline.

    a. Task 3 is currently in progress which is the conceptual design process.
    b. Kara has been pulling together the conceptual design ideas, inflatable dams, etc.
    c. James want to put together a design team, Kara, Grant, other NEI staff, and any other team members interested.
6. Schedule
    a. End of May 2015> Draft of conceptual design completed
    b. End of June 2015> Draft report completed
    c. Task 4> Ben will parameterize with model

7. Dave suggested putting together a report outline
8. Working meeting is scheduled for next Tuesday, April, 21, 2015 @ 0930 @ NEI office
9. List needs to be created giving agencies that need to be involved with this project
10. Mid-May> week of the 11th will schedule meeting with agencies.

Meeting Agenda

James A. Dodson 405 W. Power Ave Project Manager Victoria, TX 77901 Naismith Engineering, Inc. 361-649-1518

MEMORANDUM
TO: Nueces Delta Landform Modifications Project Team
FROM: James Dodson, Project Manager
DATE: April 13, 2015
Re: Project Team Conference Call Tomorrow
Date/Time: Tuesday, January 14, 2015 at 10:00 a.m.
Conference call instructions below

AGENDA

I. Arrangements for Nueces Delta Site Visit

II. Project Schedule and Work Products

III. Other business

To Join the Conference Call:
Conference call will open at 9:55 a.m.

I. Dial toll-free: 1-866-590-5055

II. When requested, enter access code: 8463538, then hit # key

III. You should be added to the conference call

4/21/2015
NEI Office
Time: 9:30 am -12:15 pm

NEI Meeting- Conceptual Design

Participants

James Dodson
Erin Hill
Jake Herring
Grant Jackson
Kara Thompson
Dave Sullivan

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1. **Introduction**
    11. Group discussed Ben's models and the permitting issues that will likely need to be addressed. The group prepared a list of the projects that will move forward into the conceptual design process.
    12. The draft report is due at the end of June 2015.
    13. After the draft report is submitted, it will need to be sent out for comment.
    14. Group discussed which groups the report may be presented to, NEAC? BBEST?

2. **Questions that need to be addressed**
    - Where do we want the water to go? Why?
    - Where do we put the structures?
    - Will the structures divert the water where it is intended?

3. **Projects 2, 3, 4, and 7 were proposed to be the projects to move forward.**

4. **Discussion on RB diversion and permitting with CBBEP**

5. **Project 7: Odem Wastewater Treatment Plant**
    - To flood the northwest corner of delta the water will have to come from Odem due to a 25 ft. elevation change.
    - If the proposed structure was in place it would drain the northwest corner rather than flood it.
    - Capture the WWTP water at the blue/red line meeting point then divert to the west
    - This is state water, either (1) Reclaimed water Authorization or (2) TCEQ Water Right Permit
    - Need to prepare a cost ration for this project
    - Most technically feasible way to get water to the northwest corner is using gravity
    - WWTP is by gravity, no pump
    - This project would require an easement
    - Question: What about rerouting Odem WWTP?
    - Comment: When the blowout occurred on White's Point, they brought a lot of mud from the blow out site to the sand pits located in the northwest corner of delta.
    - Will require both freshwater and saltwater rights

- **<u>Bottom line</u>**
- Either: (1) put in a pipe and send the water west, or (2) use a diversion structure and ditch
- Can Ben answer: What is the magic elevation to divert water through project structure #2?
- Possibly change #2 structure to point to the west using a bladder dam
- The culverts along the road need to be scouted for hydraulic issues.

6. **Project #3**
   - Move water counter clockwise at structure #3.
   - Move structure #3 to block off the delta fan at the top of the Rincon pool.
     - **<u>Bottom line</u>**
     - This project needs to be better refined

7. **Need to define main zones of delta and standardize the nomenclature for names of areas in the delta.**
   - CBBEP's name for the northwest tidal flat area is West Lake
   - Crooked Lake is west of South Lake
     - **<u>Bottom Line</u>**
     - Keep nomenclature consistent with the BOR report

8. **Project #4**
   - Need a rough estimate of bathymetry for this structure
   - This project would require a very wide bladder dam
   - ERCOT and RR Commission> transmission line data
   - **CROOKED LAKE IS NOT IDENTIFIED IN BEN'S MODELS**
   - Crooked Lake is isolated from ebb and tide. Is mostly dry.
   - Need to ask Ben about Crooked Lake

9. **For the report**
   - Build the rational why we are putting water where we are.
     - This is the basis for the conceptual design
     - Need a comparative mechanism for the "bang of the buck", need a metric
     - Discussion on using salinity as the metric
     - Questions that need to be answered
       a. Vegetation changes?
       b. Salinity changes?
       c. State Criteria.
       d. Take each structure and determine the acreage that will be inundated with water
   - James suggested having a meeting with Ben and Ken for determining the criteria
   - Design a table with objective > alternative > match criteria
   - State the reason for the timing and conditions of model
     - Low flow period
     - Only controllable period is the critical low flow period
     - Run the model after the pumps have stopped to determine retention time

- There is no management protocol for the operation of the RBP or for the RBP gate structure
- Discussion on having the operation of the RBP become a part the proposed Project structure in the report. This would give volume of water needed to achieve the project goal.

10. Discussion on the management of RBP pumping

5/1/2015
NEI Office
Time: 1:00 -3:00 pm

NEI Meeting- Conceptual Design with Ben Hodges

Attendees

James Dodson
Erin Hill
Jake Herring
Grant Jackson
Kara Thompson
Ben Hodges

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11. Meeting focused on Ben's models with much discussion on channel placement and volume of water needed for model scenario to work

15. Modifications have been made to the current model scenarios.
16. Three new/modified scenarios were discussed, none of the scenarios use control structures.
    - Scenario 1: Channel to northern tidal flat area.
    - Scenario 2: Dig a channel from Rincon Bayou to South Lake with no control structures.
    - Scenario 3: Dig a channel from mid Rincon Bayou to South Lake (this appears to be the best).
- Questions/ Comments:
    1. Need to know the flow in the model.
    2. Would a control structure be useful if placed at the top of the channel cut in Scenario 2 so Nueces Bay water would not push back into the delta?
    3. Approximate excavating depth of channels is 2 ft.

12. Questions that need to be addressed

- What is considered freshwater
- What are the differences the model is using?
    - Starting with 35 in each model
- Discussion on using % dilution for a criteria marker
- Discussion on using two colors in model to show salt and dilution
- Discussion on using blocks that show areas with salinity, 0-5, 5-15, 15-25 etc.
    - Blocks may be a good basis to compare between scenario options.
- Discussion about not including Crooked Lake in any landform modification scenario. Not practical.

13. Next Steps

- Need to talk with the City of Corpus Christi about this report including a management plan for the RBP.
- Run model at high tide which is an internal infrastructure already in place.
- Discussion on channelization of RBP is good too, in that it reduces pore water salinity.

- Run models using 1200 ac/ft. and 250,000 mgd from the Odem WWTP.

5/15/2015
Phone Conference
Time: 10:00 am – 10:30 am

NEI Meeting- Conceptual Design –

Attendees

James Dodson
Erin Hill
Kara Thompson
Ben Hodges
Kara Thompson
George Ward

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1. James gave a recap of the 5/1/15 meeting with Ben Hodges.

2. Progress Report
   a. Meeting with City of Corpus Christi (Rick Clayton) has not been scheduled.
   b. James, Erin, Jake, and Ray will meet prior to or after the scheduled NEI meeting on 5/27/2015.

3. Ben's Update on Models
   a. He added Odem WWTP (3 cfs) to the models and it shows no effect in terms of the RBP pumping regime.
   b. The Odem WWTP is a cumulative effect, source is important to freshwater availability in the delta.
   c. Parameters Ben is focusing on:
      i. Duration of pumped water
      ii. Water depth coverage
      iii. Area covered with water
         1. Channel cuts do not increase coverage.
         2. The channels allow coverage to areas that are not normally covered, at the expense to areas that typically experience water coverage.
         3. Channels should be used to flush areas in a management sense.
         4. The use of weirs or gates at channel openings could manage flushing strategies.
      iv. Flow rates have not been calculated.
      v. Question: Should the gates remain open during non-pumping conditions?
      vi. Suggestion: Keep the gates open only during the first 1/3 of pumping event to flush more delta area.

4. Project Timing
   a. Ben will have graphs and models to James by 6/18/2015

5. Next meeting 5/26/2015 or 5/27/2015

6. Contractors need to submit invoices.

5/27/2015
NDLFM Meeting @ NEI main office with phone dial in
Time: 12:00 pm – 4:00 pm

NEI Meeting- Conceptual Design _ continued–

<u>Attendees</u>

James Dodson
Erin Hill
Kara Thompson
Ben Hodges
Brien Nicolau
George Ward
Ken Dunton
Jake Herring
Rae Mooney
Grant Jackson

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1. Prior to the main team meeting, James Dodson, Erin Hill, Brien Nicolau, Kara Thompson, Jake Herring, and Rae Mooney met to discuss the upcoming meeting with the City of Corpus Christi regarding the management of the Rincon Bayou Pipeline pumping. Meeting was 12:00 pm – 1:30 pm.
    a. Discussed the RBP would be a system-wide management approach with the use of control structures.
    b. Discussed projecting a budget for operating and managing the delta system approach with CBBEP's involvement or other select groups.
    c. Discussion about "who is managing the banked water" in Lake Corpus Christi.
    d. Need to have Nueces River Authorities involvement with City and the RBP.

Team Meeting Notes

1. James recapped the 5/15/2015 meeting.
    a. Discussed Ben's models: when areas of interest flood other areas that typically inundate do not.
    b. The design recommendations now include structures.
    c. Discussed when water goes to South Lake, it quickly moves out to Nueces Bay. Appears the water is unable to move to flats.
    d. It is not clear what level the weirs need to be at for water flow.
    e. Discussed Odem's WWTP had little effect in comparison to the RBP pump regime but this recommendation will stay in the plan due to the cumulative effects.
    f. 6/15/2015 Ben will provide James with the model pictures for the report.

2. Report Outline, Assignments, and Project Schedule

   a. Format of the report was discussed. We will follow the TWDB template.
   b. No changes will be made to the report format outline James' provided.
   c. James delegated report sections to the team.
   d. Questions for Ken (we had a poor telephone connection with him via Mexico): What is the minimum depth and the duration we want to achieve with the modifications.

3. Conceptual Design Work Products – weir structures, Odem WWTP effluent diversion
   a. Discussion of trade-offs between bladder dams and weirs.
   b. Grant likes the use of bladder dams.
   c. Discussion of ladder boards.
   d. Discussion between Ben and Den on identifying parameters that identify areas that need water (ex.: 1 cm, 1mm, <15 , etc.)

4. Rincon Bayou "System Operating Plan" Concept and meeting to be held with City of Corpus Christi
   a. James will keep group updated on City's response to plan

5. Other Issues
   a. Submit invoices
   b. Need to write a one page synopsis for NEAC about this study
   c. NEAC meeting 6/22/2015, group will give a presentation.
   d. Project report draft due at the end of 6/2015.
   e. Project end date 8/30/2015.

6/22/2015
NEAC Meeting- Presenting final NDLFM Recommendations
Time: 1:30

Attendees

James Dodson
Kara Thompson
Ben Hodges
Brien Nicolau

Nueces Estuary Advisory Council (NEAC) Meeting
Monday June 22, 2015 1:30
Choke Canyon Room Water Utilities Building
2726Holly Road Corpus Christi

Agenda

1. Call to Order
2. Introductions
3. Approval of February 23, 2015 meeting minutes
4. Presentations from contractors selected for workplan priority projects

Nueces Delta Hydrodynamic Model – Ben Hodges
Nueces Landform Modifications – James Dodson
Nueces Monthly Inflow Evaluation – Cory Shockley
Nueces Nutrient Changes over Time – Paula Lemonds

5. Review of workplan project reports and SB3 funding – Ruben Solis
6. Corpus Christi Drought Situation Update – Brent Clayton
7. Other items identified by NEAC members
8. Future meeting date and time
9. Adjourn

7.3 Appendix C – Bibliography

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