# Final Report

## Evaluation of Freshwater Delivery Alternatives to East Matagorda Bay

August 26, 2015


Contributors

Barney Austin

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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.*




AquaStrategies

Job No. 14004

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# 0 Executive Summary

For many years, East Matagorda Bay (EMB) has remained relatively isolated from freshwater inflow because of the old Colorado River delta to the east and because of the Gulf Intracoastal Waterway (GIWW) to the north. Using existing available data and studies, this project investigates methods to augment freshwater inflows into EMB. The goal of this project is to determine the timing and delivery rate of fresh water to East Matagorda Bay that could have a positive impact on the health and productivity of the estuary. Additionally, this project seeks to find a cost-effective engineering solution for delivering available water from the Colorado River into East Matagorda Bay. Volume of freshwater inflow is investigated according to benefit, based upon reducing EMB salinity for a certain time period to an assumed desirable salinity target range between 20 ppt and 30 ppt. The salinity target range is based upon recent available studies for Matagorda Bay to the west. Volume of freshwater inflow to EMB is also investigated with respect to time periods where that water can be removed from the Colorado River, minimizing impacts to the new Colorado River delta.

For comparatively low freshwater volumes of 3,000 acre-feet and 16,250 acre-feet, several engineered infrastructure scenarios are investigated. Costs for these engineered delivery pipelines range from $4 million to over $150 million, with higher cost generally representing increased confidence in freshwater source (distance from the Gulf) and higher flow levels. A $16 million option diverting water from the Colorado River channel just upstream of the GIWW and discharging into the north western portion of EMB is estimated to be one of the more efficient infrastructure scenarios considering salinity of source water, cost of infrastructure and maintenance of lower salinity (20 to 30 ppt) in the western 25 percent of the bay for three to five months.

Much larger freshwater volumes, between 150,000 and 300,000 acre-feet, are necessary to be delivered to the GIWW from the coastal watersheds in order to impact EMB. A portion of this water that passes across the GIWW into the EMB, reducing salinity across large portions of EMB and is shown to increase weighted usable area of habitat for selected aquatic species. No cost for engineered infrastructure alternatives has been developed to satisfy the entirety of these large volumes. Some alternatives have been identified as beneficial, but additional modeling and study is required to further quantify the degree of benefit. Such alternatives include perforating the spoil islands between the GIWW and north shore of EMB and the Southwest Cut.

Other alternatives have been suggested by participants in the SB3 process. One includes use of brackish groundwater to supply inflow into EMB. Another alternative is to deliver water to marshes in decline located north of the GIWW rather than delivering to EMB; of all the options identified, this alternative may provide the best overall benefit at lowest cost because it can use existing infrastructure and existing already-permitted mechanisms.

Ultimately, before any freshwater diversion alternative is identified for implementation, additional study is required to quantify ecological goals and then resultant inflow volumes to achieve those goals.

# 1 Introduction

Because of natural and man-made conditions, East Matagorda Bay currently receives limited freshwater inflow in comparison to earlier periods, and in comparison to other bays and sub-bays within the Colorado-Lavaca estuary system. The resulting condition is relatively higher salinity and reduced nutrient inputs. This may be having an effect on estuarine organisms that are common to the Colorado-Lavaca estuary system and other estuary systems along the Texas coast, although that effect is not well understood at this time.

The Senate Bill 3 (SB3) Bay-Basin Area Stakeholder Committee (BBASC) for the Colorado-Lavaca system has identified East Matagorda Bay as an area where opportunity may exist to improve ecological conditions by increasing the inflow of freshwater. In 2014, the Texas Water Development Board (TWDB) provided Research and Planning Funds to help identify engineered solutions for freshwater inflow augmentation to East Matagorda Bay.

## 1.1 Problem statement

The Colorado-Lavaca estuary system, including Matagorda Bay and East Matagorda Bay is highly dynamic. Sediment deposition, flooding, meteorological activity and human rerouting have had major influences on the path the river has taken to the Gulf of Mexico and the salinity of the adjacent embayments. The gradual formation of a large log jam in the lower stretches of the river in the early part of the 19th century impeded navigation and spurred the construction of a channel around the obstruction. The subsequent removal of the log jam caused the Colorado River delta to build into then bisect Matagorda Bay. A subsequent project in the early 1990s to redirect the river into present-day Matagorda Bay further changed the hydrodynamics of the region and is causing the gradual formation of a river delta in the bay (Figure 1).

East Matagorda Bay, no longer a significant beneficiary of freshwater inflows from the Colorado River, is further isolated from coastal runoff from the north due to the Gulf Intracoastal Waterway (GIWW) and adjacent spoil islands. The most eastern portion of the bay is somewhat connected to the Gulf, however the western portions are quite isolated, both from the Gulf of Mexico and freshwater inflows (Figure 2).

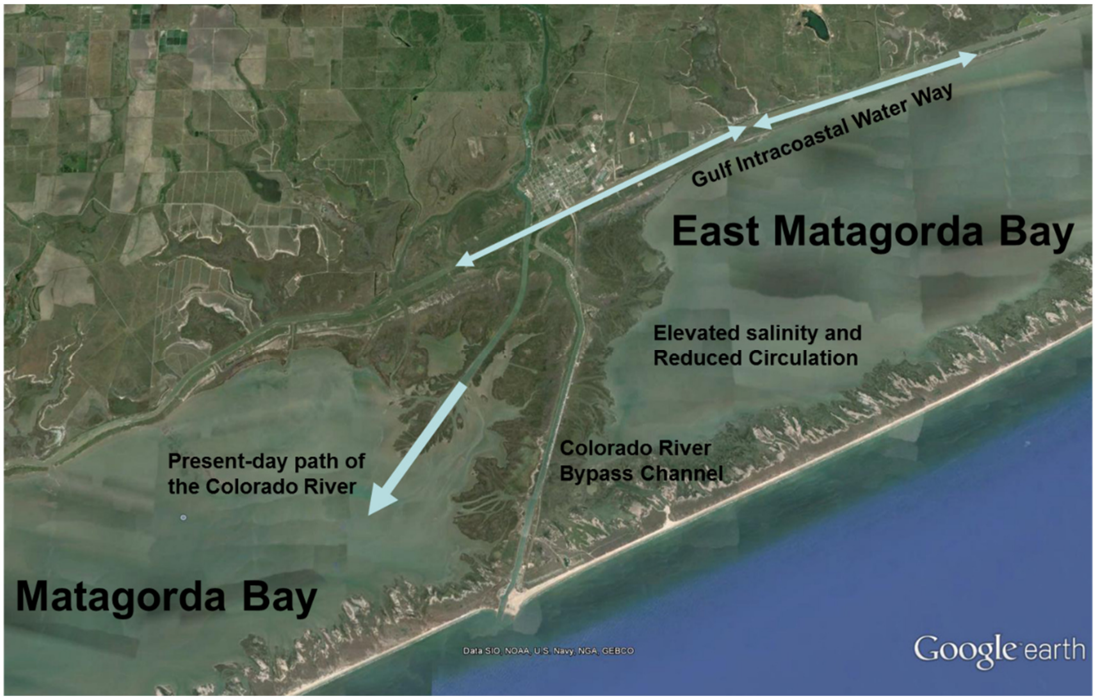



*Figure 1. Current flow path of the Colorado River into the Colorado-Lavaca estuary system.*


*Figure 2. East Matagorda Bay, showing main source of freshwater inflow and the connection to the Gulf of Mexico.*

## 1.2 Ecological Goals

The health and productivity of an estuary is dependent on a number of different factors and can be measured many different ways. For the purposes of this limited study, the ecological goals are defined as an improvement in the ecological habitat for oysters, shrimp and/or estuarine marsh vegetation based on a reduction in salinity. These goals may be achieved through maintaining or increasing the periods when salinity is within the 20-30 parts per thousand (ppt) range. More detail leading to choice of the goal salinity range, and on the timing and duration of the desired salinity range, is described in Section 3.1 of this report. Improved circulation and delivery of nutrients to East Matagorda Bay may also improve health and productivity of the species, habitats and overall estuarine system, although increases in these characteristics are not specifically targeted or quantified in this study. Increased circulation and nutrient delivery are both likely to occur as a result of increased inflow introduced from fresh surface water sources.

An extensive study of the ecological needs of the Matagorda Bay system related to freshwater inflows was performed for the Lower Colorado River Authority and San Antonio Water System. The Matagorda Bay Health Evaluation (MBHE) Inflow Criteria report was released in December 2008 (MBHE 2008), and the results of those studies translate nearly directly into the Senate Bill 3 TCEQ adopted environmental flow rules (TCEQ 2012). Those studies and the rules, however, largely omit study of the impacts of freshwater inflow into East Matagorda Bay because of the limited amount of inflow and the negligible impact changes to Colorado River flow would have on East Matagorda Bay. Additional effort is recommended by the Colorado-Lavaca Bay and Basin Area Stakeholder Committee to further characterize East Matagorda Bay (C-L BBASC 2012).

## 1.3 Scope of this project

The main purpose of this study is to determine the timing and delivery rate of fresh water to East Matagorda Bay that could have a positive impact on the health and productivity of the estuary. The frequency and duration of freshwater delivery that would be beneficial is compared to the timing of possible diversions from the Colorado River, while being cognizant of the potential negative impacts to Matagorda Bay from reductions in freshwater inflows. Rough construction and Operation and Maintenance costs for diversion structures and conveyance facilities to bring water from the Colorado River to East Matagorda Bay are also presented for a number of different alternatives.

With a limited budget and time frame for conducting this work, no new models were developed. Instead this project relies on existing flow and salinity data, and the tools and models developed for the MBHE report.

# 2 Background and Existing Conditions

## 2.1 Hydrology

The hydrology of the study area has been studied extensively by the Texas Water Development Board, Lower Colorado River Authority, US Army Corps of Engineers and consultants. The following section summarizes historical information and presents model results and flow calculations for East Matagorda Bay.

### 2.1.1 Colorado River and Matagorda Bay

Historically, the Colorado River flowed directly into Matagorda Bay, which at one time included the area now known as East Matagorda Bay. Over time the river became obstructed by silt and woody debris that extended miles upstream from the mouth of the river at the bay. Between 1925 and 1929, the log jam was cleared and subsequent river flows moved the debris and silt into Matagorda Bay, building a new delta (Barcak et al. 2007). This delta grew to bisect the bay and by 1935 the river was discharging directly into the Gulf of Mexico. Beginning in the 1920s and continuing through the 1940s, the Gulf Intracoastal Waterway (GIWW) had been constructed along with, by 1944, a set of floodgates (later converted to locks) at the intersection of the GIWW and the Colorado River (Lin et al. 2002).

The bisection created East Matagorda Bay, a secondary Bay in the Matagorda Bay system, and resulted in reduced freshwater inflows into the Matagorda Bay system. In 1991, the US Army Corps of Engineers dredged a diversion channel through the delta to direct freshwater inflows into Matagorda Bay. Freshwater can also enter Matagorda Bay through the GIWW where it intersects the Colorado River just above the bay near the town of Matagorda. While freshwater from the Colorado River during extremely high flow conditions can also enter East Matagorda Bay (EMB) through the GIWW through small passes along the north end of the bay, the majority of the freshwater inflow to EMB is localized from coastal watersheds.

### 2.1.2 Coastal Watersheds

East Matagorda Bay does not receive inflows from any major gaged river or tributary. Rather there are eight ungaged coastal watersheds that contribute to East Matagorda Bay. Figure 3 shows these coastal watersheds which include Water Hole Creek (#13106), Caney Creek (#13105), Peyton Creek (#13101) and Lake Austin via Live Oak Bayou (#13104), Linnville Bayou (#13107), Big Boggy Creek (#13102), and Little Boggy Creek (#13103), as well as surface runoff from the Brazos-Colorado Coastal basin (#13108 A report published by the Texas Water Development Board (TWDB) titled *Coastal Hydrology for East Matagorda Bay* (Shoenbaechler and Guthrie, 2011) estimates the balance of freshwater inflows for East Matagorda Bay from 1977 to 2009 on a daily, monthly, and annual basis.

The calculation of the balance of freshwater inflows includes estimates of surface runoff from the 8 coastal watershed using the Texas Rainfall-Runoff (TxRR) model. The balance also considers other hydrological components including diversions, return flows, evaporation from the Bay and precipitation over the Bay. An annual summary of the balance of freshwater inflows to East Matagorda Bay is included in Section 2.1.4.

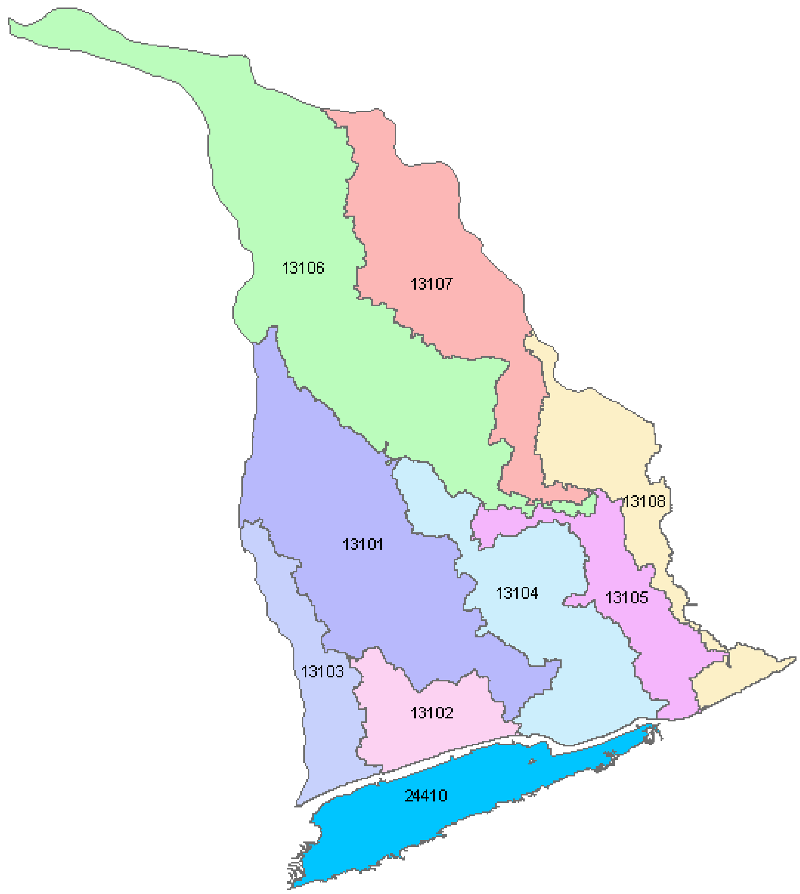



*Figure 3. Ungaged watershed delineation used in TxRR to determine ungaged inflows to the East Matagorda Bay System (Shoenbaechler and Guthrie, 2011).*

### 2.1.3 Diversions and return flows

The ungaged surface inflows determined by the TxRR model were adjusted for known permitted agricultural, municipal, and industrial diversions and return flows obtained from the TCEQ and the TWDB Irrigation Water Use estimates (Shoenbaechler and Guthrie, 2011).

There are 19 major water rights with permitted diversions and 8 major NPDES permitted return flows to the coastal watershed (Figure 4). From the data provided with the TWDB report (Shoenbaechler and Guthrie, 2011) we calculated that on an annual basis, from 1977 to 2009, the maximum amount of water diverted is 8,054 acft/yr, while the average is 4,640 acft/yr. Return flows represent 14,619 acft/yr on average, and a maximum of 21,289 acft/yr. Return flows are significantly higher that diversions because a large portion are irrigation return flows from water that originated from the Colorado River.

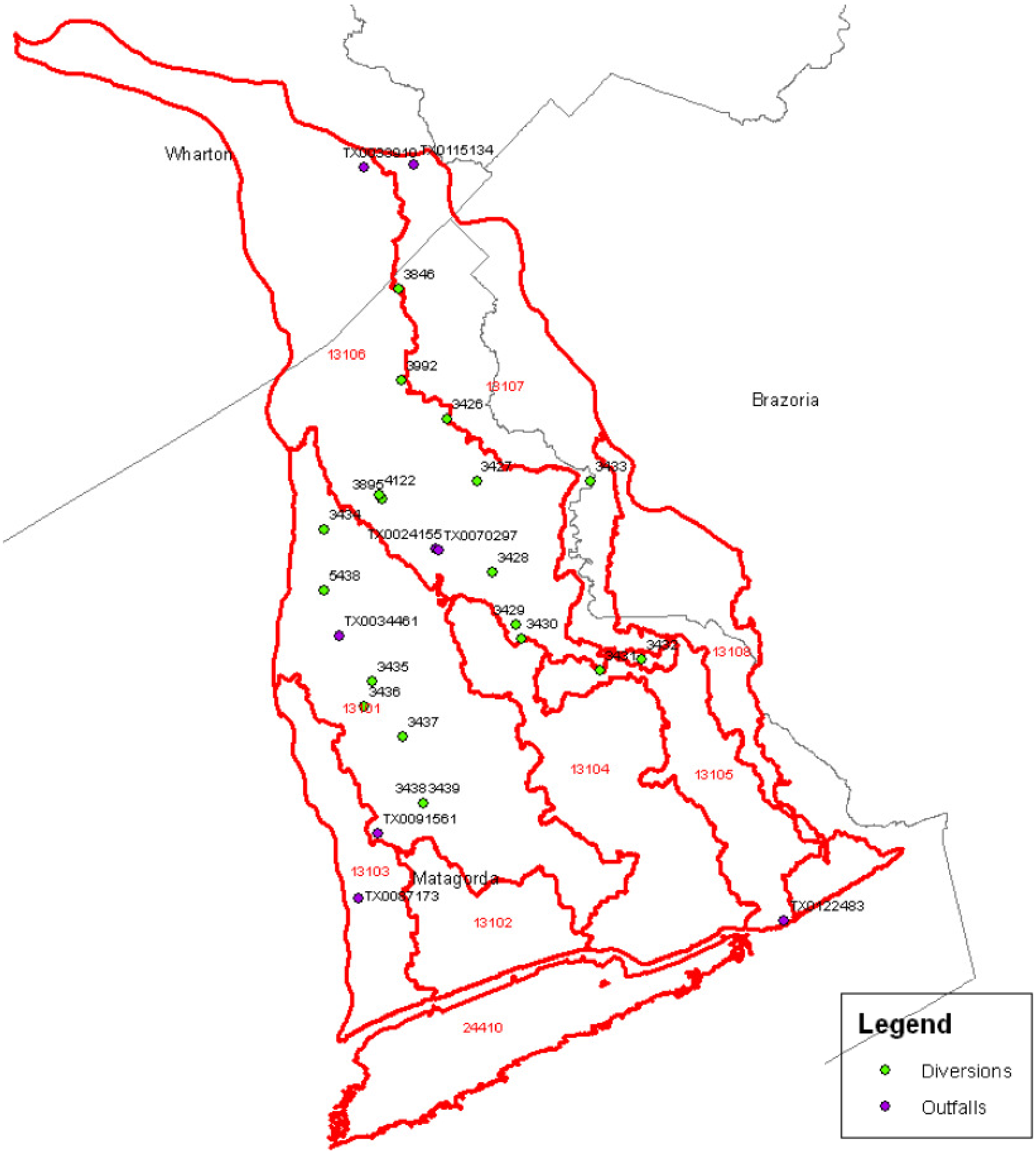



*Figure 4. Location of permitted diversion points and wastewater outfalls in the East Matagorda Bay watershed (Shoenbaechler and Guthrie, 2011).*

### 2.1.4 Freshwater Inflow to East Matagorda Bay

The balance of freshwater inflow ranged from a minimum of 4,059 acft/yr in 1988 to a maximum inflow of 1,266,059 acft/yr in 2004 Figure 5. On average, the balance of freshwater inflow in the vicinity of East Matagorda Bay during the 1977 to 2009 time period was estimated to be 524,054 acft/yr. The present study to demonstrate the impact of inflows on habitat is based upon these estimates of freshwater inflow to East Matagorda Bay developed by TWDB. The methodology used by TWDB to develop these estimates is described by Shoenbaechler and Guthrie (2011).

Monthly inflows to the Matagorda Bay system (including East Matagorda Bay) used in the MBHE study as the input from the MBHE RMA-2 model (Figure 6 and Figure 7) are derived from earlier versions of the balance of freshwater inflow estimates to East Matagorda Bay from TWDB (Figure 5) (MBHE 2008). The coastal watersheds west of Caney Creek (13101 through 13104 on Figure 3), including Little Boggy and Lake Austin watersheds, are located east of the Colorado River and are most likely to contribute inflows (Figure 6 and Figure 7) to the main body of East Matagorda Bay. Coastal watersheds 13105, 13106, 13107 and 13108 (Figure 3) are included in the TWDB inflow balance for the East Matagorda Bay area; however, because of their location east of Caney Creek and the connection to the Gulf at Mitchell’s Cut (just east of the far east end of EMB), inflow contributed by these watersheds typically passes towards the Gulf rather than into EMB. Despite this, the TWDB Inflow Balance that accounts for all of these flows including precipitation and evaporation is used in evaluation of flows for this project because actual proportion of flows entering the main body of EMB from any of these coastal watersheds is not quantified at this time.

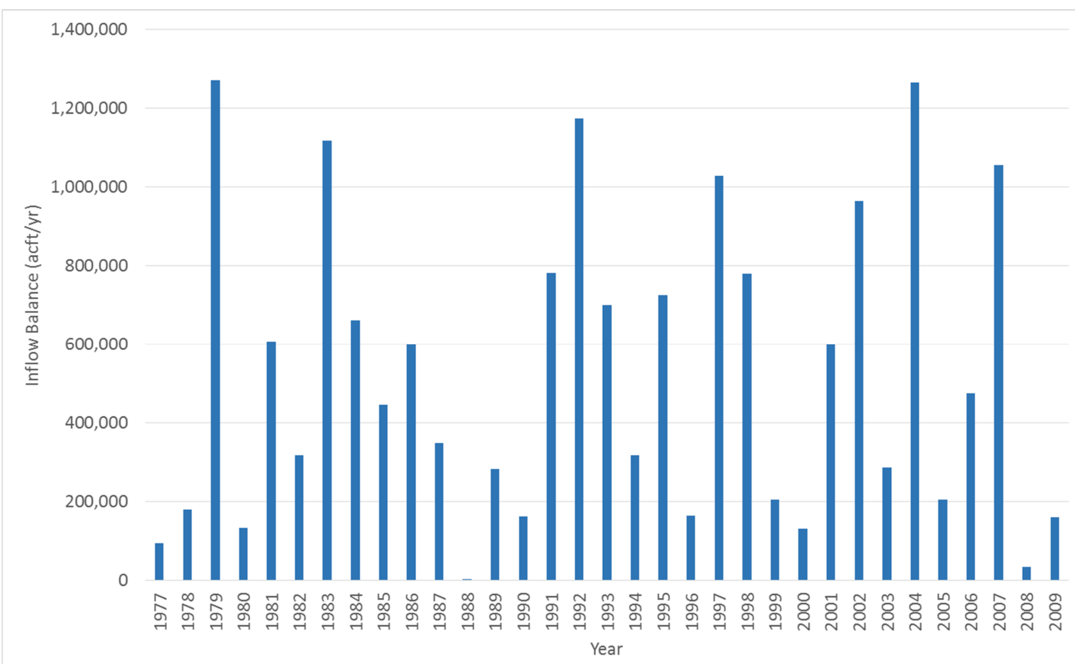



*Figure 5. Annual Estimates of Freshwater Inflow Balance for East Matagorda Bay from 1977 to 2009 (Shoenbaechler and Guthrie 2011).*

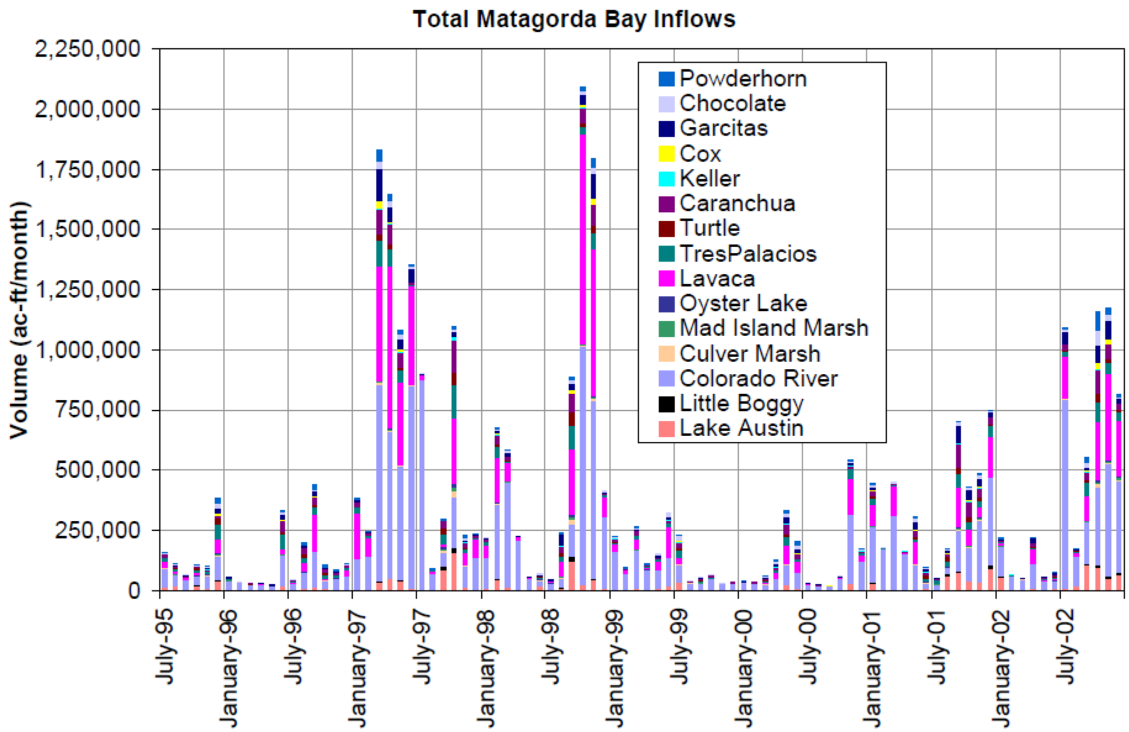



*Figure 6. Distribution of monthly inflows to the Matagorda Bay system (MBHE 2007).*

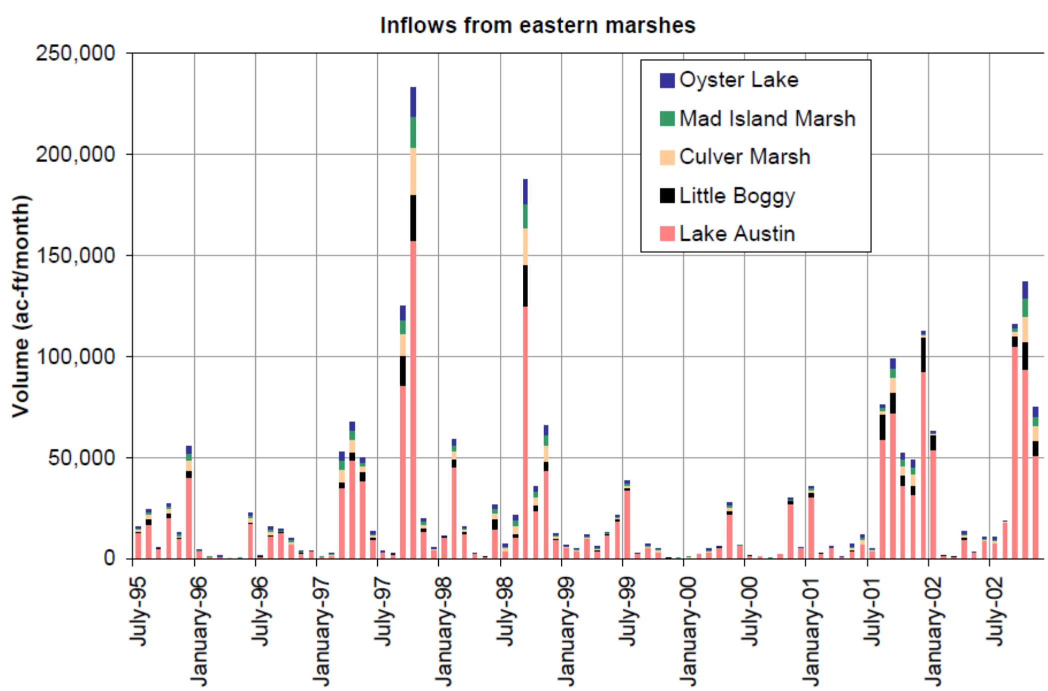



*Figure 7. Distribution of monthly inflows to the Matagorda Bay system from selected marshes (MBHE 2007).*

A proportion of Colorado River flow does travel east toward East Matagorda Bay through the GIWW locks, under low flow conditions when the locks are open; however, this water generally stays within the GIWW. The proportion varies with flow in the Colorado River (Figure 8); the maximum flow traveling east ("GIWW+OB E") is generally not more than 265 cfs (a condition that occurs when Colorado River flow is around 4,500 cfs) (MBHE 2007b). Based upon studies of Colorado River flows in the vicinity of the GIWW intersection (i.e., considering Colorado River flow reported at the Bay City USGS gage, minus South Texas Project [STP] diversions, plus TWDB coastal watershed 14010) for the time period following the Colorado River diversion (after August 1, 1991) through August 2006, the flow eastward of the GIWW intersection is lower than 245 cfs 90% of the time, lower than 100 cfs 50% of the time and lower than 25 cfs 10% of the time.

The Gulf Intracoastal Waterway complicates the hydrology and circulation of water in the vicinity of East Matagorda Bay. The GIWW channel is maintained for navigation and the dredge material is disposed on either side. The east-west flow in the channel combined with the spoil island from dredging activities combine to intercept some portion of the freshwater inflows that could enter East Matagorda Bay from the watersheds in Figure 3. On the other hand, the GIWW also conveys, or at least has the potential to convey, fresh water from watersheds both to the east and west into the Bay.

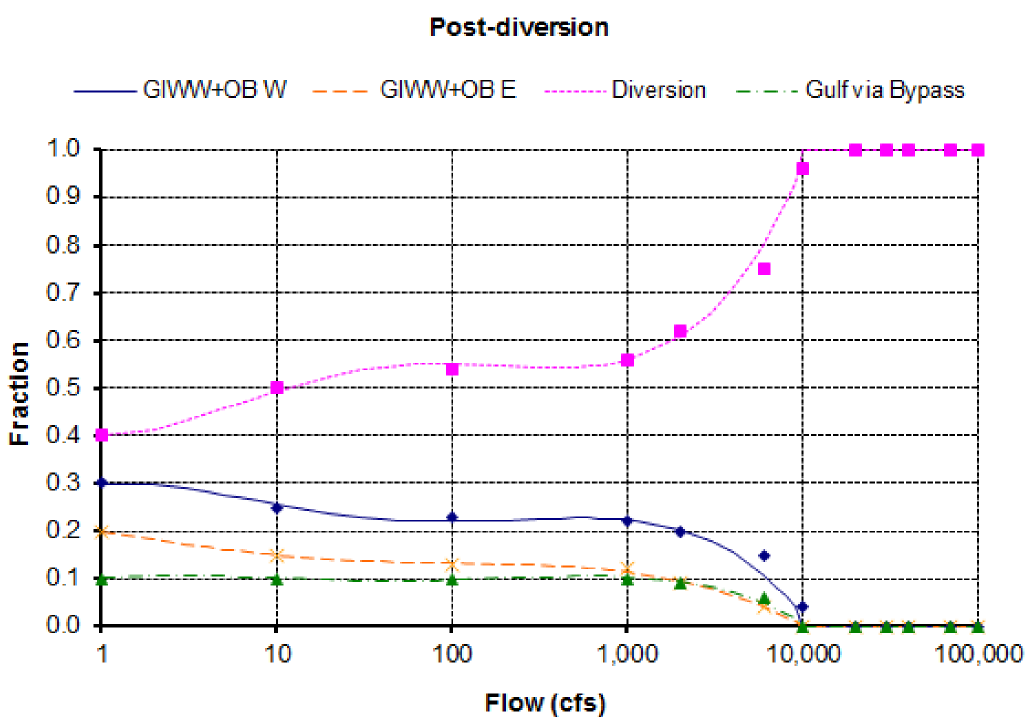



*Figure 8. Split of Colorado River flow, post-diversion (MBHE 2007b)*

## 2.2 Salinity

The Lower Colorado River Authority (LCRA) has maintained salinity monitoring stations at a number of locations throughout the Matagorda Bay system, with continuous data available at select stations including the East Matagorda Bay (EMB) Tripod and the EMB Shellfish Marker C (Figure 9).

Point salinity data available from 1982 to 2012 within the Colorado River channel upstream (north) of the GIWW near the South Texas Project (STP) diversion point (Figure 10, top left) illustrates that salinity in the channel rarely exceeds 5 ppt subsequent to construction of the Colorado River diversion channel in 1992.

Time series daily-averaged sonde data from 1992 to 2014 in the Eastern Arm of Matagorda Bay (WMB Tripod, south west of the Colorado River diversion delta) indicates a salinity regime typically lower than 25 ppt, with some extended periods between 30 and 35 ppt during low inflow periods (Figure 10, bottom left). The East Matagorda Bay Tripod (Figure 10, bottom right) from 1998 to 2014 exhibits higher salinity values where typical salinity is lower than 30 ppt with periods between 35 and 40 ppt, with occasional salinities as high as 45 ppt. Comparison of daily-averaged salinity values for coincident days (1998 to 2014) at the WMB Tripod and EMB Tripod indicates much greater variability in salinity in WMB and indicates limited periods where salinity is lower than 10ppt in the EMB (Figure 11, left).

Limited continuous data is available from 1998 to 2002 in the eastern end of East Matagorda Bay at the Shellfish Marker C location (Figure 10, top right). Available data indicates lower salinity on the east end compared to the west end (Figure 11, right). Data indicates greater variability in east end salinity in response to watershed inflows and tidal exchange in contrast to relatively constant salinity conditions in the west end (note the horizontal banding in Figure 11, right).

A snapshot of salinity gradients across both Matagorda Bay and East Matagorda Bay is provided for illustration in Figure 12. This figure is derived from RMA2/RMA4 hydrodynamic/salinity model developed for the MBHE study (MBHE 2009). The snapshot for July 2000, a low-flow period (see Figure 5 and Figure 7), shows complex variability between the eastern end of EMB where salinity shows influence of Gulf of Mexico salinity, the western end of EMB where this isolated area is hypersaline (approximately 40 ppt) and where the Delta area of Matagorda Bay shows lower salinity under influence of freshwater inflow from the Colorado River (Figure 12). Based upon two-year salinity averages at locations relevant to an oyster analysis, the MBHE salinity model shows open bay salinity to be consistent during typical conditions (20-24 ppt); for dryer periods, areas near the east exhibit high salinity near 28 while western areas can have as high as 31ppt (MBHE 2007).


*Figure 9. LCRA continuous salinity monitoring locations (data at grey rain drops available online: waterquality.lcra.org).*

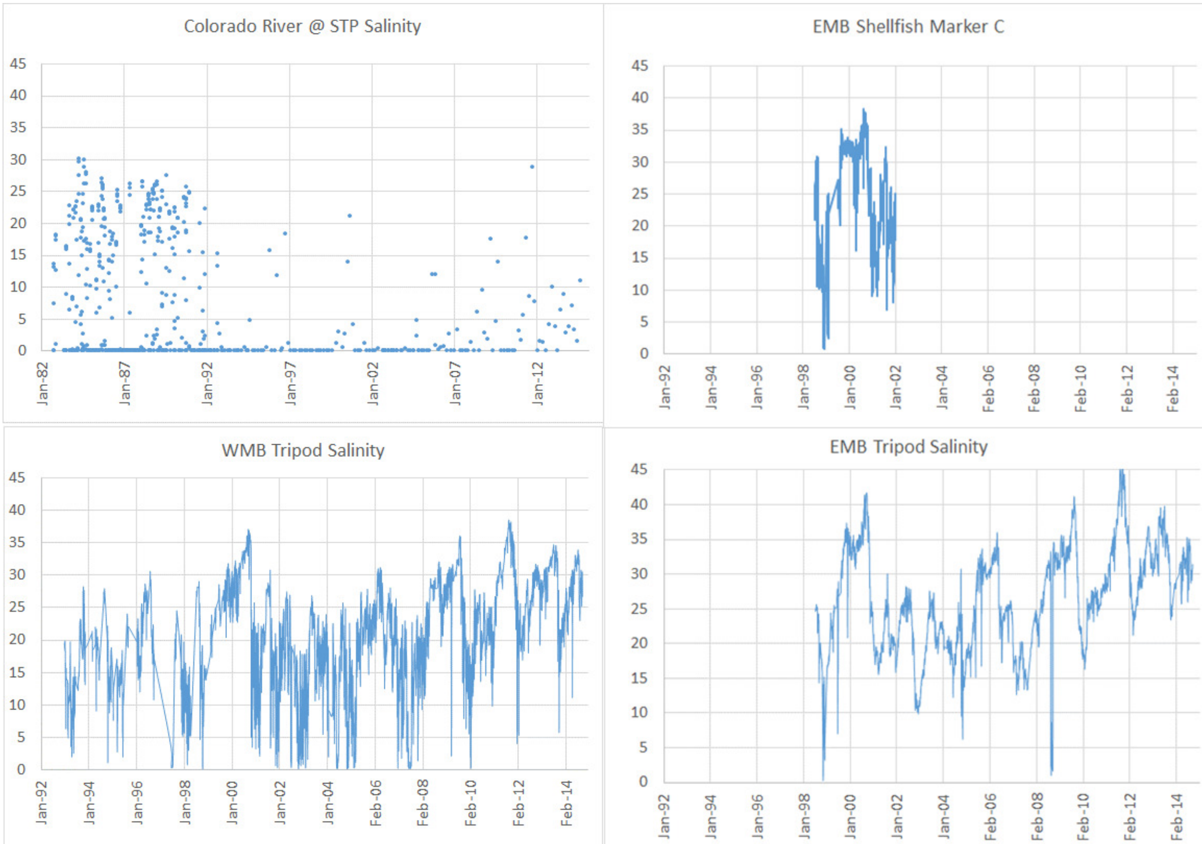



*Figure 10. Selected LCRA daily salinity (ppt) sonde data.*

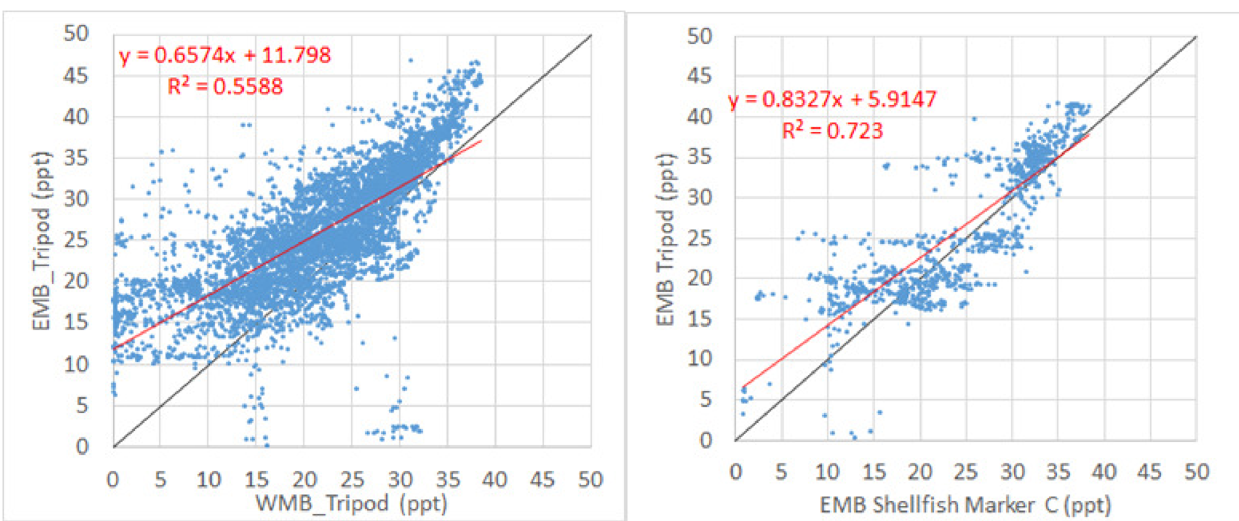



*Figure 11. Daily salinity data, (LEFT) comparison of Eastern Arm of Matagorda Bay (WMB_Tripod) to East Matagorda Bay west end (EMB_Tripod), and (RIGHT) East Matagorda Bay west end (EMB_Tripod) to east end (Shellfish Marker C).*

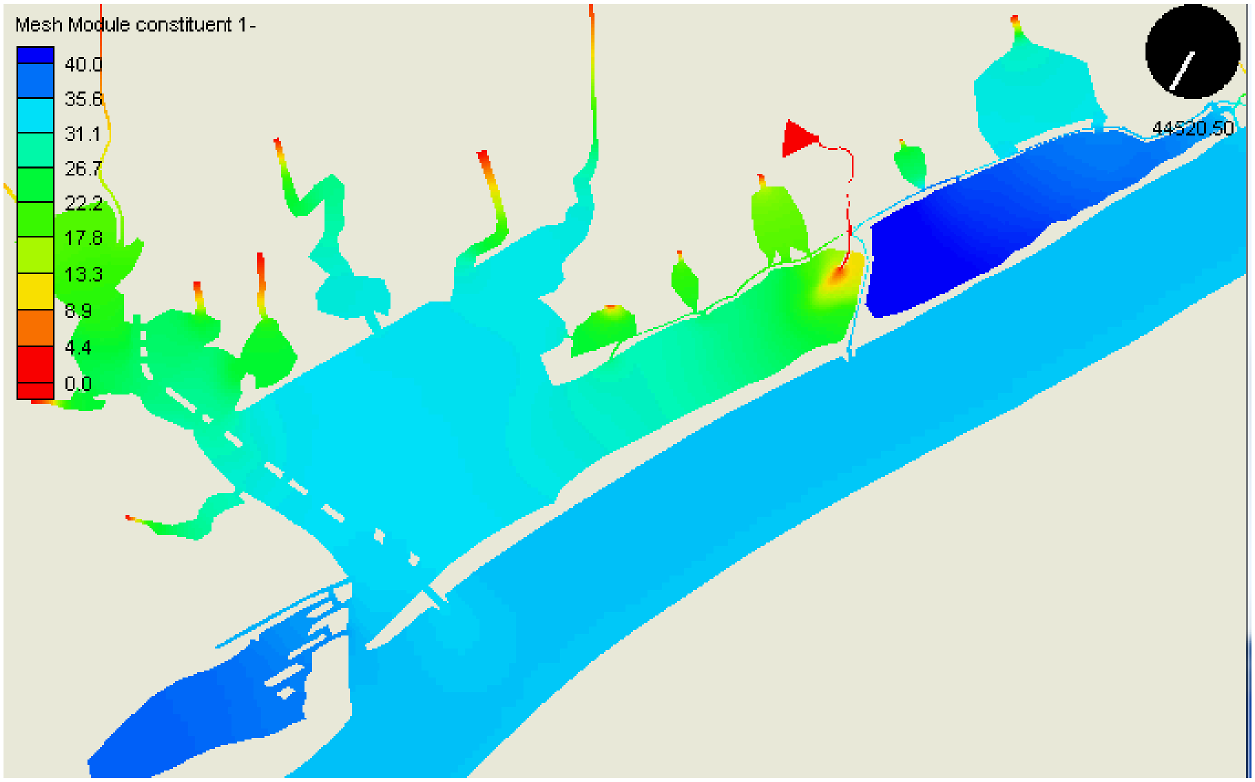



*Figure 12. MBHE RMA2/RMA4 Salinity Model year July 2000 (MBHE 2009). Salinity in parts per thousand.*

Additional analysis of salinity data at the EMB Tripod location is here presented to evaluate typical salinity levels, duration of high salinity events and response of salinity to inflow events. Typical salinity conditions are higher than 25 ppt. Days exceeding 30 ppt represent approximately 37% of the historical record, and 12% of the days exceed 35 ppt (Figure 13). Several extended periods exist in the record when salinity exceeds 30 ppt at the EMB Tripod sonde location, and these periods range from 6 months to over one year (Figure 14). Periods of one to two months are evident in the record where salinity exceeds 40 ppt. Salinity increase (response) is on average approximately +2.5 ppt (rise) per month following a salinity reduction inflow event (Figure 15). This represents the gradual import of salinity resulting from exchange with the Gulf of Mexico, as well as increases in salinity concentration resulting from evaporation. High salinity periods generally occur during low rainfall periods coincident with high evaporation periods during summer.

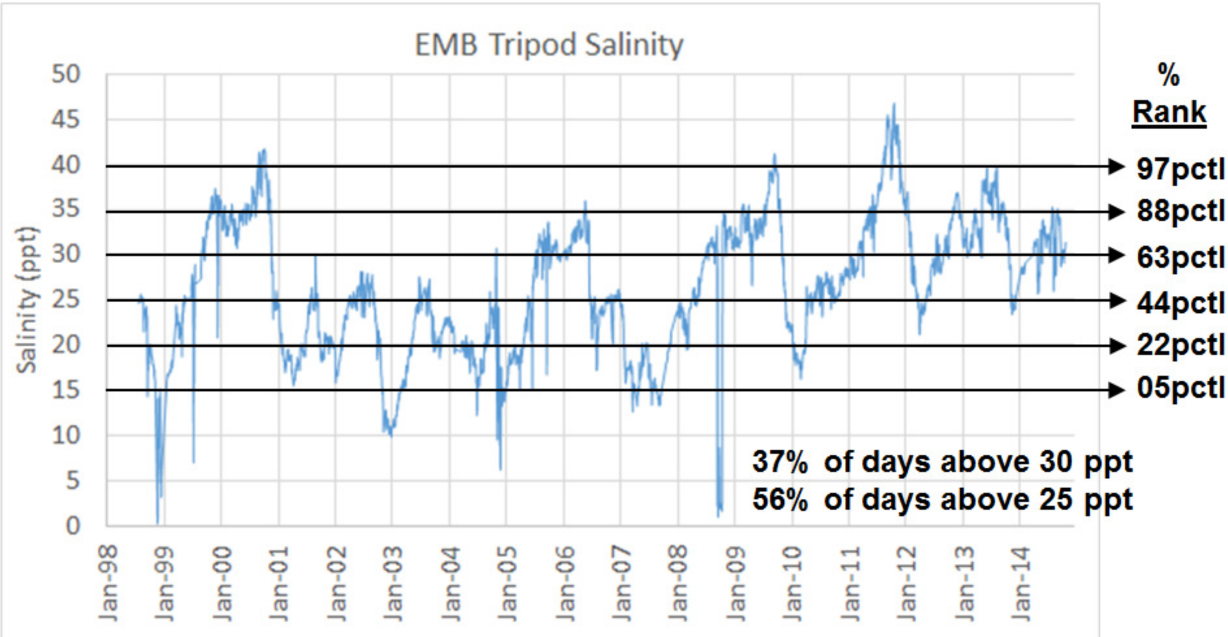



*Figure 13. Historical observed salinity data at East Matagorda Bay "Tripod" sonde, with percentile statistics.*

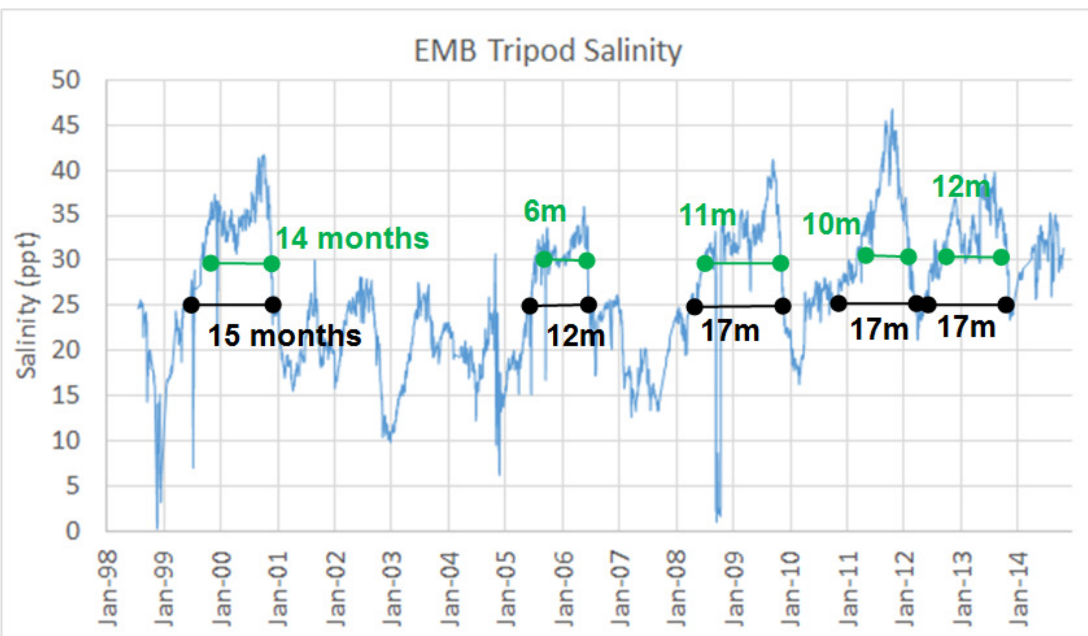



*Figure 14. Historical observed salinity data at East Matagorda Bay "Tripod" sonde, with duration of events exceeding 25 ppt and 30 ppt.*

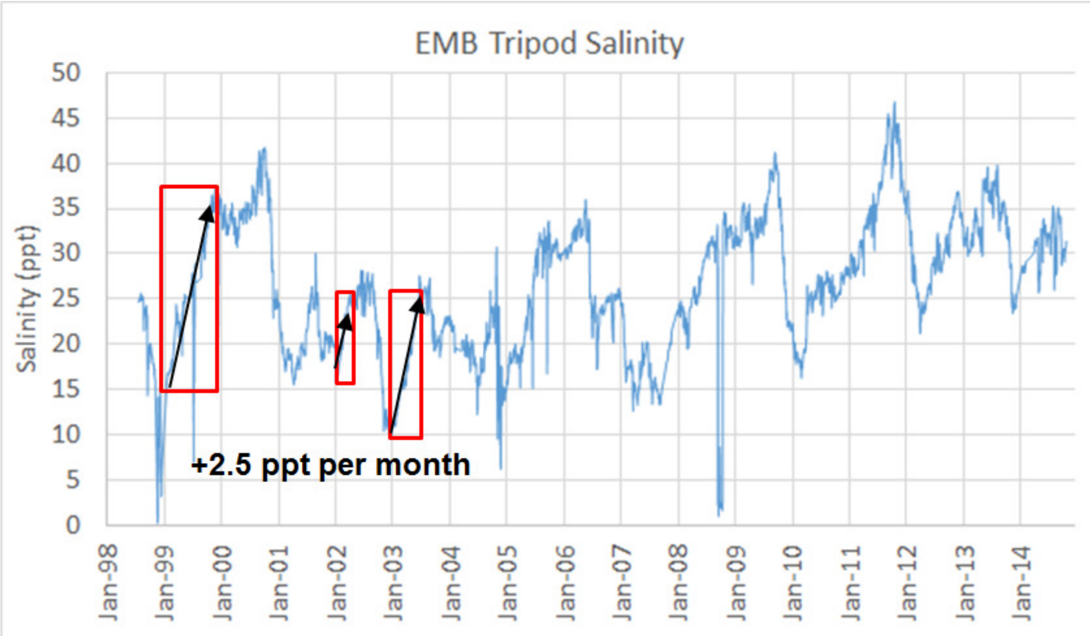



*Figure 15. Historical observed salinity data at East Matagorda Bay "Tripod" sonde, with illustration of rebound following inflow freshening events.*

## 2.3 Ecology

The Matagorda Bay Health Evaluation (MBHE) was conducted in 2008 as part of the Lower Colorado River Authority - San Antonio Water System Water Project (LSWP). The MBHE used a suite of models and data analyses to establish Matagorda Bay Inflow Criteria for the Colorado River representing the full range of inflow conditions to protect bay health and productivity (MBHE 2008). East Matagorda Bay was included in the model grids and analysis; however, it was determined that changes in EMB were driven by localized freshwater inflow rather than by the Colorado River so little additional analysis of model results was conducted of EMB during the MBHE study. Despite this, the MBHE study represents much of the data useful for characterizing flow to habitat to organism relationships for EMB. This section is a description of available information and Section 3.1 describes how this information is used in this current study.

### 2.3.1 Marsh Habitat and Aquatic Organisms

For the Eastern Arm of Matagorda Bay near the Colorado River diversion channel, a suite of inflows were recommended (see Table 1) to provide a range of salinity habitat conditions (Table 2). These same inflow values have become part of the TCEQ SB3 rules for this basin (TCEQ 2012).

*Table 1. Freshwater inflow in acre-feet (AF) to Delta area of Matagorda Bay (condensed from MBHE 2008).*

| Inflow Criteria | Flow | |
|---|---|---|
| | AF / 30 days | Annualized |
| MBHE 4 | 95,000 | 1,140,000 |
| MBHE 3 | 54,000 | 648,000 |
| MBHE 2 | 37,000 | 444,000 |
| MBHE 1 | 25,000 | 300,000 |

*Table 2. Habitat quality rank for Delta-area of Matagorda Bay (MBHE 2008)*

| TROPHIC LEVEL | HABITAT QUALITY RANK* | | | | |
|---|---|---|---|---|---|
| | Selected 90-100% WUA | Good 75-90% WUA | Fair 50-75% WUA | Poor 25-50% WUA | Refuge <25% WUA |
| | Salinity range (ppt) | | | | |
| **Shellfish** | | | | | |
| White Shrimp | 8-15 | 15-20 | 20-25 | 25-30 | > 30 |
| Blue Crab | 5-15 | 15-20 | 20-25 | 25-30 | > 30 |
| Brown Shrimp | 10-25 | 7-10, 25-30 | 30-32 | 32-35 | >35 |
| **Forage fish** | | | | | |
| Gulf Menhaden | 5-15 | 15-20 | 20-23 | 23-28 | > 28 |
| Atlantic croaker | 5-15 | 15-20 | 20-23 | 23-26 | > 26 |
| **Low Estuarine Marsh** | 0-15 | 15-20 | 20-25 | 25-30 | >30 |

* Weighted usable area (WUA) calculated for each species includes selection for physical habitat and salinity.

### 2.3.2 Benthic organisms

Data for East Matagorda Bay to Matagorda Bay collected during 2005, a relatively low flow year, show that the two bays exhibited comparable abundance, biomass and diversity of benthic organisms (macrofauna) (Montagna et al. 2008). Based on data analyzed for that study, East Matagorda Bay salinity for that period was comparable to Matagorda Bay (mean 23 ppt) but had a slightly larger range. East Matagorda Bay also demonstrated high biomass and diversity of macro-benthic communities, when compared to other stations in the Colorado-Lavaca estuary system (Montagna et al. 2008b, Palmer et al. 2011); these findings are based upon the relatively limited data set (2005 only) in EMB and should be verified with additional data in the future.

Oysters were studied extensively during the MBHE studies and indices were developed to characterize condition of oysters and dermo (a parasite that impacts oysters) (MBHE 2007). The indices were found to have good relationships with freshwater inflow in Matagorda Bay; limited effort was expended in East Matagorda Bay. The indices include as parameters antecedent two-year average of salinity, antecedent two-year average of winter temperature and three-month rolling average temperature.

# 3 Freshwater Inflow Influence on Habitat

Salinity is used in this project as a surrogate indicator to estimate ecological response; changes in salinity represent changes in habitat that can result in changes to abundance, distribution or diversity of organisms within the estuary. The following section identifies the salinity target ranges presumed to be beneficial to the ecological health of East Matagorda Bay and discusses amounts of additional freshwater needed to achieve the target salinity ranges. An overview of the habitat conditions that result during various salinity conditions is also presented. Lastly, the impact of reduced inflow on the Colorado Delta and Eastern Arm of Matagorda Bay due to diverting freshwater to East Matagorda Bay is investigated.

## 3.1 Salinity targets, seasonality, timing

To begin an evaluation of inflow quantity, a general target is to reduce duration of high salinity events, that is, to reduce time that salinity in selected areas of East Matagorda Bay is greater than 30 ppt. More specifically, the target is to increase the time that salinity is between 20 ppt and 30 ppt.

This salinity target range of 20 ppt to 30 ppt is chosen with consideration to:

- Reduce occurrences of salinity >30 ppt:
    - Benthic communities benefit from salinity below 30 ppt (Palmer et al. 2011)
    - Promote oysters with 2-year salinity average between 18 and 27 ppt (MBHE 2008)
- Promote “Fair” salinity ranges between 20 and 25 ppt during particular months (Table 2, MBHE 2008):
    - 20-23 ppt
        - Atlantic Croaker (Jan-Jun)
        - Gulf Menhaden (Apr-Aug)
    - 20-25 ppt
        - White Shrimp (Jul-Nov)
        - Blue Crab (Feb-Jun)
    - 30-32 ppt
        - Brown Shrimp (Apr-Jul)

This salinity target range is based upon existing limited information within EMB (see Section 2.3), based upon salinity values applied to the Matagorda Bay in the vicinity of the diversion channel (MBHE2008); because the rationale for identifying ecologically beneficial salinity values (from a multitude of data sources within EMB, within the Matagorda Bay system and across the Texas coast) is complex and described in detail within the MBHE studies (MBHE 2007a, MBHE 2008), the rationale is not further discussed here. The salinity target range used for the present study does not represent an explicit recommended salinity maintenance strategy for East Matagorda Bay. Rather, this salinity target range is being used to evaluate how much freshwater inflow would be required to realize a lower salinity condition consistent with the salinity values applied to other estuarine areas. This salinity target range for EMB deserves considerable further evaluation.

Time of year that the salinity target range occurs will influence the species that can derive benefits. As summarized in the bullet list above, seasonality is less influential to oysters and benthic organisms than to the more mobile aquatic organisms. Rather than timing, the duration of the salinity target range is what influences macrobenthic organisms (e.g., promoting a lower 2-year average salinity between 18 and 27 ppt). Mobile organisms like fish, shrimp and crabs will individually derive more benefit from salinity target range conditions during certain seasons. For example, Atlantic croaker, Gulf menhaden and blue crab all benefit from conditions between 20 and 25 ppt during the early parts of the year and specifically April, May and Jun; whereas, white shrimp benefits from the same 20-25 ppt salinity range later in the year, July through November. Having a higher fair salinity range of 30-32 ppt, Brown shrimp are likely to benefit from existing conditions in EMB in the early part of the year. As little as one month of lower salinity conditions within the salinity target range can have positive benefit to the organisms; in this study, one month is assumed to be the minimum time to maintain the salinity target range.

A suite of other, more complex, impacts are possible from providing this salinity target range through injection of freshwater inflow into EMB. Some possible impacts should be further evaluated in relation to the following concepts:

- Sea grass benefits from water clarity and high salinity
    - Increased freshwater inflow and associated suspended sediment concentration may result in increased turbidity that reduces sea grass;
    - Increased freshwater inflow will decrease salinity and may increase nutrients which are both factors potentially leading to increased epiphyton that is detrimental to sea grass;
- The recreational fishery in the western end of East Matagorda Bay currently exhibits very good conditions with no reason to change, and
- The depths in the western end of East Matagorda Bay are not conducive to oyster dredging, therefore oyster improvements may not improve harvest.

## 3.2 Freshwater amounts required to change salinity conditions

Using existing flow information and salinity modeling information, the influence of freshwater inflows on salinity conditions in East Matagorda Bay were investigated. The influence was investigated using mass-balance calculations and/or predictions of an existing salinity model (MBHE 2009) that was applied to historical conditions. To fully evaluate that influence of specific inflow volumes specifically into EMB, a new suite of scenarios would need to be developed and applied to an appropriately calibrated hydrodynamic and salinity model. The new scenarios could more fully evaluate a wide range of possible antecedent conditions thereby further evaluating uncertainty of salinity response.

### 3.2.1 Entire Bay

The year 2002 is used as an example of a typical year where nearly 1,000,000 ac-ft was the net balance (Figure 5) from all TWDB watersheds (Figure 3). A portion of that total for 2002, arising from watersheds 13101, 13102, 13103 and 13104 that more closely impact the GIWW adjacent to EMB, totals approximately 500,000 ac-ft, roughly half of the inflow balance. The early part of the year represents extremely low inflow until an inflow event between October and December occurred (Figure 7).

Following several months of low flow from contributing watersheds (<33,000 ac-ft combined February through July 2002), the salinity pattern in EMB exceeds 25 ppt in all areas and exceeds 30 ppt in the western end that receives limited inflow and in the eastern end that is most connected to the Gulf (Figure 16). With moderately increased inflow during August (25,000 ac-ft), the salinity drops from 25 ppt to 20 ppt in the central third of EMB (Figure 17).

The modest reduction in salinity would not be anticipated to remain for more than a month or two because of circulation and exchange with Gulf water through Mitchell's Cut – the dredged extension of Caney Creek to the Gulf of Mexico, at the east end of East Matagorda Bay.

Following larger inflows arising in primarily the Lake Austin watershed (Figure 18), the salinity at the end of December is uniform across EMB at approximately 16 ppt. In a small zone near the far eastern end adjacent to Mitchell's Cut, salinity is close to Gulf water because of the exchange with the Gulf (Figure 18).

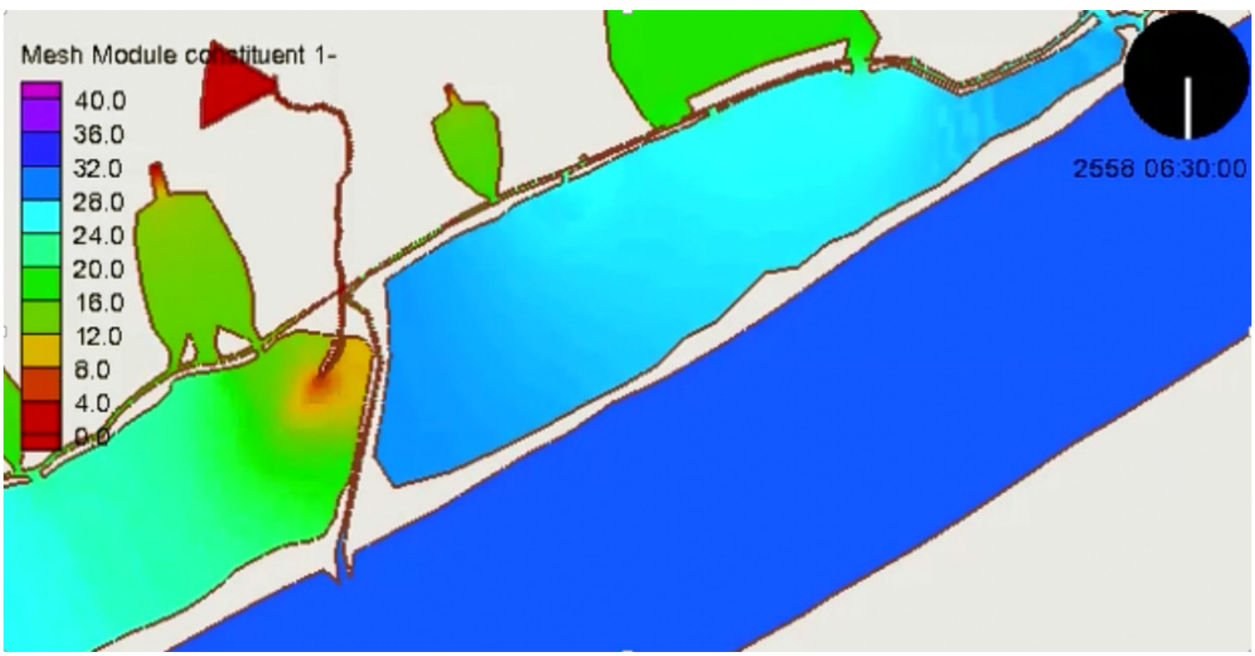



*Figure 16. RMA2 salinity prediction at end of June 2002. Salinity in parts per thousand*

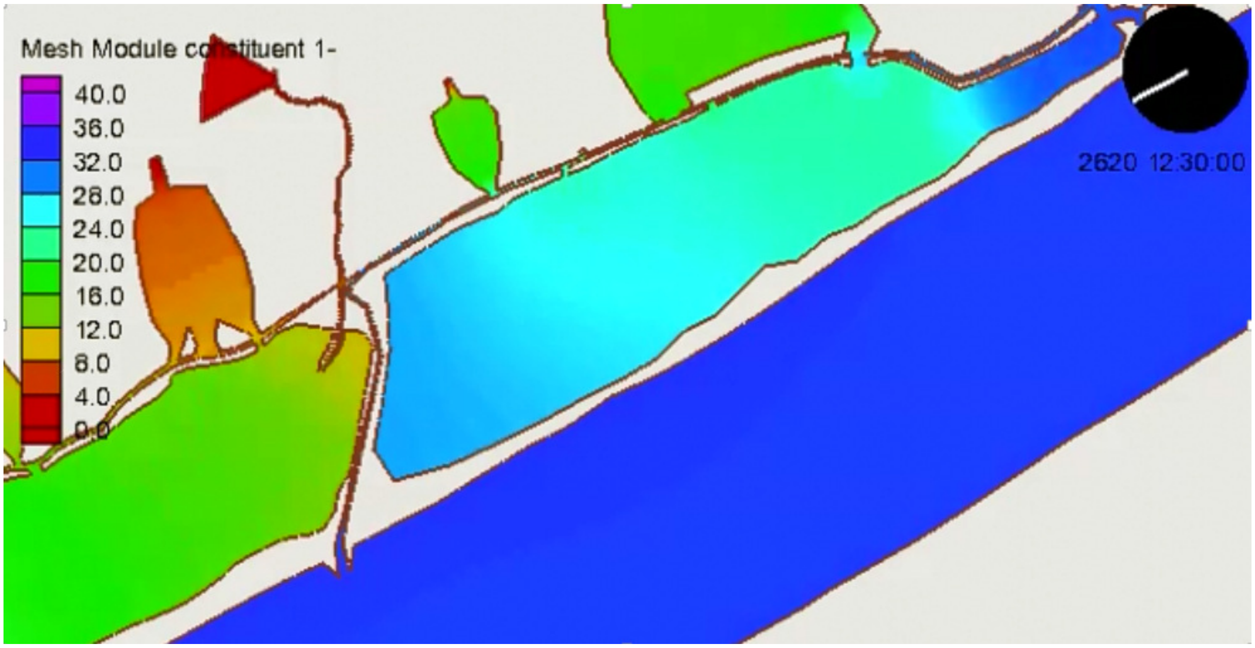



*Figure 17. RMA2 salinity prediction, end of August 2002. Salinity in parts per thousand*

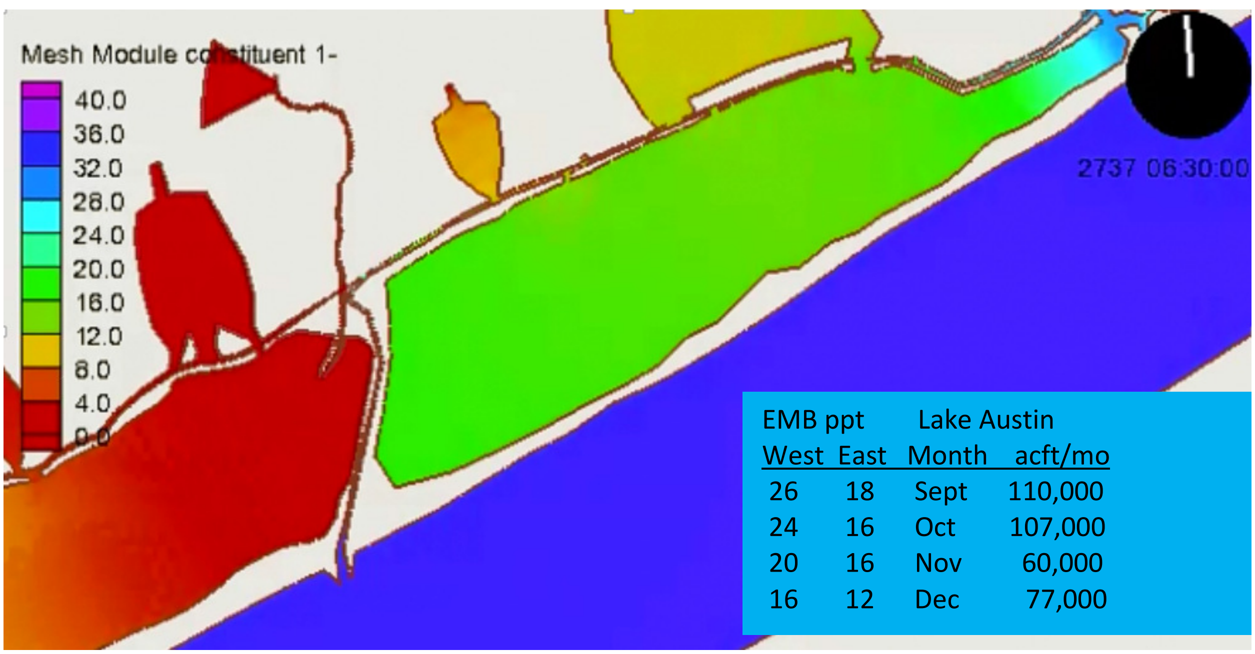



*Figure 18. RMA2 salinity prediction, end of December 2002. Salinity in parts per thousand*

### 3.2.2 West End

Since the western end of EMB is relatively isolated and has no major points of exchange with either the GIWW or the Gulf of Mexico, the western end is investigated as a location where injected freshwater is anticipated to remain for longer durations and therefore have a greater impact.

A spreadsheet mass balance calculation was performed to estimate what constant inflow amount, over what time, would result in a measureable impact to salinity. The calculation considered volume, antecedent salinity, salinity rebound (Figure 15) and the constant freshwater inflow amount. Note that the salinity rebound, since determined from bay observation data, accounts for evaporation and precipitation.

Targeting a bay volume of approximately 25% of EMB (Figure 19) where starting natural bay salinity is 30 ppt, salinity was brought within the target range 20 to 30 ppt using approximately 16,125 ac-ft of water delivered to the western end of EMB. The freshwater was delivered at a uniform rate (273 cfs) over a 30 day period. The resulting salinity pattern (Figure 20) exhibits a 5-month period of salinity in the target range. A similar calculation that also considers tidal range and diffusion/dispersion across the eastern boundary was performed; that calculation estimated a 2-month period of salinity in the target range. Because of assumptions associated with these simple calculations, a hydrodynamic/salinity model is recommended for further assessment and refinement of salinity impact from freshwater inflow.

If a lower flow rate of constant freshwater inflow was delivered to the bay, 50 cfs for one month representing approximately 3,000 ac-ft, a reduced impact zone (6% of EMB) and reduced duration of impact can be expected.

## 3.3 Evaluation of habitat conditions based upon MBHE Weighted Usable Area

Weighted Useable Area (WUA) was modeled as part of the MBHE study for the period from 1996 to 2002 for five bay species (MBHE 2007). Two bay species, white shrimp and blue crab, were chosen as part of this project to demonstrate the impact of monthly inflows on habitat/WUA.

The WUA for White Shrimp and Blue Crab were evaluated in consideration of the monthly balance of freshwater inflows to East Matagorda Bay (Shoenbaechler and Guthrie 2011) for selected monthly time periods during years where total inflow represents low, medium and high flow conditions (Figure 21 and Figure 23).

The WUA was determined for White Shrimp each year according to time-in-bay, July to November, evaluated as part of the MBHE (2007) study. The WUA was determined for Blue Crab each year from February to June. Mean time-in-bay inflow for each season and mean WUA for time-in-bay months are also included on the figures (represented with an 'x').

Since a single month flow does not represent the lasting effects of large freshwater inflow events, WUA was also investigated compared to a four-month trailing average inflow balance flow (Figure 22 and Figure 24).

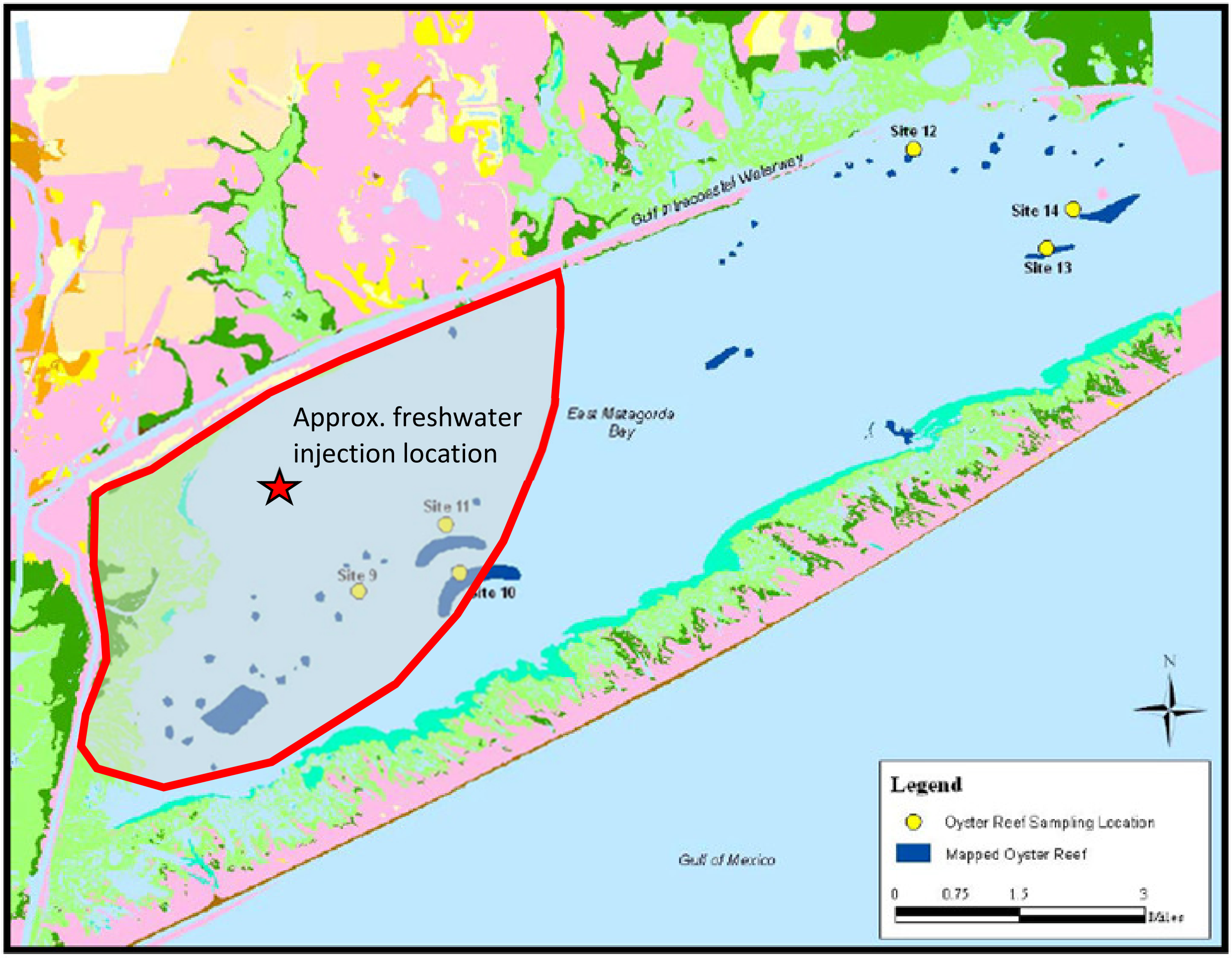



*Figure 19. Salinity target range impact area of East Matagorda Bay outlined in red, approximately 25% of volume.*

For white shrimp, 4-month average flow greater than 80,000 ac-ft/month (approximately 320,000 ac-ft total over 4 months) results in high habitat conditions. Average flows, lower than 50,000 ac-ft/month, tends to result in lower WUA conditions (Figure 22). Note that some months labeled as high flow months (blue diamonds) show high WUA despite low flow; this is because of extremely high antecedent months greater than 6 months prior.

For Blue Crab, 4-month average flow greater than 75,000 ac-ft/month (approximately 300,000 ac-ft over 4 months) results in high WUA conditions (Figure 24). Average flows lower, than 50,000 ac-ft/month, do not improve WUA over low-flow WUA conditions.

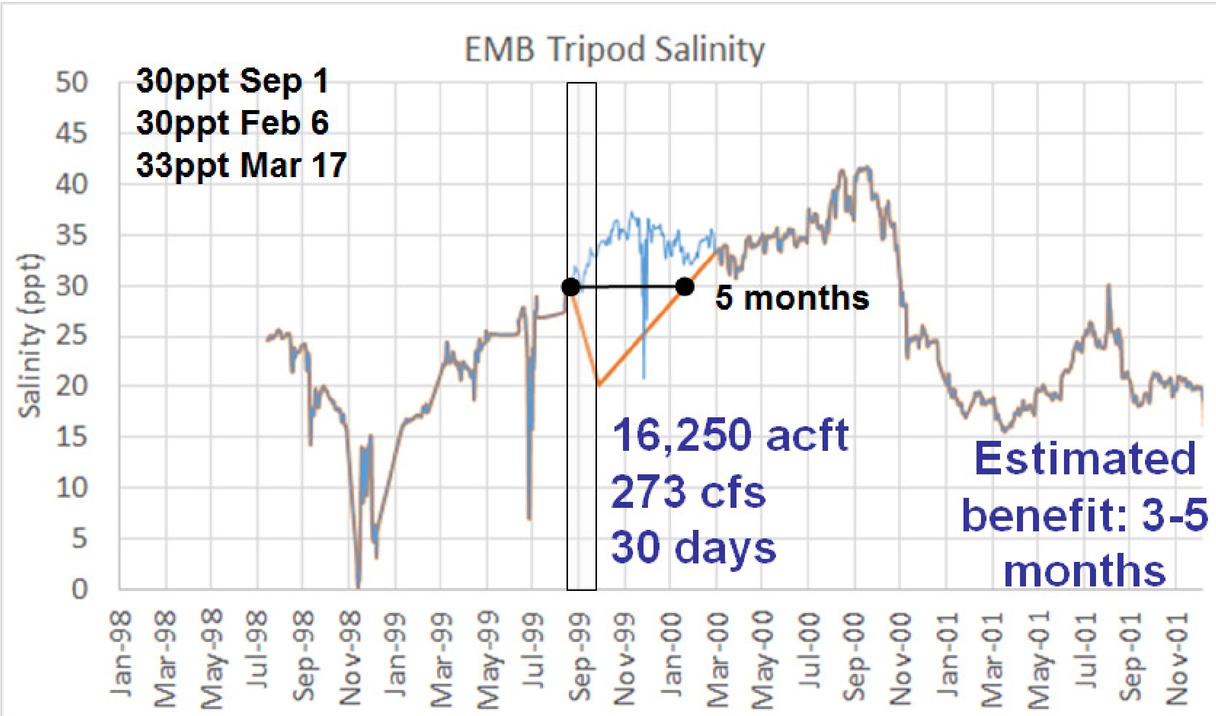



*Figure 20. Historical observed salinity at EMB Tripod, with potential salinity (orange) showing effect of an injection of freshwater into the western end of EMB*

Plots of WUA are subsequently presented to evaluate how differences in inflows affect habitat. Figure 25, for white shrimp, shows WUA for the month and year highlighted in Tables A, B and C. Each table summarizes the balance of freshwater inflows and WUA related to the figure. For white shrimp, average inflows of greater than 80,000 ac-ft/month result in significant increase in WUA value; this is evident in comparing October 2000 to the significantly higher November 2001. Higher inflow balance for 1997 result in higher WUA (November 1997).

For blue crab, Figure 26 illustrates differences in WUA where inflow amounts less than 25,000 ac-ft/month show negligible increase in WUA (June 2001 compared to May 2000). Inflow balance of nearly 100,000 ac-ft/month in early 1997 results in high WUA in June 1997.

Since the TWDB Inflow Balance used for this analysis includes coastal watersheds that may contribute very little freshwater inflow into the main body of EMB, using the inflow balance is considered to be conservative. In other words, since some flow included in the inflow balance likely bypasses EMB, the inflow balance flows are likely higher than the inflow entering EMB and influencing salinity. Because the degree of influence of each of the coastal watersheds on EMB is not well understood at this time, the total inflow balance was used for the assessment presented in this report.

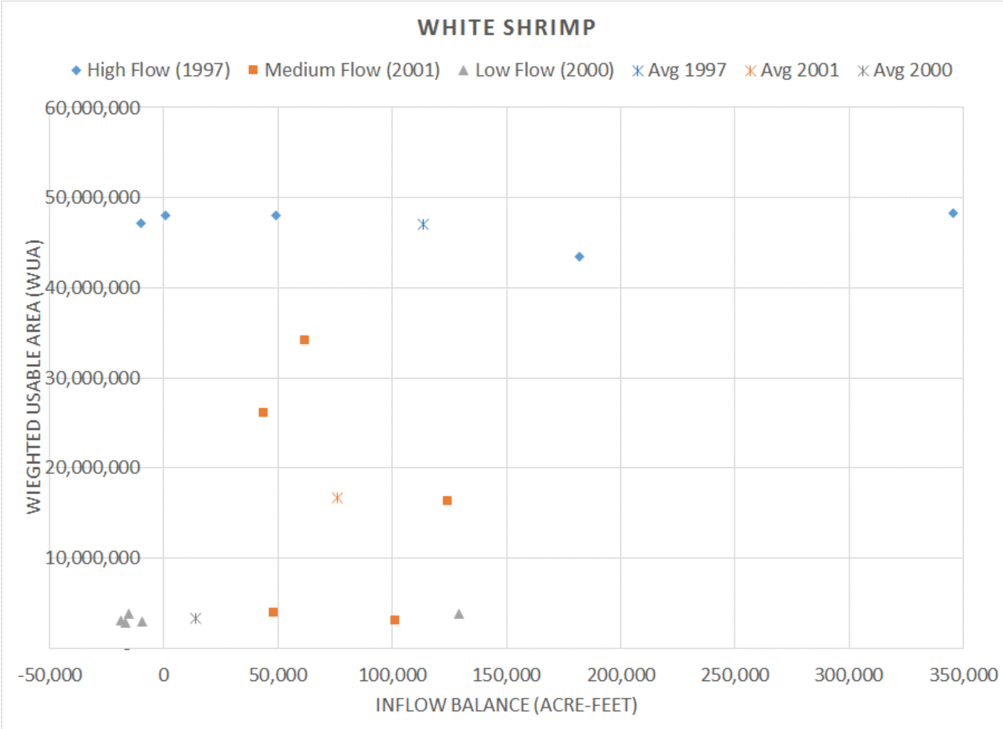



*Figure 21. Inflow Balance vs. White Shrimp WUA*

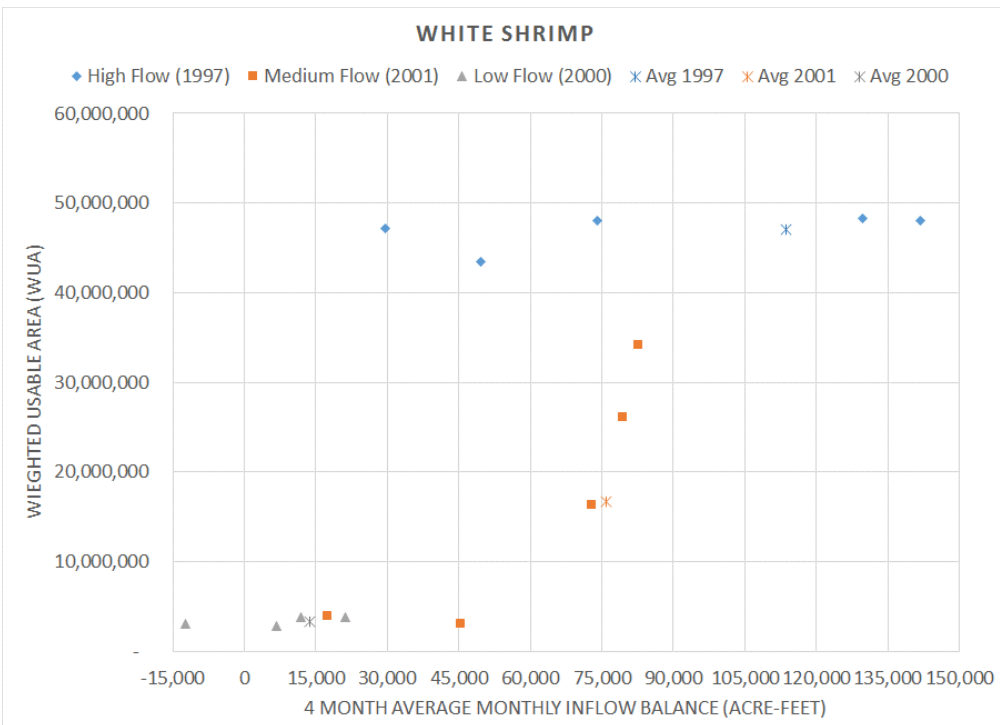



*Figure 22. 4-month average monthly Inflow Balance vs. White Shrimp WUA (square meters)*

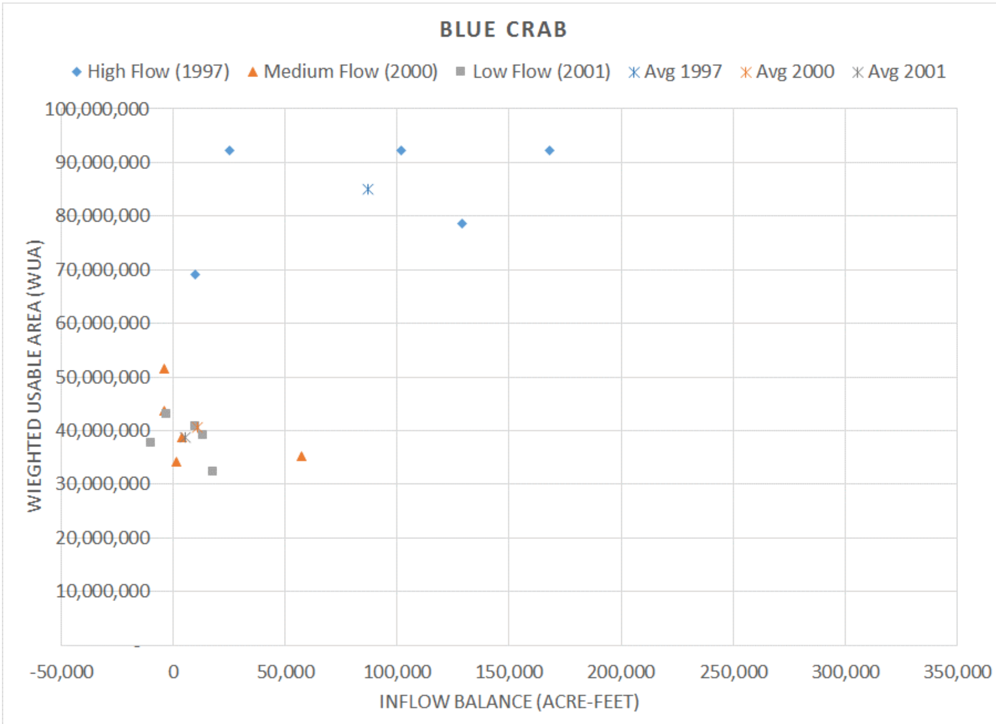



*Figure 23. Inflow Balance vs. Blue Crab WUA (square meters)*

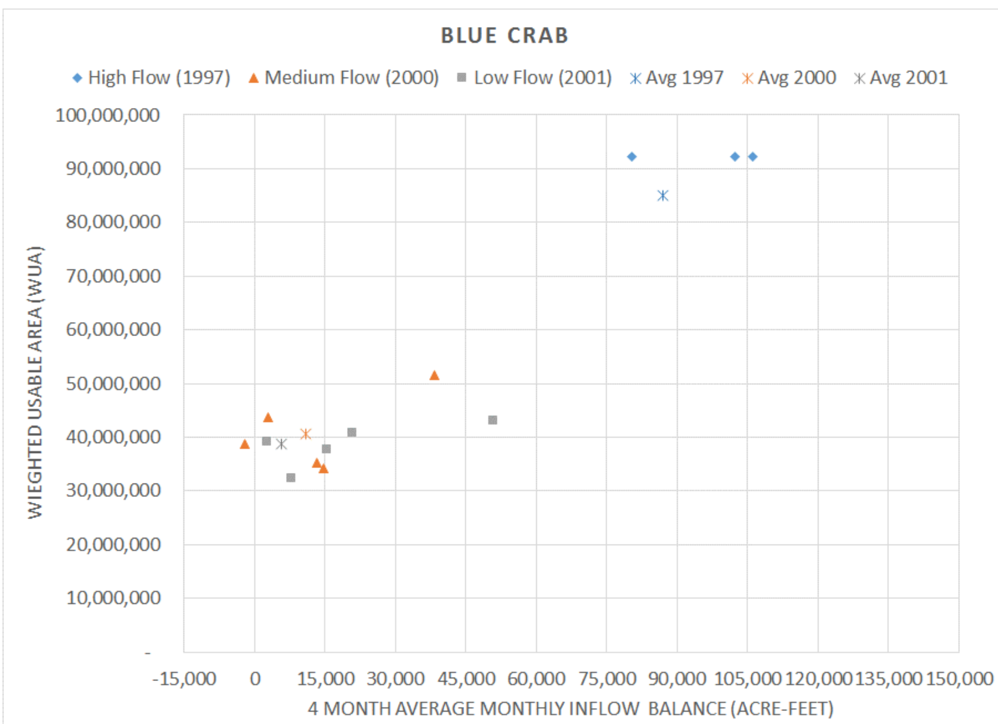
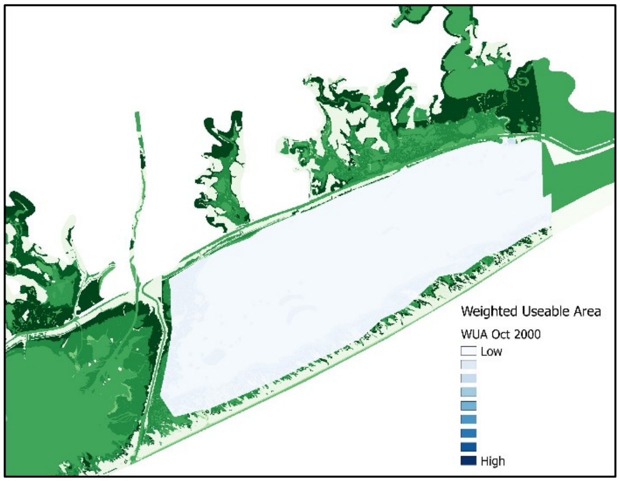
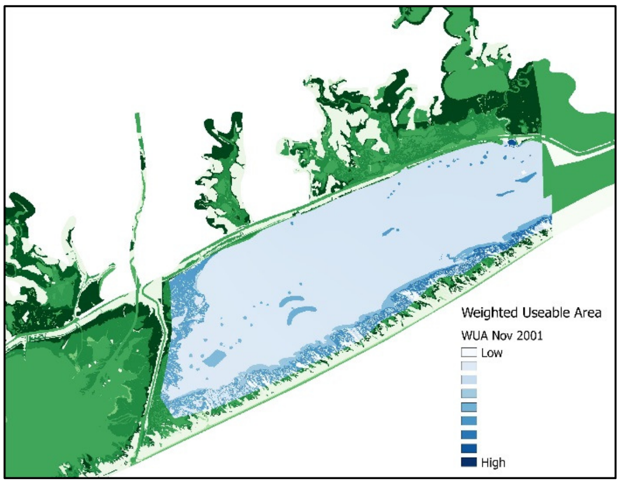



*Figure 24. 4-month average monthly Inflow Balance vs. Blue Crab WUA (square meters)*



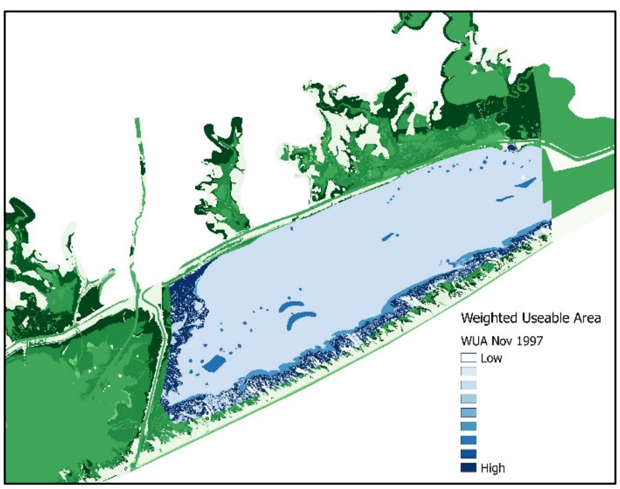

A. White Shrimp Low Inflow Year, 2000

| Month/ Year | Inflow Balance (acft) | Evap (acft) | Precip (acft) | Surface Inflow (acft) | WUA (sq. meters) |
|---|---|---|---|---|---|
| 7/2000 | -15,565 | 24,064 | 1,464 | 7,035 | 3,769,030 |
| 8/2000 | -16,755 | 20,931 | 1,142 | 3,034 | 2,852,313 |
| 9/2000 | -18,799 | 22,219 | 789 | 2,631 | 2,994,882 |
| 10/2000 | -9,366 | 19,350 | 2,050 | 7,934 | 2,943,858 |
| 11/2000 | 129,240 | 11,300 | 28,455 | 112,085 | 3,779,265 |




B. White Shrimp Medium Flow Year, 2001

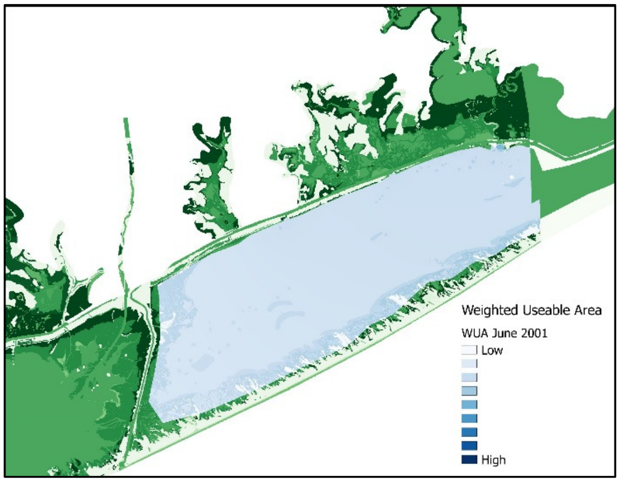
| Month/ Year | Inflow Balance (acft) | Evap (acft) | Precip (acft) | Surface Inflow (acft) | WUA (sq. meters) |
|---|---|---|---|---|---|
| 7/2001 | 48,404 | 16,189 | 5,533 | 59,060 | 3,973,135 |
| 8/2001 | 101,343 | 17,243 | 16,130 | 102,456 | 3,008,733 |
| 9/2001 | 124,234 | 13,085 | 14,636 | 122,683 | 16,260,510 |
| 10/2001 | 43,576 | 11,797 | 6,235 | 49,138 | 26,131,830 |
| 11/2001 | 61,908 | 7,933 | 15,250 | 54,591 | 34,195,852 |




C. White Shrimp High Flow Year, 1997

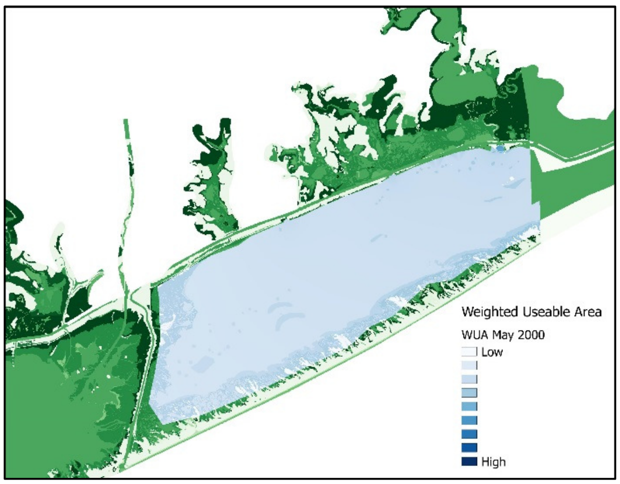
| Month/ Year | Inflow Balance (acft) | Evap (acft) | Precip (acft) | Surface Inflow (acft) | WUA (sq. meters) |
|---|---|---|---|---|---|
| 7/1997 | 734 | 18,000 | 10,298 | 8,436 | 48,049,792 |
| 8/1997 | -9,841 | 18,700 | 3,646 | 5,213 | 47,177,696 |
| 9/1997 | 182,066 | 16,512 | 29,813 | 168,765 | 43,451,940 |
| 10/1997 | 345,760 | 10,619 | 25,644 | 330,735 | 48,282,690 |
| 11/1997 | 49,149 | 6,652 | 15,840 | 39,961 | 48,052,292 |

*Figure 25. White Shrimp Weighted Useable Area (WUA) for selected months during high, medium and low flow years.*



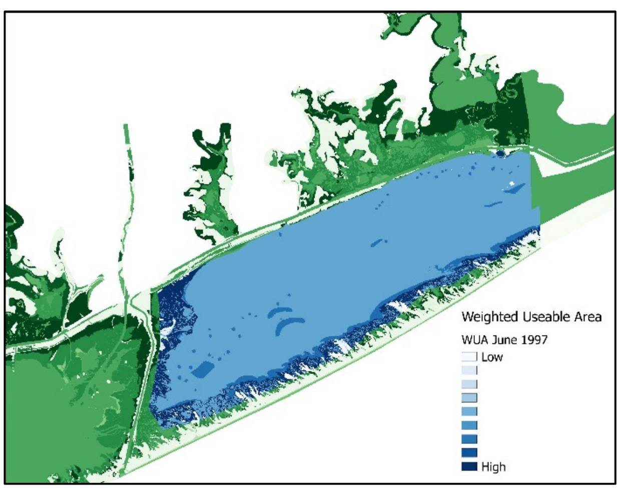

A. Blue Crab Low Flow Year, 2001

| Month/ Year | Inflow Balance (acft) | Evap (acft) | Precip (acft) | Surface Inflow (acft) | WUA (sq. meters) |
|---|---|---|---|---|---|
| 2/2001 | -2,969 | 6,177 | 29 | 3,179 | 43,097,512 |
| 3/2001 | 9,684 | 6,821 | 6,176 | 10,329 | 40,868,452 |
| 4/2001 | -9,805 | 12,998 | 293 | 2,900 | 37,812,976 |
| 5/2001 | 13,465 | 14,256 | 10,831 | 16,890 | 39,126,092 |
| 6/2001 | 18,009 | 18,384 | 9,953 | 26,440 | 32,409,390 |




B. Blue Crab Medium Flow Year, 2000

| Month/ Year | Inflow Balance (acft) | Evap (acft) | Precip (acft) | Surface Inflow (acft) | WUA (sq. meters) |
|---|---|---|---|---|---|
| 2/2000 | -4,192 | 11,622 | 2,752 | 4,678 | 51,559,492 |
| 3/2000 | -4,168 | 20,668 | 8,607 | 7,893 | 43,749,596 |
| 4/2000 | 4,135 | 18,443 | 5,562 | 17,016 | 38,783,616 |
| 5/2000 | 57,570 | 22,424 | 10,830 | 69,164 | 35,134,920 |
| 6/2000 | 1,725 | 22,190 | 2,049 | 21,866 | 34,246,952 |




C. Blue Crab High Flow Year, 1997

| Month/ Year | Inflow Balance (acft) | Evap (acft) | Precip (acft) | Surface Inflow (acft) | WUA (sq. meters) |
|---|---|---|---|---|---|
| 2/1997 | 9,772 | 6,914 | 8,053 | 8,633 | 69,185,440 |
| 3/1997 | 128,891 | 12,078 | 27,073 | 113,896 | 78,599,856 |
| 4/1997 | 168,251 | 14,791 | 21,003 | 162,039 | 92,213,488 |
| 5/1997 | 102,025 | 13,741 | 13,247 | 102,519 | 92,296,272 |
| 6/1997 | 25,409 | 17,475 | 13,158 | 29,726 | 92,296,272 |

*Figure 26. White Shrimp Weighted Useable Area (WUA) for selected months during high, medium and low flow years.*

## 3.4 Impact of reduced inflow on Colorado River Delta and Eastern Arm of Matagorda Bay

The freshwater diversion amounts identified in preceding analyses, if diverted from the Colorado River, represent freshwater that does not make it to the Colorado River delta. These amounts are summarized as follows:

- Localized impacts: 3,000 acft for 1 month
- Localized impacts: 16,600 acft for 1 month
- Baywide impacts: 75,000* acft for 2 months
- Baywide impacts: 80,000* acft for 4 months

The impact of diverting 3,000 acft/month out of the Colorado River on salinity in the Eastern Arm of Matagorda Bay is 1 ppt during low flow conditions and even less significant during higher flow conditions (Figure 27). If 16,600 acft/month is diverted, that will increase salinity in the Eastern Arm of Matagorda Bay approximately 3 to 4 ppt during low flow conditions, and increase less than 1 ppt during high flow periods. (Figure 28).

The two larger flow amounts (marked with * above) that would have baywide impacts in EMB may be larger than necessary since those values were derived from the TWDB inflow balance for EMB. In other words, a lower diversion amount (possibly lower by as much as half) could elicit the same salinity change in EMB. Additional analysis is required to determine what proportion of the TWDB inflow balance has greatest impact on EMB conditions. Until that work can be completed, the recommendation in this report is to recognize that transferring over 40,000 acft of water in a month requires proportionally larger infrastructure than the localized 16,600 acft scenario, a scenario which is already likely cost-prohibitive.

Colorado River monthly inflows at Bay City less the monthly diversions from the South Texas Power Project for 1995 to 2014 were used to determine when freshwater can be diverted to East Matagorda Bay with minimal impact to the Eastern Arm of Matagorda Bay/Delta area. The degree of impact chosen in this analysis is less than 1ppt change in salinity at the WMB Tripod transect of the Eastern Arm of Matagorda Bay delta (representing approximately the standard error for the salinity-inflow relationships (Figure 27). Diversions would only be allowed when inflow conditions are meeting or higher than MBHE 3/SB3 Level 3 (Table 3). The last two columns of Table 3 denote the number of months where an allowable diversion could occur inside of the “time in bay” seasons for white shrimp and blue crab.

At the lowest diversion rate of 50cfs, the Diversion Threshold would be 57,000 acft/month (i.e., MBHE 3 54,000 ac-ft/mo plus 3,000 ac-ft/mo). At the next higher diversion rate (275cfs) the threshold is 71,000 ac-ft/month. Results of the delta flow impact analysis are shown in Table 3. In general, the lower inflow amounts could be available in more than half of the months between 1995 and 2014. Larger inflow amounts could be available in just over one quarter of the years analyzed.

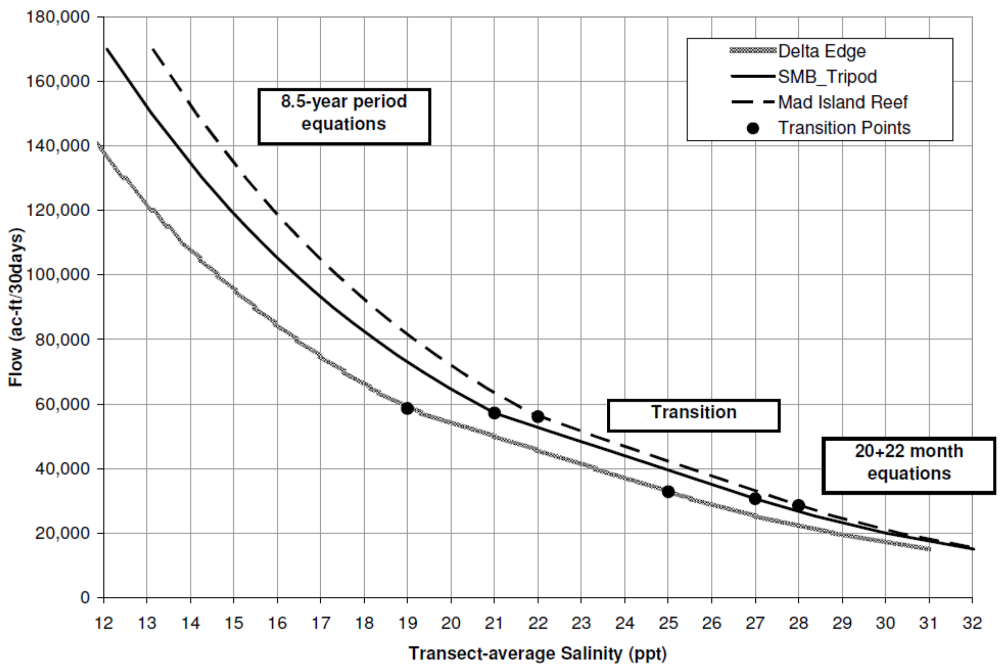



*Figure 27. Relationship between inflow and average salinity in Delta area of Matagorda Bay (MBHE 2008).*

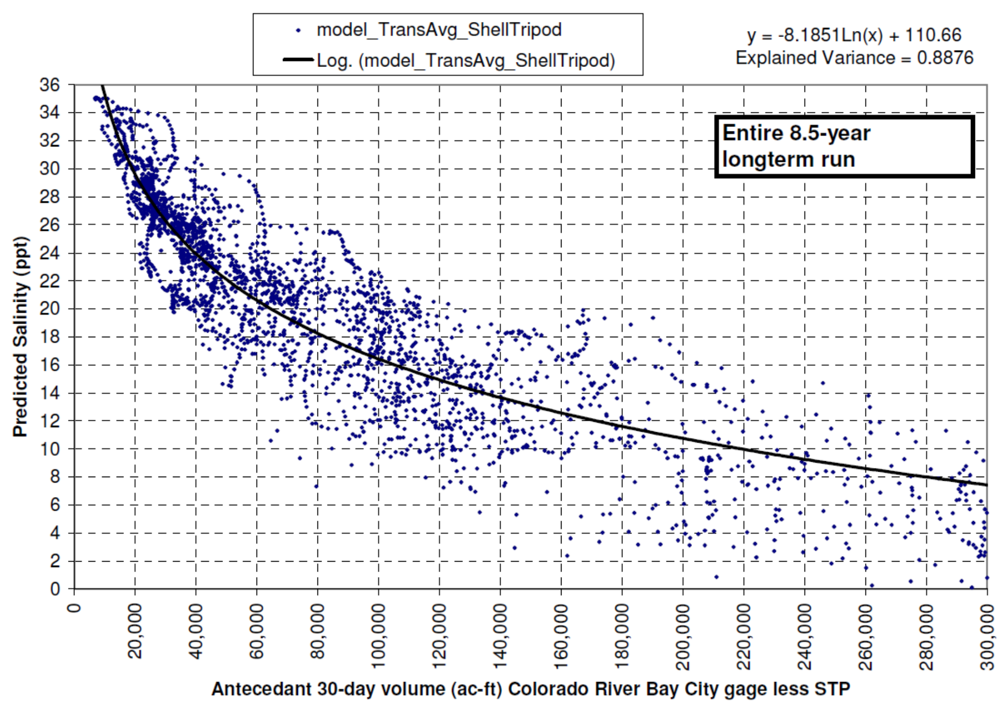



*Figure 28. Predicted Salinity in Matagorda Bay at Tripod vs. antecedent 30 day flow (ac-ft) (MBHE 2008).*

While this report analyzes the availability of river flows based on actual flows from 1995 – 2014 for potential diversions from the Colorado River to East Matagorda Bay, actual water availability for any potential new diversions will be based on the TCEQ's Full Authorization WAM for the Colorado River Basin. If a new or amended water right is necessary to deliver water to EMB, the timing and number of times could be far fewer than the potential maximum amounts presented in Table 3.

*Table 3. Impact of Freshwater Diversions on Eastern Arm of Matagorda Bay during 1995 to 2015.*

| Impact Area (% of EMB) | Diversion Rate (cfs) | Diversion Volume | Diversion Threshold Acft/month | Time Periods Available to Divert | # of White Shrimp Time in Bay (Jul-Nov) Seasons* | # of Blue Crab Time in Bay (Feb-Jun) Seasons* |
|---|---|---|---|---|---|---|
| 6% | **50** | 3,000 acft for 1 month | 57,000 | 118 / 240 months | 11 /20 seasons | 13 / 20 seasons |
| 25% | **275** | 16,600 acft for 1 month | 71,000 | 106 / 240 months | 10 /20 seasons | 12 / 20 seasons |
| 100% | **1240** | 75,000 acft for 2 months | 129,000 | 11 / 20 years | 4 / 20 seasons | 8/20 seasons |
| 100% | **1325** | 80,000 acft for 4 months | 134,000 | 7 / 20 years | 2/20 seasons | 2/20 seasons |

*Count of at least one occurrence of diversion conditions out of each season; the count represents maximum possible irrespective of potential restrictions imposed by water rights permitting.

# 4 Freshwater Delivery Alternatives for Localized Benefits

The goal of this project is to determine the timing and delivery rate of fresh water to East Matagorda Bay that could have a positive impact on the health and productivity of the estuary. Additionally, this project seeks to find a cost-effective engineering solution for delivering available water from the Colorado River into East Matagorda Bay. To do this a number of different scenarios were considered. From a practical perspective, the dam just below Bay City forms an impoundment from which water is easy to divert. The dam further prevents coastal saline water from moving any further up the river. The down side to that option is that the dam is some 20 miles from where the fresh water is needed. A pipeline to convey the water would be expensive to build and maintain. Moving further down the river may save pipeline costs, but a more sophisticated diversion structure would need to be built and one would have to contend with elevated salinities, likely occurring when the water is needed most.

The possibility of using natural channels was also considered for this study. Live Oak Creek – a tributary of Lake Austin, which eventually discharges in the eastern arm of East Matagorda Bay – originates a very short distance from the Colorado River. Using a natural channel presents the opportunity for instream flow enhancement, which is attractive for a number of reasons. Interestingly, Live Oak Creek is the focus of an ongoing mitigation project. The down side is that conveyance through a natural channel is not as efficient as a pipeline. Another issue is that it is not clear how much of the diverted water would actually make it to East Matagorda Bay, if allowed to flow naturally. Furthermore, the point of delivery to the bay is less ideal in the eastern reaches, where better circulation occurs.

To minimize capital and O&M costs, the diversion could be placed in the Colorado River Diversion Channel. While the salinity of the water in this part of the estuary is often close to that of the Gulf, the water would only need to be conveyed a couple of hundred yards.

Another alternative is to place the diversion point in the Colorado River Delta, in Matagorda Bay. While much closer to the desired point of delivery, this diversion location would present engineering (and permitting) challenges.

The following describes a total of seven different scenarios that were considered. Figure 29 shows these scenarios schematically.

1. Diverting water from Colorado River channel upstream of Bay City Dam, transmit by gravity or pressure flow through a pipeline downstream to western end of East Matagorda Bay.

2. Diverting water from Colorado River channel upstream of Bay City Dam, transmit by gravity or pressure flow through a pipeline into Live Oak or Cottonwood Creek, convey in channel downstream into Peyton Creek, and on into Lake Austin where it will discharge through Live Oak Bayou into the GIWW near the north eastern edge of East Matagorda Bay.

3. Diverting water from Lake Austin, transmit by gravity or pressure flow through a pipeline into the north eastern edge of East Matagorda Bay.

4. Diverting water in Colorado River channel from upstream of GIWW (downstream of STP), transmit by gravity or pressure flow (with appropriate backflow prevention) through a pipeline to western end of East Matagorda Bay.

5. Diverting water from the old Colorado River channel, convey by gravity or pressure through a pipeline into an existing St. Mary's Slough to the west end of East Matagorda Bay.

6. Diverting water from the Colorado River diversion channel, convey by gravity or pressure through a pipeline into an existing St. Mary's Slough to the west end of East Matagorda Bay.

7. Diverting water from Peyton Creek, transmit by gravity or pressure flow through a pipeline into the north eastern edge of East Matagorda Bay.

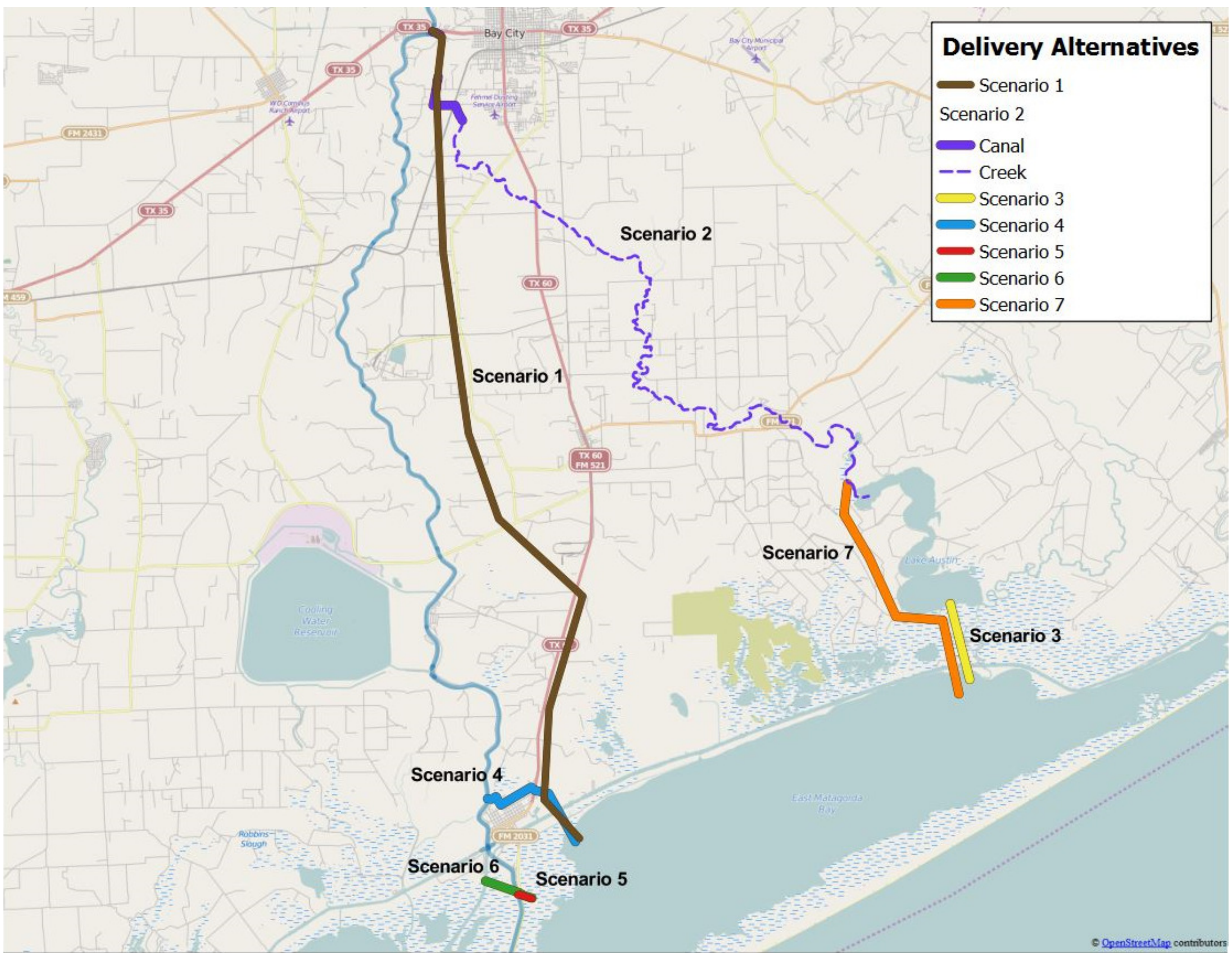



*Figure 29. Freshwater Delivery Alternative Scenarios for Localized Benefits*

## 4.1 Estimated costs for scenarios

To effectively evaluate the various scenarios, estimated construction costs were developed. These estimated costs are feasibility-level only and should not be used to plan for construction. Limited facility planning was performed to provide the basic infrastructure components necessary to carry out the objectives of each scenario. These numbers were developed based on the cost estimating procedures described in the 2011 South Central Texas Regional Water Plan, Appendix A. By comparing the relative cost between each of the alternatives, better decisions can be made in the planning phase. Final project costs will be dependent on many variables including construction market conditions, labor, material and equipment costs, land acquisition requirements, and government regulations.

As described previously, two flow rates are considered for comparison: 50 cfs and 275 cfs. Facilities for each scenario (1 through 7) were delineated and sized for both of these flow rates. The basic assumptions made in the development of the facilities are presented below.

- The system operates at the design flow. It is either on or off.
- Assume 5 fps pipe velocity to size conveyance system. Pipe diameters were calculated to be 42-inches for 50 cfs and 90-inches for 275 cfs.
- Basic river intake and pump station configurations were satisfactory (no special design considerations, Figure 30). Actual pump curves were utilized to estimate horsepower. Vertical turbine pumps were considered for the analysis. The number of pumps, pump sizes and power requirements are shown in Table 4, below.
- The hydraulic head loss for each pipeline scenario was estimated. Coefficients of friction for each pipe were estimated to be 0.125 and 0.111 per 100 feet of pipe for 50 cfs and 275 cfs, respectively (Nayar, Piping Handbook 6th Edition, 1992)
- An additional 25 feet of head was added to the total head loss and elevation change to account for minor losses and to provide sufficient pressure to force flow through the diffusers (for the bay delivery scenarios).
- Pump station capital costs also included costs to locate sufficient power at the various pump station sites.
- Pipeline routes were estimated following existing public rights-of-way. Land acquisition would incur additional cost.
- The Gulf Intracoastal Waterway crossings were accomplished by using Horizontal Directional Drilling (HDD) technique to avoid impacting the use of the channel (Figure 31). For the 50 cfs alternative, one 42-inch diameter HDD is capable of delivering to flow to the bay. For the 275 cfs alternative, there are limitations on the diameter of pipe that can be installed using HDD technology and because the bay is only a couple feet deep, the planned facilities include six (6) separate 42-inch HDD lines drilled under the Gulf Intracoastal Waterway and into the bay to properly diffuse the fresh water (Figure 32).

- For the applicable scenarios, fresh water is introduced to the bay using a 42-inch pipeline laid on the bottom with 52, 6-inch diffuser ports, on each side of the pipe at the spring line for approximately 500 feet (Figure 32). The pipe is anchored to the bottom using concrete weights and straps. The configuration is modeled after other diffuser systems used in ocean wastewater outfalls. This arrangement is thought to minimize plugging of the ports and reduce impacts from biological growth if screens were used. In specific areas where diffuser pipe diameter is similar to typical water depths, diffuser pipe size may be reduced and/or the pipe partially buried. Typical water depths are 2 to 4 feet in the western end of EMB.
- Unit cost estimates from previous years were extrapolated to 2015 dollars by estimating 2.5% annual inflation rate.
- A twenty (20) percent contingency was added to all estimated construction costs to account for unknowns at this feasibility level estimate.
- Design, construction oversight and permitting costs are not explicitly included in the tables below but can be estimated at 12-15% of construction cost.

*Table 4. Pumping and power requirements.*

| Pumping and Power Requirements | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Flow Rate = 50 cfs | | | | | | Flow Rate = 275 cfs | | | | | |
| | | | Horsepower | | | | | | Horsepower | | | |
| Scenario | No. of Pumps | Pump Capacity (gpm) | Each [1] | Total [1] | Power use [2] (kWh) | Annual Power Cost[3] ($) | No. of Pumps | Pump Capacity (gpm) | Each [1] | Total [1] | Power use [2] (kWh) | Annual Power Cost[3] ($) |
| 1 | 5 | 4,500 | 204 | 1,020 | 547,642 | $43,811 | 10 | 12,500 | 660 | 6,600 | 3,543,566 | $283,485 |
| 2 | 4 | 6,000 | 96 | 384 | 206,171 | $16,494 | 9 | 14,000 | 156 | 1,404 | 753,813 | $60,305 |
| 3 | 3 | 7,500 | 72 | 216 | 115,971 | $9,278 | 8 | 16,000 | 144 | 1,152 | 618,513 | $49,481 |
| 4 | 3 | 7,500 | 72 | 216 | 115,971 | $9,278 | 8 | 16,000 | 144 | 1,152 | 618,513 | $49,481 |
| 5 | 3 | 7,500 | 66 | 198 | 106,307 | $8,505 | 8 | 16,000 | 132 | 1,056 | 566,971 | $45,358 |
| 6 | 3 | 7,500 | 66 | 198 | 106,307 | $8,505 | 8 | 16,000 | 132 | 1,056 | 566,971 | $45,358 |
| 7 | 3 | 7,500 | 180 | 540 | 289,928 | $23,194 | 4 | 35,000 | 816 | 3,264 | 1,752,454 | $140,196 |

[1] Horsepower includes rated HP for the pump plus 80% efficiency of the motor.
[2] Power use based on full capacity flow for 30 days annually.
[3] Power cost calculated using $0.08 per kWh.

### 4.1.1 Capital Cost Summary

The following tables present the probable costs for each scenario, for both flowrates considered. Table 5 is for 50 cfs and Table 6 is for 275 cfs.

*Table 5. Probable costs for infrastructure sized for 50 cfs delivery.*

| Probable Costs for Flow Rate of 50 cfs | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Scenario | Length (ft) | Elev. △ (ft) | Pipe Dia. (in) | Intercoastal Waterway Crossing | Estimated Headloss (ft) | Intake & Pumping Station | Pipeline & Appurtenances | HDD & Diffuser | Total Est. Construction Cost | Contingency (est 20%) | Total Planning Cost |
| 1 | 117,803 | 15.73 | 42 | Yes | 147.3 | $5.4 M | $36.4 M | $0.4 M | $42.2 M | $8.4 M | $50.6 M |
| 2 | 5,697 | 13.75 | 42 | No | 7.1 | $3.1 M | $1.8 M | -- | $4.9 M | $1.0 M | $5.9 M |
| 3 | 3,666 | 1.48 | 42 | ? | 4.6 | $2.8 M | $1.0 M | $0.4 M | $4.2 M | $0.9 M | $5.1 M |
| 4 | 6,001 | 3.04 | 42 | Yes | 7.5 | $2.8 M | $1.7 M | $0.4 M | $4.9 M | $1.0 M | $5.9 M |
| 5 | 691 | 1.46 | 42 | Yes | 0.9 | $2.6 M | $0.1 M | $0.4 M | $3.1 M | $0.7 M | $3.8 M |
| 6 | 2,331 | 1.46 | 42 | Yes | 2.9 | $2.6 M | $0.6 M | $0.4 M | $3.6 M | $0.7 M | $4.3 M |
| 7 | 36,067 | 3.25 | 42 | Yes | 45.1 | $3.6 M | $11.0 M | $0.4 M | $15.0 M | $3.0 M | $18.0 M |

*Table 6. Probable costs for infrastructure sized for 275 cfs delivery*

| Probable Costs for Flow Rate of 275 cfs | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Scenario | Length (ft) | Elev. △ (ft) | Pipe Dia. (in) | Intercoastal Waterway Crossing | Estimated Headloss (ft) | Intake & Pumping Station | Pipeline & Appurtenances | HDD & Diffuser | Total Est. Construction Cost | Contingency (est 20%) | Total Planning Cost |
| 1 | 117,803 | 15.73 | 90 | Yes | 130.8 | $14.1 M | $112.6 M | $2.4 M | $129.1 M | $25.8 M | $154.9 M |
| 2 | 5,697 | 13.75 | 90 | No | 6.3 | $6.0 M | $5.0 M | -- | $11.0 M | $2.2 M | $13.2 M |
| 3 | 3,666 | 1.48 | 90 | Yes | 4.1 | $5.5 M | $3.0 M | $2.4 M | $10.9 M | $2.2 M | $13.1 M |
| 4 | 6,001 | 3.04 | 90 | Yes | 6.7 | $5.5 M | $5.3 M | $2.4 M | $13.2 M | $2.6 M | $15.8 M |
| 5 | 691 | 1.46 | 90 | Yes | 0.8 | $5.3 M | $0.7 M | $2.4 M | $8.4 M | $1.7 M | $10.1 M |
| 6 | 2,331 | 1.46 | 90 | Yes | 2.6 | $5.3 M | $1.8 M | $2.4 M | $9.5 M | $1.9 M | $11.4 M |
| 7 | 36,067 | 3.25 | 90 | Yes | 40.0 | $9.6 M | $34.1 M | $2.4 M | $46.1 M | $9.2 M | $55.3 M |

### 4.1.2 Operation and Maintenance Cost Summary

The estimated operation and maintenance (O&M) costs were developed using industry percentages taken from the 2011 South Central Texas Regional Water Plan, Appendix A. These include 1 percent annually for pipelines and distribution facilities and 2.5 percent annually for intakes and pump stations. Electrical power costs were calculated based on 30 days of operation annually (see Section 3.1 for rationale behind 30 days) and using current electrical rates of $0.08 per kWh. Table 7 provides a summary of the estimated O&M cost anticipated for the facilities required for each flow rate and each scenario.

*Table 7. Probable annual Operations and Maintenance costs for 50 cfs and 275 cfs options.*

| | Flow Rate = 50 cfs | | | | Flow Rate = 275 cfs | | | |
|---|---|---|---|---|---|---|---|---|
| Scenario | Intake & Pump Station | Pipelines & Distribution | Total Annual O&M Cost | **Total Annual O&M Cost** | Intake & Pump Station | Pipelines & Distribution | Annual Power Cost | **Total Annual O&M Cost** |
| 1 | $135,000 | $368,000 | $43,811 | **$546,811** | $352,500 | $1,150,000 | $283,485 | **$1,785,985** |
| 2 | $77,500 | $18,000 | $16,494 | **$111,994** | $150,000 | $50,000 | $60,305 | **$260,305** |
| 3 | $70,000 | $14,000 | $9,278 | **$93,278** | $137,500 | $54,000 | $49,481 | **$240,981** |
| 4 | $70,000 | $21,000 | $9,278 | **$100,278** | $137,500 | $77,000 | $49,481 | **$263,981** |
| 5 | $65,000 | $5,000 | $8,505 | **$78,505** | $132,500 | $31,000 | $45,358 | **$208,858** |
| 6 | $65,000 | $10,000 | $8,505 | **$83,505** | $132,500 | $42,000 | $45,358 | **$219,858** |
| 7 | $90,000 | $14,000 | $23,194 | **$127,194** | $240,000 | $365,000 | $140,196 | **$745,196** |

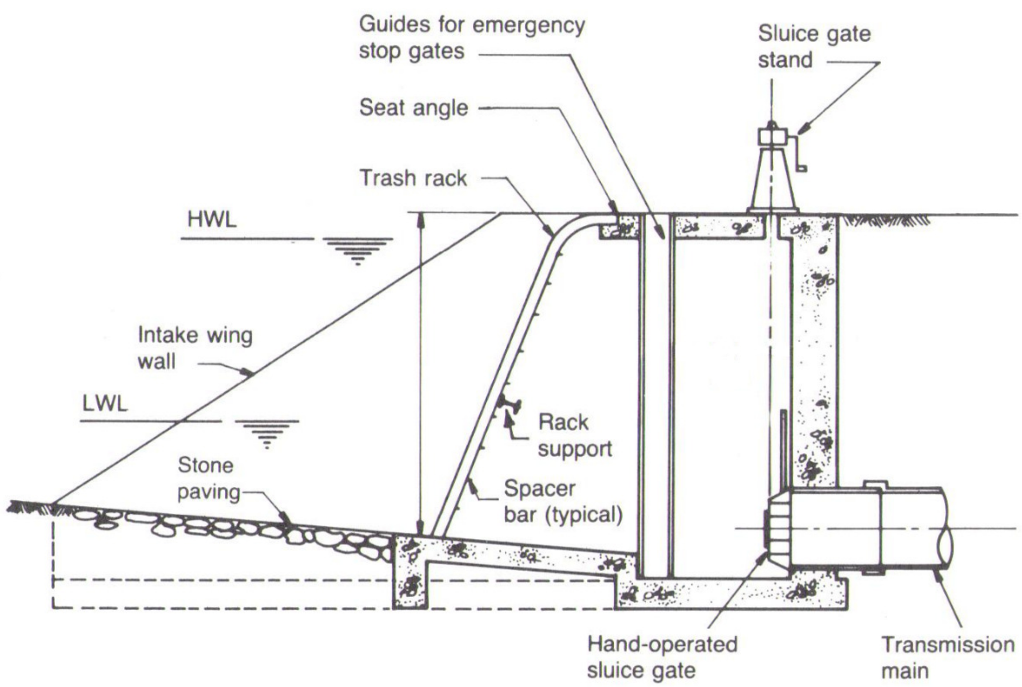



*Figure 30. Section view of a typical river intake structure.*

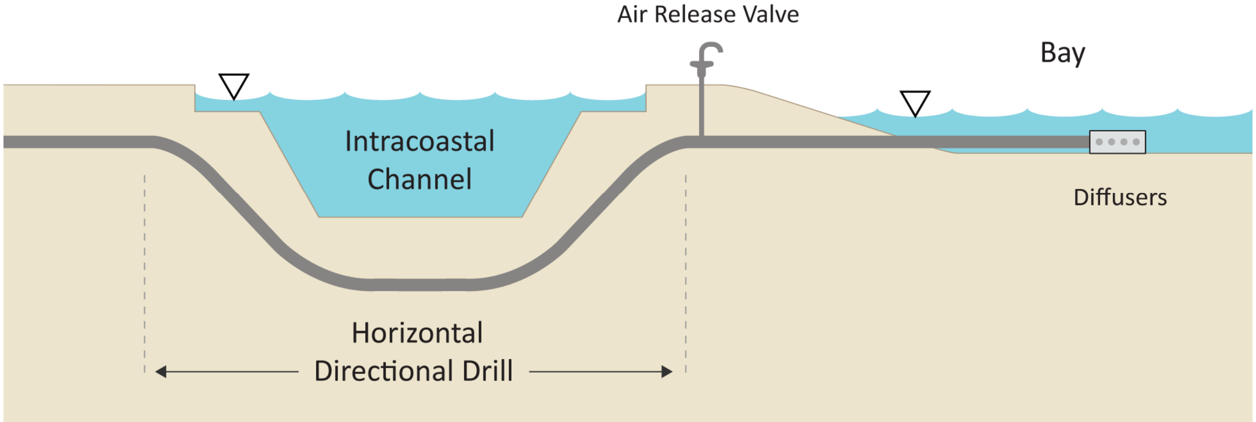



*Figure 31. Diagram of Delivery Pipeline Directional Drill under the GIWW to the Bay (not to scale).*

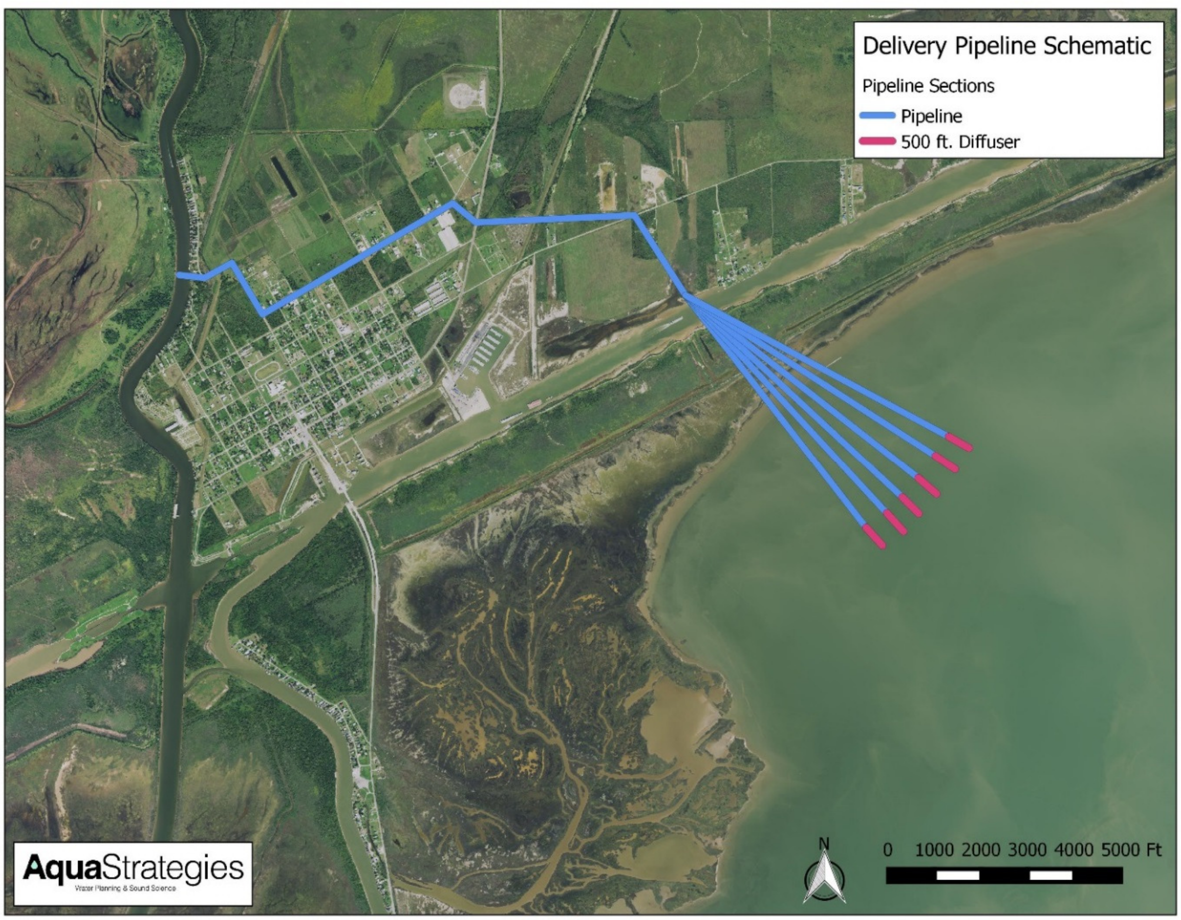



*Figure 32. Freshwater Delivery Pipeline Schematic showing diffuser structure.*

## 4.2 Permitting Discussion

To complete a river diversion and pipeline project, a number of permits will be required.

For any project that results in disturbance or discharge of sediment into waters of the United States (i.e., wetland or stream areas), a U.S. Army Corps of Engineers (USACE) Clean Water Act (CWA) Section 404 permit will be required, along with an associated CWA Section 401 certification for water quality. Any of the pipeline projects have potential to disturb such areas during construction, as do the location of the intakes and discharge locations. The permit requires identification of the type and acreage of disturbed habitat types, as well as identification of replacement comparable habitat areas. The replacement areas are to be set aside and managed in perpetuity to mitigate for losses associated with the project.

Preliminary conversations with TCEQ staff indicated that a diversion permit would be possible to obtain for this project, though the details were not thoroughly discussed. Any diversion of waters of the state of Texas for beneficial use (or transfer of water using natural beds and banks) are required to obtain a water rights permit from the Texas Commission on Environmental Quality (TCEQ). The permit must generally include a diversion amount, a diversion rate, an availability determination and description of the use. Because of water availability constraints (available water in this basin is very junior and may not be available at most beneficial times), and because this use for ecological purposes may not be considered a beneficial use covered under existing Texas statutes, the amount of water necessary to achieve these benefits may need to be (1) delivered under existing permits with existing infrastructure, or (2) authorized through a rule making process that identifies a specific set-aside amount. If using existing permits, an permit amendment may be necessary if there is a change to any of the permitted use conditions, including type of use, and the amendment may change the priority date such that amount of water available for that permit may change. Making a diversion as part of an environmental flow set-aside introduces a new concept that has not yet been addressed in any of the basins.

Other more specific permits may be required related to configuration of river intake structures and protection of aquatic species; county road crossings; flood impacts for higher flow scenarios; and stormwater erosion control during construction.

Additional analyses will be required to further quantify benefits of augmented inflows into EMB, and to further quantify impacts of reduced inflow in Matagorda Bay to the west as well as any portion of the Colorado River channel downstream of a diversion location.

# 5 Other Alternatives

A number of creative alternatives to pipeline construction were identified by the project team, stakeholders and science team members during this project.

## 5.1 Augmented flow pathways between GIWW and north side of EMB

The marshland and spoil islands located on the south side of the GIWW to the north of the EMB north shoreline are preventing some level of exchange between GIWW waters and EMB waters. To engineer additional openings in the barrier (whether the openings are a series of culverts or dredged channels) may provide sufficient exchange to allow freshwater exiting the marsh areas north of the GIWW to migrate into EMB and change conditions in EMB. The location, number and configuration of the potential cuts have not been evaluated in this study and would need to be further studied to quantify the level of benefit expected.

This option would require coordination with the USACE to mitigate potential navigation channel shoaling impacts and address permitting issues related to existing dredge material disposal areas.

## 5.2 Southwest Cut

An intermittent opening to the old channel (Scenario 5 in section 4.1) would help reduce 2-year salinities to a level closer to seawater and can reduce duration of hypersaline conditions. This scenario is similar to the previously proposed Southwest Cut, which is a proposed dredged channel and culvert system connecting the southwest portion of EMB with the old Colorado River channel and associated Gulf water (Kraus and Militello 1996). The peak daily tidal flow is estimated between 20 and 60 cubic meters per second (700 cfs and 2,120 cfs). This high rate of daily exchange can have significant local impact on circulation and salinity conditions near the cut, and may also provide benefit to mobile aquatic species by allowing another access point into EMB (Kraus and Militello 1996).

To pinpoint the benefit, if the proposed gravity-flow culverts beneath Farm to Market road (FM) 2031 were fitted with adjustable gates, this would allow Gulf water to exchange with EMB water only when EMB can best benefit. Best benefits may be achieved during high-salinity periods in EMB (where open gates would allow lower salinity Gulf water into EMB). During low-salinity periods in EMB, closed gates may provide best benefit by maintaining low salinity conditions within EMB as long as possible.

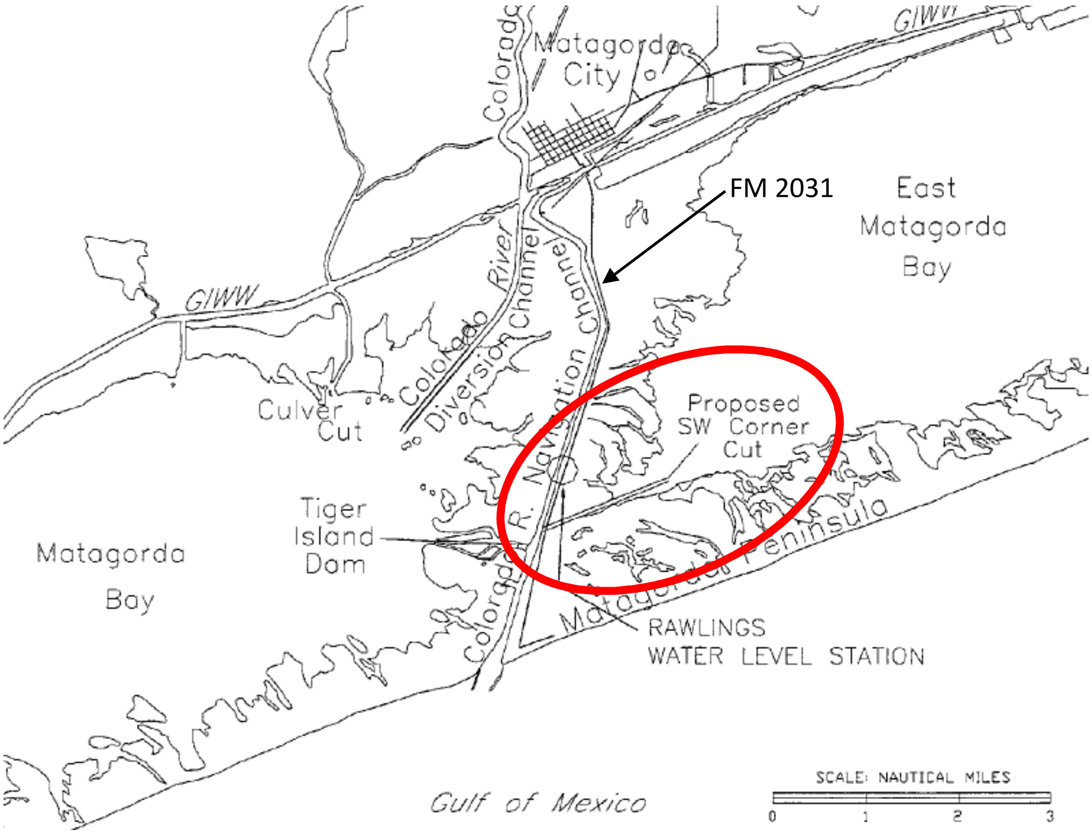



*Figure 33. Illustration of location of proposed Southwest Cut (Kraus and Militello 1996).*

## 5.3 Brackish Groundwater

An interesting alternative to surface water was suggested at a recent Colorado-Lavaca BBASC meeting. Groundwater in the Gulf Coast Aquifer is another possible source in this part of the state, and despite the fact that it is likely brackish, it still would help bring down salinity levels in the bay. It should be possible to obtain the proposed volumes and flow of water with a small well field just north of the Gulf Intracoastal Waterway, per discussions with Matt Webb (TWDB). While this scenario has merit, it is beyond the scope of this project. Although groundwater would help reduce salinity levels in the Bay, one detail to further evaluate is that groundwater would not bring with it the same beneficial nutrients offered by surface water.

## 5.4 Alternative marsh focus areas and freshwater destinations

The tangible benefits of augmented freshwater inflow into EMB are not well understood, while at the same time declines in marsh vegetation have been observed (anecdotal) in the Little Boggy, Big Boggy and other marsh areas north of the GIWW north of EMB (Figure 34).

The marsh declines are presumed to be the impact of reduced inflows into the marshes resulting from cessation or dramatic reduction of rice farming over the last several years. Without the discharges of water used for flood irrigation practices for rice farming, the marshes that received the discharge water are experiencing drastically reduced freshwater flows that have been historically experienced.

Diverting water through the existing canals may be possible to augment flow levels through the marshes. This would require cooperation with the LCRA and local operators to ensure routing of water through public and private canal systems to achieve appropriate discharge locations.

The volume required for marsh benefits will need to be determined, as will field verification of specific marsh areas that can most benefit from these flows. Depending on the amount required to be beneficial, the marsh water may be able to be used for rice irrigation purposes before being discharged into the marsh.

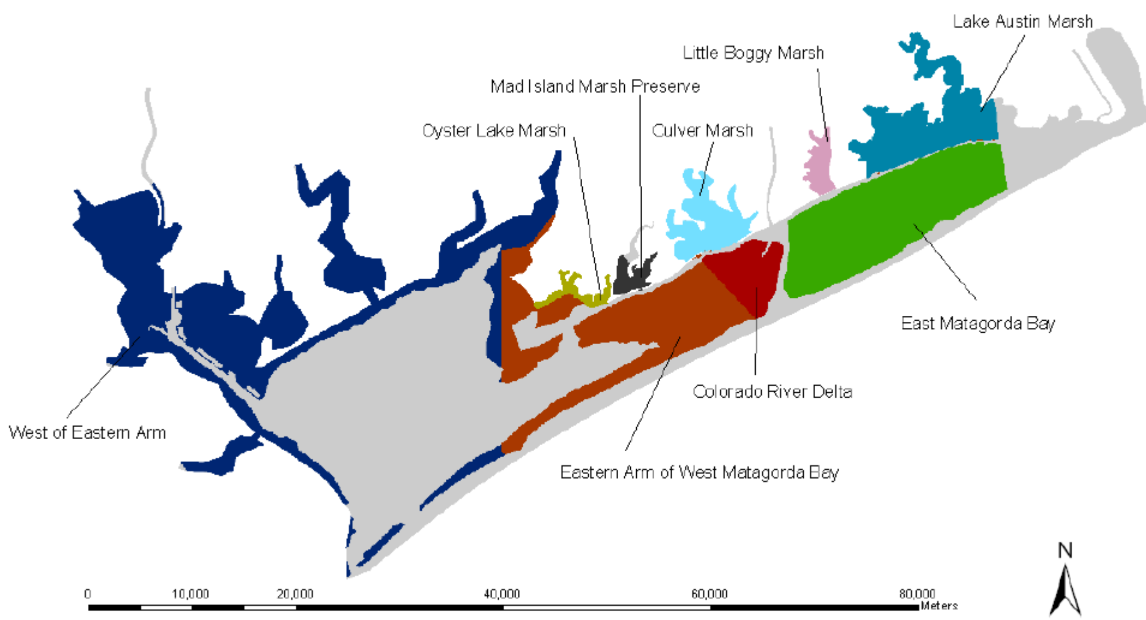



*Figure 34. Marsh areas, including Little Boggy Marsh and the Lake Austin/Big Boggy Marsh complex (MBHE 2007).*

# 6 Conclusions and Recommendations

This project relies heavily upon existing information. For the purposes of this project, ecological goals are based upon beneficial impacts to habitat assumed to result from reductions in EMB salinity resulting from introducing freshwater into EMB. A key assumption for some scenarios is that it would be possible to obtain a permit to divert fresh water away from the Colorado River.

A number of scenarios were investigated for diversion structures and conveyances to East Matagorda Bay. To have an impact on the entire bay, a large amount of water is required, with associated high costs and uncertainty on water availability, and therefore providing large amounts of water does not appear to be a viable option. The lower-flow localized options appear to provide some level of benefit using amounts of water that could be feasible to divert. The infrastructure costs range from $4 million to $155 million. The lower cost options represent diversions with more potential for salt water influence, and therefore reduced salinity benefit. For example, water diverted from the Colorado delta like Scenario 6 will have higher salt content than more expensive options like Scenario 4 that diverts from upstream of the GIWW or Scenario 1 that diverts from upstream of the Bay City dam. Similarly, water diverted from the Bay City dam and transferred to Lake Austin via Live Oak Creek (Scenario 2) will have limited impact to EMB because of flow patterns in the GIWW will tend to transport the freshwater away from EMB.

Of the localized options, Scenario 4 at 275 cfs (diversion point just above the GIWW on the Colorado River with capital costs around $16 million) appears to best balance cost and EMB salinity reduction considering likelihood of low-salinity diversion water. Another option is to pump groundwater from the Gulf Coast Aquifer and deliver this water to the Bay. While intriguing, this option was not investigated due to time and budget constraints. Specific next-step tasks related to these options are included in Section 6.1 below.

Greater health improvements to the estuary could potentially be derived through use of existing irrigation infrastructure to deliver water to the coastal marshes on the north side of the GIWW. For the same volume of water, delivery to the northern coastal marshes may have much greater long-term beneficial impact than delivery of the same amount of water to any portion of EMB. The marsh status north of the GIWW appears to be in decline due to saltwater intrusion, but further survey work and analysis of historical aerial photography is necessary to quantify the impacts and causes.

Another possibility for improving circulation and delivery of both fresh water and nutrients to the western portions of East Matagorda Bay could be achieved by cutting through the spoil islands on the south side of the GIWW at strategic locations. This, combined with a change in dredge disposal practices by the US Army Corps of Engineers, has potential benefits, while avoiding the capital and O&M costs associated with the other alternatives described here.

The full effect of a delivery of fresh water to bay circulation and salinity can be obtained through refinement of existing hydrodynamic models. To more effectively determine where and when to deliver fresh water, it is recommended that additional modeling work be performed, building on the models developed for the LCRA-SAWS project. Similarly, the water circulation in the marsh areas north of the GIWW should be modeled to determine the impacts of additional fresh water.

## 6.1 Areas for future study

The following studies would provide data and/or refine assumptions identified in this project:

1. Conduct additional analysis and/or measure field data to identify ecological goals and quantify specific ecological benefits to providing augmented inflows to East Matagorda Bay. Determine short-term, long-term and seasonal ecological goals and indicators (e.g., salinity).
2. Refine hydrodynamic salinity model to be able to better evaluate specific inflow scenario volumes, level of influence each contributing coastal watershed has on EMB conditions, and beneficial injection locations.
3. Characterize the status of marshes north of the GIWW, compare current-day condition to recent (last 10 years) historical condition, and determine potential cause (evaluate reduction in irrigation return flows as one specific potential cause).
    a. Identify flow volumes beneficial to the wetlands.
    b. Identify land owners amenable to investigating flow strategies and/or land management, including rice farmers, irrigators, water rights holders, etc.
4. Coordinate with USACE to determine feasibility of reconfiguring the spoil islands on the north side of EMB.
5. Investigate feasibility of brackish groundwater for use in EMB inflow augmentation, include consideration of nutrients with water quality component.
6. Conduct a TCEQ Full Authorization WAM model analysis to determine when water in amounts consistent with Scenario #4 are available (this analysis would need to be updated after refined beneficial volumes are identified following above studies 1, 2 or 3).

# 7 References

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# 8 Appendix A – TWDB comments

The following comments received from TWDB on a draft version of this report were addressed in this final version of the report.

# *Evaluation of Freshwater Delivery Alternatives to East Matagorda Bay*

AquaStrategies

Contract # 1400011759

**TWDB comments to Final Draft Report**

This study report presents a summary of possible water conveyance solutions for increasing freshwater inflows to East Matagorda Bay. The options focus on delivering water from the Colorado River via seven routes ranging from (1) a pipeline delivering river water diverted at Bay City to the western end of East Matagorda Bay to (2) using that same diversion point to deliver water via a natural pathway of channels that flow eastward into Lake Austin and then drain into eastern East Matagorda Bay to (3) very short diversions of water from the Colorado River just above the Intracoastal Waterway or (4) from the existing Diversion Canal into western East Matagorda Bay. The study includes advantages and disadvantages as well as a rough cost estimate for installation and maintenance of each option at two flow rates (50 cfs and 275 cfs). Overall, this report will be helpful in determining the most likely strategies to provide environmental flows to the East Bay.

## REQUIRED CHANGES

### General Draft Final Report Comments

This study report determined target river diversion and bay inflow rates and their potential impact on bay conditions using estimates of the *freshwater inflow balance* of the estuary. This estimate accounts for inflow, diversions/returns, and precipitation on to and evaporation from the bay. This evaluation therefore broadly accounts for the effect of additional freshwater inflow by also considering inflow needs as a result of net evaporation. In East Matagorda Bay, mean net evaporation is -12,111 acre-feet (evaporation being greater than precipitation) during the period of record used in this study. Most studies of freshwater inflow needs have been based on estimates of *total freshwater inflows* to the bay from the contributing drainage basins – bay precipitation and evaporation has not been accounted for in previous analyses.

The study report also determines target inflow amounts for diversions from the Colorado River into East Matagorda Bay based on improvements to salinity condition and useable habitat for important fisheries species. The study report does not specifically address differences in water surface elevation between the points of diversion and discharge – as described in the scope of work and which would be a beneficial statistic for determining the ability for gravity flow – but does calculate an estimated inflow volume and quantifies the associated benefit. Because the study report accounts for pumping in the scenarios and their cost estimates, the need for reporting water surface elevation differences is less important to report here and therefore may not need to be included.

A number of comments were received addressing the use of the data and information from the MBHE studies conducted primarily for Matagorda Bay but which provided some data and information for East Matagorda Bay. Specific comments are outlined below, but generally the concerns of reviewers can be addressed by clarifying, where appropriate within the report, the information that is or is not specific to East Matagorda Bay as it relates to any technical analyses or interpretations of results.

Please spell-check, proofread for grammar and logic, and correct all page breaks to ensure section titles are associated with the subsequent paragraphs. Please also standardize the use of *Gulf Intracoastal Waterway* (GIWW) and correct the references to *Intercostal Waterway* or *Channel* (*e.g.*, bottom of page 39).

**Specific Draft Final Report comments**

*Cover Page* – Please add the following language to the cover page of the final report:

> *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.*

*Section 1.1. Problem Statement, page 6* – Please add the phrase "*and human rerouting*" to the second sentence, as such: "*Sediment deposition, flooding, meteorological activity, <u>and human rerouting</u> have had major influences on the path the river………*", or a similar phrase to represent the anthropogenic activities that have affected the river.

*Section 1.2. Ecological Goals, page 8* – Please add the phrase "*of the species, habitats, and overall estuarine system*", to the sentence: "*Improved circulation and delivery of nutrients to East Matagorda Bay may also improve health and productivity <u>of the species, habitats, and overall estuarine system</u>, although increases in these characteristics are not …*".

*Section 1.2. Ecological Goals, page 8* – Please include a discussion and reference(s) to support the use of the target goal of 20 – 30 ppt as the desired salinity to support the habitat goals for East Matagorda Bay. Please also include mention of seasonal variability in salinity and how this compares to the selected 20 – 30 ppt range. Also address, if possible, a minimum time period of salinity reduction that would be necessary to incur benefit to the ecosystem. (*Note*: Please include a brief justification in the *Executive Summary* and more detailed discussion in *Section 3.1 Salinity Targets, Seasonality, and Timing* as well.)

*Section 2.1.1. Colorado River and Matagorda Bay, page 9* – Please replace the word "minimal" with the word "reduced" in the following sentence: "*The bisection created East Matagorda Bay, a secondary bay in the Matagorda Bay system, and resulted in <u>reduced</u> freshwater inflows…*". Characterization of "*minimal*" inflows having occurred may be subject to question. Certainly inflows to Matagorda Bay were "*reduced*" as a result of the bisection. Although main river channel discharged directly into the Gulf, a significant portion, with exact amount being in dispute, of flow reached Matagorda Bay through various cuts and during high flow periods via overbanking.

*Section 2.1.4. Freshwater Inflow to East Matagorda Bay, page 13* – Please verify that the MBHE studies referenced in the report are based on estimates of freshwater inflow *balance* as opposed to total freshwater inflow. Additionally, please reference TWDB, rather than Schoenbaechler and Guthrie (2011), when describing "earlier versions" of inflow estimates. TWDB develops the estimates using a fairly routine methodology; however, Schoenbaechler and Guthrie (2011) simply describe the methodology plus the particulars associated with development of the version of inflows (versions TWDB201001 and TWDB 201004) published in that report. For example, "… *are derived from earlier versions of the balance of freshwater inflow estimates to East Matagorda Bay from the TWDB…*"

*Section 2.1.4. Freshwater Inflow to East Matagorda Bay, page 15* – Please include a reference citation for the discussion and values stating the contribution of Colorado River flows to East Matagorda Bay. Please also include a discussion of the other potential sources of inflow (*i.e.*, Oyster Lake, Mad Island)

and their relative contribution to the overall inflow to East Matagorda Bay. Please be sure to include mention of any water sources that will be used in scenario development.

*Section 2.2. Salinity, pages 15-16* – Please include the period of record for salinity data that is discussed.

*Section 2.3. Ecology, page 21* – Please provide a description of the information and analyses from the MBHE that are specific to East Matagorda Bay and which apply to any technical determinations or discussion of results in this study. East Matagorda Bay is ecologically, physically, and hydrologically unique in comparison to Matagorda Bay and the results for Matagorda Bay may or may not be representative of conditions and responses in East Matagorda Bay. Please also include a statement of the indicator species that were used to inform the technical analyses and their salinity requirements during the period of hydrological analysis as salinity tolerances and requirements may vary seasonally or over the life-span of individuals.

*Section 2.3.2. Benthic Organisms, page 22* – Although the use of information about benthic organisms is based on existing data, of which there is relatively little for East Matagorda Bay, and the report clearly states that the information presented is based solely on the work of Montagna *et al*. (2008) for data collected in 2005, please acknowledge that this data limitation restricts any comparisons to Matagorda Bay. Additionally, please better explain the reason for including a discussion of benthic organisms and oysters. The relationship between this section and the study analyses and results is unclear.

*Section 3.1. Salinity Targets, Seasonality, and Timing, page 23* – Please explicitly identify the species-salinity requirements that were obtained from studies reporting on the needs of species in East Matagorda Bay as opposed to being based on species information from other Texas bay systems. Include citations if necessary. If all information is derived from studies of East Matagorda Bay, then please clearly state as such. Please also include mention of seasonal variability in salinity and how this compares to the selected target salinities.

*Section 3.2.1. Entire Bay, page 24* – Please clarify whether the analysis and results for this section and the West End took into account the indirect influence of increased flows on the Colorado River between October – December. Please also include a more thorough explanation that the results obtained for this analysis may be optimistic and may not represent the salinity response under all possible antecedent conditions. Also note how the analysis is limited and the specific benefits of utilizing a hydrodynamic and salinity transport model to resolve uncertainties with respect to inflow needs relative to salinity improvement.

*Section 3.2.2. West End, page 26* – Please clarify the following in this section: In the 2nd paragraph, clarify whether the calculation considered "freshwater inflow" or "freshwater inflow balance" (refer to general draft report comments near the top of this document). In the 3rd paragraph, clarify that the analysis is targeting a "*bay volume of approximately 25%*". Please restate in this section that the starting salinity condition exceeded 30ppt.

*Section 3.4. Impact of Reduced Inflow on Colorado …, page 34* – Please include a statement that while the report analyzes the availability of river flows based on actual flows from 1995 – 2014 for potential diversions from the Colorado River to East Matagorda Bay, actual water availability for any potential new diversions will be based on the TCEQ's Full Authorization WAM for the Colorado River Basin.

*Section 4. Freshwater Delivery Alternatives for Localized Benefits, page 37* – Please remove the word "*excess*" from the first sentence that describes the goal of the project and which characterizes the river as having "*excess water*". Under most conditions, there is not excess water but rather there may be water that has been dedicated to a different or beneficial purpose. Perhaps consider rephrasing this description of the project goal to reflect the description given on page 8, "…*to determine the timing and delivery rate of fresh water to East Matagorda Bay that could have a positive impact on the health and productivity of the estuary*."

*Section 4. Freshwater Delivery Alternatives for Localized Benefits, page 37* – In the list of seven scenarios, please clarify the pathways that will rely on conveyance through a pipe versus through a natural or open waterway.

*Section 4.1. Estimated Costs for Scenarios, page 40* – A 42-inch pipe is planned for delivering water into East Matagorda Bay, please verify or explain how the pipe dimensions (height in particular) compare to the depth of water in the approximate region it will be placed. Also, please reconcile this description with the depiction in Figure 32.

*Section 4.1.2. Operations and Maintenance Cost Summary, page 41* – The first paragraph describes that electrical costs were based on "*30 days of operation annually*". Please describe why 30 days was selected for the cost estimate.

*Section 4.2. Permitting Discussion, page 44* – Please clarify whether the preliminary conversations with TCEQ, which indicated a diversion permit might be possible, included consideration of available, unappropriated water for this purpose or if the BBASC might have to pursue alternatives to dedicate water for this purpose. The following information was provided by TCEQ as a comment on this draft report: *Although it may be possible to obtain a water rights permit for the project, it could be extremely difficult to obtain such a permit because of water availability constraints. If existing permits are used for the project those permits may need to be amended to allow for this use. Any permit issued, including a set-aside, would have the most junior priority date in the Colorado Basin which would likely limit water availability for the project. In addition, it would be difficult to authorize a set-aside that would be subsequently diverted.*

*Section 5.2. Southwest Cut, page 45* – The second paragraph discusses FM 2031. Please show this location on Figure 33 or another appropriate figure.

*Section 5.3. Brackish Groundwater, page 46* – Please do not qualitatively describe the groundwater quantities in the Gulf Coast Aquifer as "*plentiful*". This may lead to misrepresentation of the availability of this resource.

**Figures and Tables Comments**

Figure 5. Please add the term "balance" to the figure caption describing "freshwater inflow to East Matagorda Bay" so that it reads, "freshwater inflow balance for East Matagorda Bay".

Figures 21 - 24. Please verify the values and provide units for the WUA axis. Note also that the text refers to "blue triangles" for high flow months, but the symbols are better characterized as "blue diamonds".

Figure 25. Please verify the values for WUA and provide units.

Figure 32. This figure describes multiple delivery pipes carrying water across the GIWW, but the text on page 40 (*Section 4.1*) describes a single delivery pipe crossing the GIWW.

Table 3. Please clarify the meaning of the columns for number of white shrimp or blue crab "time in bay seasons". Please add an explanation to the text of Section 3.4 as well.

Tables 5 and 6. Please correct the table caption to ready “probable” rather than “probably.

**SUGGESTED CHANGES**

### General Draft Final Report Comments

The report has numerous sections which somewhat hinder the flow of the content and the reader’s understanding. Please consider consolidating sections, where appropriate to improve clarity and reduce misunderstanding and redundancy.

### Specific Draft Final Report Comments

*Section 2.1.3. Diversions and return flows, page 10* – Please consider including a table of water rights and NPDES permits.

*Section 3.2.1. Entire Bay, page 24* and *Section 3.2.2. West End, page 26* – Please consider combining these two sections.

*Section 3.4. Impact of Reduced Inflow on Colorado …, page 34* – One reviewer expressed concern that the timing of available flows from the Colorado River may not match well with the periods in which inflow is most needed in East Matagorda Bay. Please also consider adding a caveat stating that actual availability for a new project would be based on the TCEQ’s Full Authorization WAM for the Colorado River Basin.

*Section 5.3. Brackish Groundwater, page 46* – Please consider rephrasing the last sentence to indicate that groundwater *may not bring the same nutrients* as offered by surface water. Unless it is known that the groundwater source offers no nutrients.

*Section 6.1. Brackish Groundwater, page 46* – Please consider mentioning either the need to gather additional data and information on the benefits of delivering water to the eastern versus western sides of East Matagorda Bay or the need to make a stakeholder decision regarding this matter in order to better determine any future phases of work. Knowing the benefits of delivery to the eastern versus western sides of the bay in comparison to the costs associated with the relevant scenarios may aid stakeholders in selecting the scenario(s) to pursue in the next phase.

### Figures and Tables Comments

*Table 3.* Please consider adding a caveat stating that actual availability for a new project would be based on the TCEQ’s Full Authorization WAM for the Colorado River Basin.

Solving

water resources

challenges through

sound science and

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