CONNECTING WATER TO LIFE

Desalination Brine Discharge Modeling – Corpus Christi Bay System
EFDC+ Modeling Report

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DRAFT – PE SEAL ADDED TO FINAL VERSION

Executive Summary

The objective of this modeling project was assess the relative effect on ambient conditions resulting from potential desalination brine discharges into the vicinity of the La Quinta Ship Channel within the Corpus Christi Bay system. To assess impacts and the relative merit of differing discharge locations, volumes, and salinity concentrations, LRE Water, LLC developed an EFDC+ model of the Corpus Christi Bay system. This model is similar to the SUNTANS model previously constructed for simulating discharges into Corpus Christi Bay (Furnans, 2019), yet better represents the bathymetry and other known discharges into the bay system. The EFDC+ model is widely recognized and accepted, commercially available, and capable to be run on standard laptops or desktop computers.

The EFDC+ model was applied to the January 1, 2010-December 31, 2011 period, with a 2-month simulated "spin-up" time for numerical stability. This modeling period includes a "wet" year (2010) with periodic large freshwater inflows into the bay system, as well as a "dry" year (2011) with prolonged periods of low inflows. These simulation periods were selected to demonstrate the cumulative effect on the transport and mixing of the modeled discharge during both wet and dry conditions. As noted in Longley (1994), the Corpus Christi Bay system has a residence time of 1.4 years. This indicates that the 2-year modeled simulation period (2010-2011) included in this study would have provided sufficient duration for all water within the bay system to have been replaced by inflows.

A baseline EFDC+ model was constructed and validated against measured temperature and salinity data collected at six long-term monitoring stations within Corpus Christi Bay. Model results showed generally strong agreement with measured salinity values, as well as observed trends in bays salinity over time. The agreement between observed and measured water temperatures was not as strong, yet the EFDC+ model was able to adequately reproduce trends in temperature data. Overall, the EFDC+ modeled tended to over predict water temperatures, and slightly under predict salinity.

Using the baseline, validated EFDC+ model, multiple simulations were performed to evaluate salinity increases from brine discharges at three locations (A, B, and C) and using varying concentrations and discharge volumes. Discharges at Location B were not simulated extensively, as this location was generally deemed less favorable than Location A (within Corpus Christi Bay south of the La Quinta Channel) and Location C (within the La Quinta Channel, 1500 ft east of the channel's western end). In general, discharges at either Location A or Location C led to depth-averaged salinity increases of less than 2 ppt at distances of 500 ft and 1000 ft. Location A produced slightly less salinity increases that Location C. Splitting the discharges evenly between Location A and Location C resulted in smaller salinity increases at each location.

The modeled salinity increases at each of the six long-term monitoring station locations were computed and documented for all modeled scenarios. Salinity increases, when averaged daily, monthly, or seasonally, are small compared to the observed range of salinity values at each station. The largest salinity increases attributable to the modeled brine discharges generally occur at times when the ambient salinity within the Corpus Christi Bay system is low.

The final set of modeling simulations performed using the EFDC+ model consisted of simulating the likely variable salinity concentration within the proposed desalination plant discharge into the bay. For these scenarios, discharge concentrations were variable in time, based on mathematical calculations of salinity concentration and the model-calculated salinity at the proposed water intake location. Results from these scenarios indicated less than a 0.6 PPT increase in monthly-averaged salinity would result from discharging brine from a 30 MGD production facility using 40% recovery and a discharge into the La Quinta Channel.

Introduction

The primary objective of this modeling project was to determine how the proposed discharge of brine from desalination operations would alter the distribution of salinity within the Corpus Christi Bay system. A secondary objective was to assess the relative merits and detractors of three proposed discharge locations, and of various discharge characteristics (flow rate and salinity). For this project, potential discharges were simulated at three separate locations (A, B, and C) in the vicinity of the head of the La Quinta Ship Channel along the northern boundary of Corpus Christi Bay. (Figure 1).

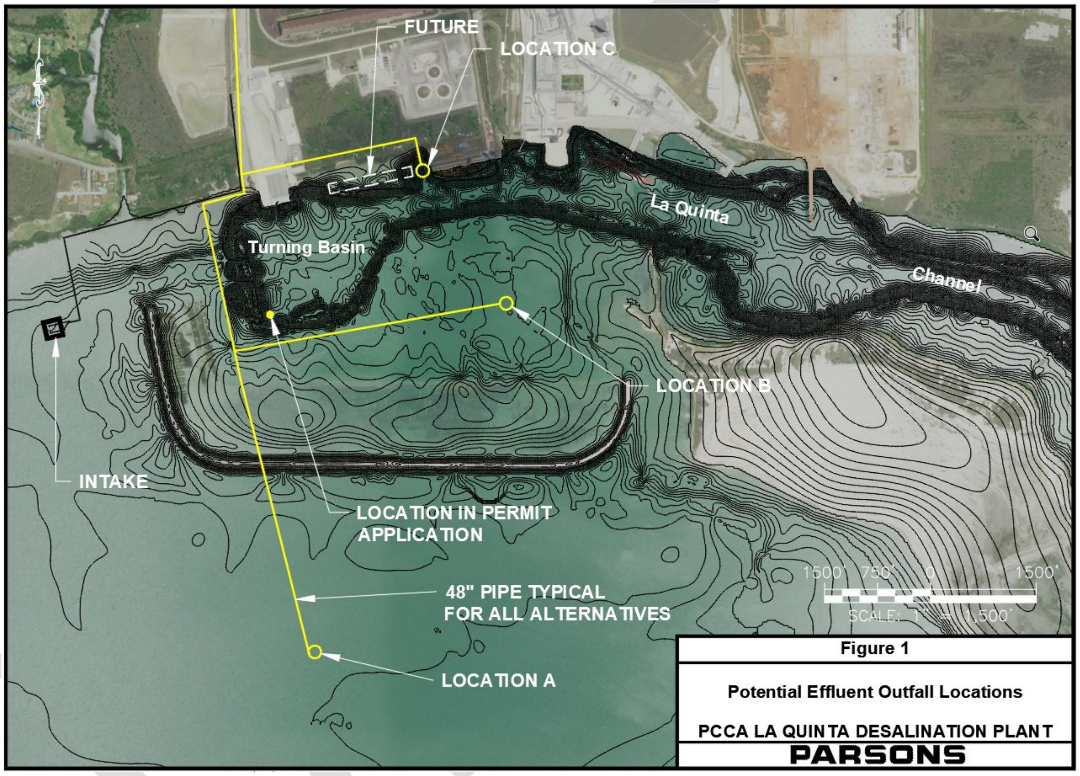


Figure 1 – Proposed brine discharge locations A, B, and C located near the western end of the La Quinta Ship Channel within Corpus Christi Bay. Graphic copied from Parsons (2021).

To achieve these objectives, LRE Water developed a suite of EFDC+ models of the Corpus Christi Bay System (Figure 2), and simulated water circulation patterns, salinity distributions, and temperature distributions throughout the system. The models included both open water and defined ship channel locations, with the channels accurately represented in shape, location, and depth. The EFDC+ models were also based, in part, upon the SUNTANS model of the Corpus Christi Bay System that was developed previously by LRE Water to study the impact of brine discharge from a desalination facility located on Harbor Island (Furnans, 2019).

Figure 2 – Modeled domain, including Corpus Christi Bay, Nueces Bay, Redfish Bay, and portions of Aransas Bay and Laguna Madre.

LRE Water used the EFDC+ model to simulate possible discharges for the purpose of assessing: 1) the extent to which each modeled discharge may increase the ambient salinity over time, 2) the spatial extent of any salinity increases resulting from each discharge, and 3) the temporal extent of any salinity increases, including the determination of whether each discharge would result in the accumulation of salt over time in the vicinity of each discharge. To assess the impact of each modeled discharge on salinity distributions throughout the bay system, model results were compared to those obtained from a "base scenario" EFDC+ model, which differed from each "Test Case" model, only by the exclusion of simulated desalination brine discharges from the area around the head of the La Quinta ship channel. Comparing model results therefore allows for the discernment of salinity variations resulting solely from natural environmental conditions, as well as those resulting from the simulated brine discharge.

All EFDC+ models simulated the period from November 1, 2009 to January 1, 2012. The modeled period from November 1, 2009 through December 31, 2009 is excluded, however, from all modeling results presented in this report. The modeled period in 2009 was used as a numerical "spin-up" period after which modeled conditions were generally numerically stable and not contingent upon the initial conditions assumed for November 1, 2009. Comparisons of model results were conducted for the period between and including January 1, 2010 to December 31, 2011. This period included a generally "wet" year (2010) with numerous freshwater inflow events exceeding 3,000 cfs as well as an extremely dry year (2011) when inflows remained below 20 cfs for a majority of the year. Tidal forcing was also relatively mild in 2011, which would affect the exchange of water between the bay system and the Gulf of Mexico and could alter the fate and transport of any desalination brine discharges.

The remainder of this report details the EFDC+ Corpus Christi Bay system models, and our analysis regarding potential impacts of the proposed desalination brine discharge near the head of the La Quinta ship channel.

EFDC+ MODEL – Corpus Christi Bay System

As shown in Figure 2, the EFDC+ model of the Corpus Christi Bay system extends from the Northern portion of Aransas Bay to Laguna Madre. It simulates water movement through the following bays/waterbodies: Aransas Bay, Redfish Bay, Corpus Christi Bay, Nueces Bay, Oso Bay, and Laguna Madre. It excludes both Copano Bay and Baffin Bay from the model domain. Water exchange with the Gulf of Mexico occurs through the Aransas Pass jetties as well as through the Packery Channel. Atmospheric conditions (winds, solar radiation, etc.) were obtained from publically available sources and were identical to those used and incorporated into the SUNTANS model of the system (Furnans, 2019).

The EFDC+ model software is available by subscription as part of the EE Modeling System distributed DSI, Inc. (https://dsi.llc/eems as of 10/23/2023). The EFDC+ software is a modified version of the Environmental Fluid Dynamics Code (EDFC) model originally developed by Dr. John

M. Hamrick and freely distributed by the US Environmental Protection Agency (https://www.epa.gov/ceam/environment-fluid-dynamics-code-efdc - download-page as of 10/23/2023). The EFDC+ model software contains tools for developing model simulations, as well as for processing models, troubleshooting model runs, and visualizing or analyzing model results. LRE Water did not modify any of the EFDC+ model source code as part of this project, and only utilized functionalities already present within the EFDC+ software.

BASE CASE – EFDC+ Model Development for the Corpus Christi Bay System

Prior to assessing the impact of modeled desalination brine discharges, it is necessary to create a model "Base Case" which simulates conditions common to all EFDC+ Corpus Christi Bay System models. The Base Case model incorporates system bathymetry, tidal input forcing, wind forcing, atmospheric forcing, river inflows, and any other modeled variables, which will be simulated in all modeled "Test Case" variations. In this section, we detail the properties of the Base Case Corpus Christi Bay system model, and present model verification through the comparison of modeled and observed data.

Perhaps the most significant driver of circulation patterns within the Corpus Christi Bay System is the shape of the system, defined by the numerical grid and bathymetric data within the EFDC+ model. Bathymetric data is defined as model input, with the model user supplying the depth (below mean sea level) to the bottom within all grid cells in the simulation. The final bathymetry used in this modeling is shown in Figure 3, which also depicts the entire model domain.

Bathymetry used within the EFDC+ Base Case model of the Corpus Christi Bay system is largely identical to that included in the SUNTANS model (Furnans, 2019), with depths derived from hydrographic survey data publically available from the U.S. Army Corps of Engineers. The EFDC+ Base Case model was constructed specifically to properly represent the location, width, and depth of all ship channels within the system, including the Corpus Christi Bay (CCB) Ship Channel, the La Quinta (LQ) Ship Channel, the Gulf Intra Coastal Waterway (GIWW), the Lydia Ann Channel, and the Corpus Christi Inner Harbor. These channels provide conduits for the movement of water, especially in transferring tidal fluxes into and from the Gulf of Mexico. For each of these channelized features, the EFDC+ Base Case bathymetry was constructed so that grid cells aligned with each channel feature and reasonably represented the physical shape of each feature. It was not possible, however, to properly align the model grid cells representing the Aransas Channel between Aransas Pass and the GIWW, where the channel separates Redfish Bay along State Highway 361. It was also not possible to fully resolve the complex bathymetry of Redfish Bay, including all the islands around Harbor Island (Figure 3). The EFDC+ model approximates the bathymetry in these areas.

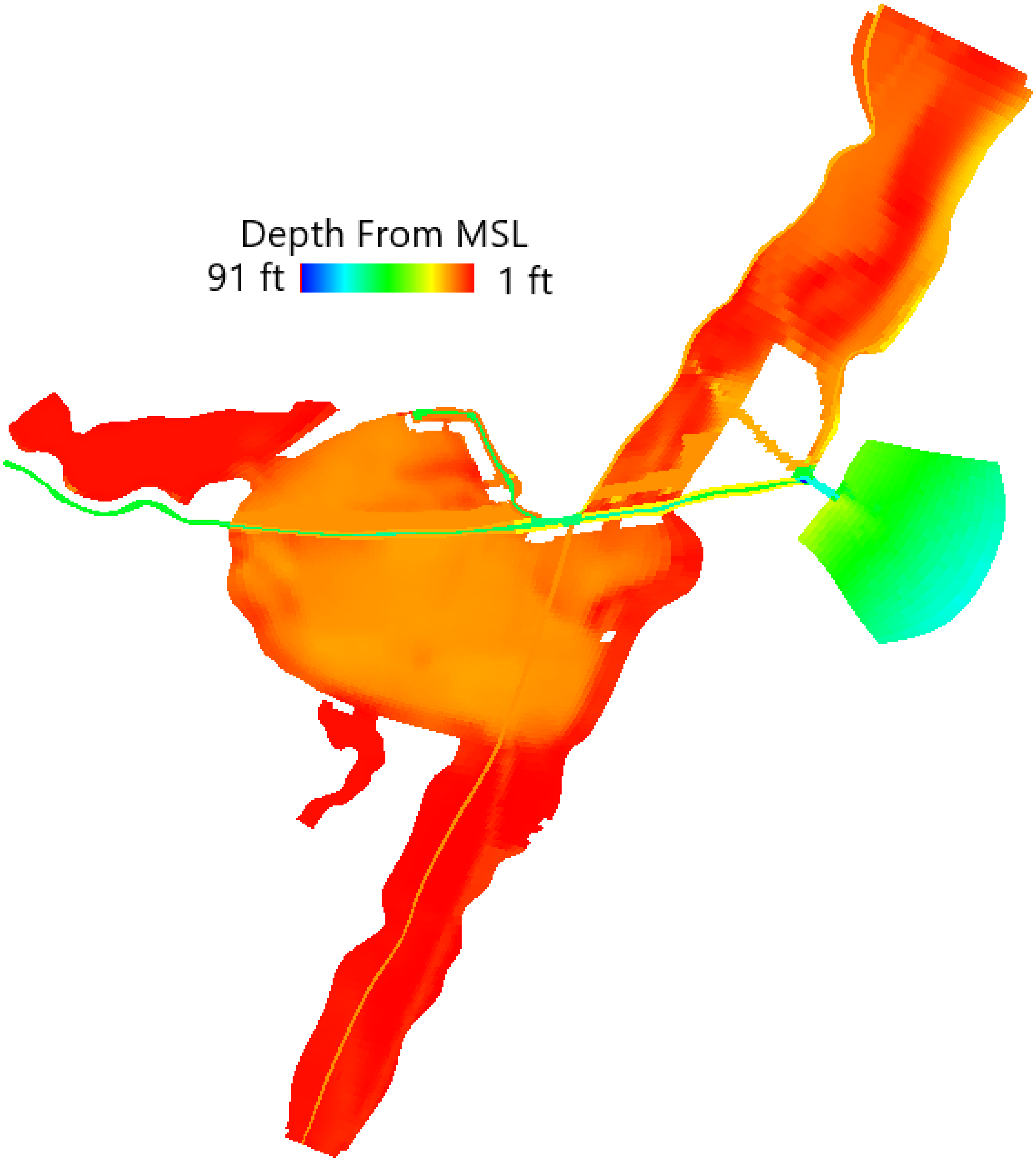


Figure 3 – Bathymetry within the EFDC+ model of the Corpus Christi Bay System

Figure 4 presents a close-up view of the model bathymetry and numerical grid structure in the vicinity of the intersection between the Corpus Christi Bay Ship Channel and the La Quinta Ship Channel. As modeled with EFDC+, the Corpus Christi Bay Ship Channel is represented as one series of connected grid cells aligned primarily in the E-W direction, whereas the La Quinta Ship Channel is represented by grid cells aligned primarily in the N-S direction. At the channel intersection, the system bathymetry was modeled with the same depth of the Corpus Christi Bay Ship Channel, yet consisting of a grouping of two adjacent rows of cells. These adjacent rows of deeper cells extended eastward until the intersection with cells representing the GIWW, which were aligned in the N-S direction and had a shallower bathymetry outside of Corpus Christi Bay Ship Channel. The grid structure included within the Base Case model was created specifically to allow for alignment of grid cells representing existing channelized features within the system bathymetry.

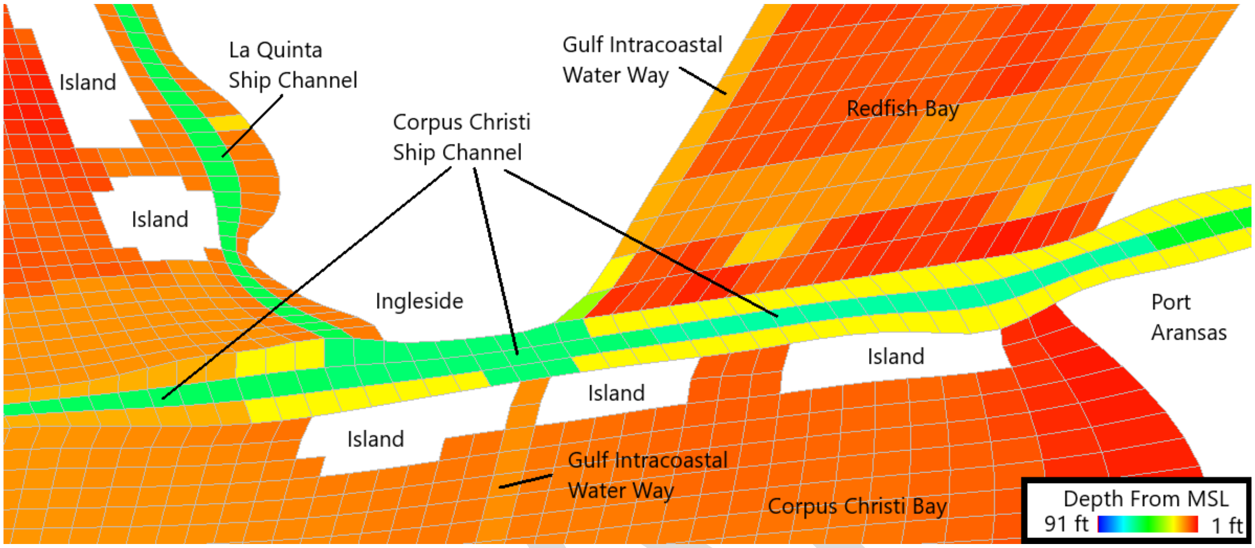


Figure 4 – Bathymetric model and grid cell extent at the intersection of the La Quinta Ship Channel, Corpus Christi Ship Channel, and Gulf Intracoastal Water Way.

The Base Case EFDC+ model of the Corpus Christi Bay system contains 11,510 quadrilateral grid cells covering the surface. Each grid cell had its own shape, with varying widths and lengths. The average cell horizontal dimension is approximately 350 m (1150 ft) in length. The model was setup as a SIGMA-ZED-coordinate model, consisting of up to 25 vertical layers of gridcells making up the water column in any given location. Each vertical layer had a nominal cell height of 1.1m (3.6 ft). At each grid cell location, the water column is simulated by defining the number of active cells based on the local bathymetry (depth) divided by 1.1 m. For example, if the local depth were 3.5 m, the water column would consist of 4 active cells, with three full cells of 1.1 m vertical extent, and one cell of 0.2 m vertical extent at the model bottom. The model would also include simulations of cells above and below the water column, incase such cells become active (due to water level increases, or sediment scour). The total number of active grid cells within the Base Case model is 47,581.

EFDC+ Base Case Model Setup - Inflows

Along with bathymetry, water circulation and salinity levels are largely dictated by the freshwater inflows entering into the Corpus Christi Bay system. Inflows are specified as model inputs, and within the EDFC+ model of the Corpus Christi Bay system the following inflow sources are included:

- Oso Creek at Corpus Christi, TX (USGS Gauge #08211520)

- Nueces River near Mathis, TX (USGS Gauge #08211000)

Inflows entering the bay system at each of these locations will vary in time, and will introduce freshwater at different rates, resulting in variable mixing and flushing impacts throughout the bay system. Figure 5 depicts the modeled freshwater inflows into the Corpus Christi Bay system for the modeled period from January 1, 2010 to December 31, 2011. The model period was selected in part due to the large variation in inflow conditions that occurred during this time. For example, 2010 was generally considered a “wet” year across Texas, and as shown in Figure 5 contained four inflow events that approached or exceeded 4,000 cfs. These events, including the large 12,000 cfs inflow event that occurred from mid-September to early October 2010, are likely to lower salinities throughout the bay, including those that may result from the modeled desalination brine discharge. Aside from these high inflow events, 2010 also included periods of low inflows, during which salinity increases are likely. Modeling 2010 is therefore likely to produce information related to salinity accumulation and flushing frequency during wet periods.

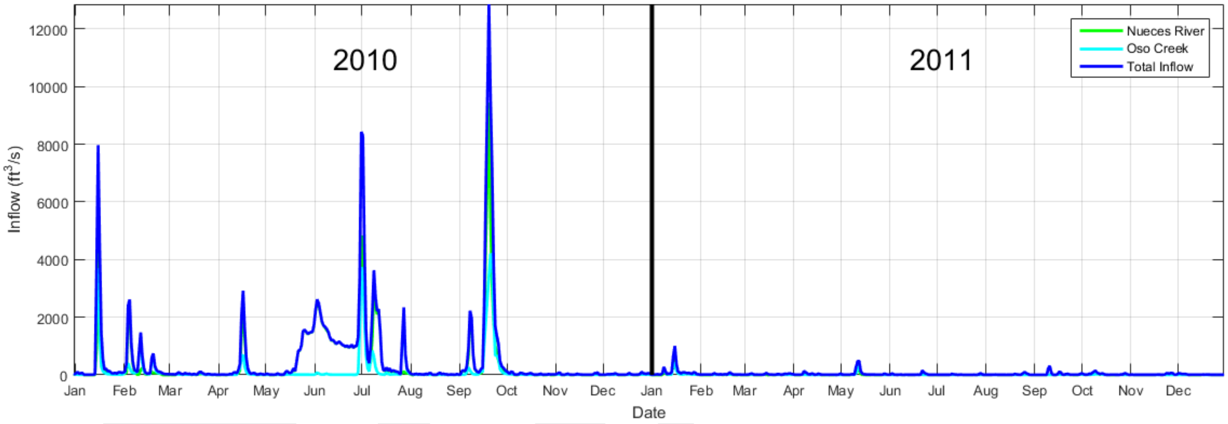


Figure 5 – Freshwater inflows to the EFDC+ Models – including flows from the Nueces River and Oso Creek

In contrast to 2010, 2011 is often considered as the single worst drought year in recorded Texas history. Figure 5 demonstrates the difference between inflows in 2011 and 2010, with 2011 only having two small inflow events, and with having long periods of total inflows less than 20 cfs. Modeling 2011 is therefore likely to produce information related to salinity accumulation during long dry periods. Inflow conditions in 2011 are likely to represent a “worst case” scenario for assessing the impact of the potential desalination brine discharges on salinity levels within the bay system.

EFDC+ Model Setup – Tidal Forcing, Boundary Conditions, & Initial Conditions

Along with bathymetry and freshwater inflows, water circulation and salinity levels are largely dictated by the tidal forcing, which governs the exchange of water between the bay systems and the Gulf of Mexico. Within the Corpus Christi Bay system EFDC+ model, tidal forcing is specified as modeled input water levels at the outermost model cells representing the Gulf of Mexico (Figure 3).

Water levels used as model input were based on data recorded at Bob Hall Pier and available through the TCOON network and other sources. Identical tidal forcing data was used in the previous SUNTANS model of the Corpus Christi Bay system (Furnans, 2019). Tidal forcing within the EFDC+ model was also imposed on model cells representing the Packery Channel and the Fish Pass through Mustang Island, yet for these locations the tidal amplitude was dampened by 50%. Tidal forcing data used in the EFDC+ model is shown in Figure 6.

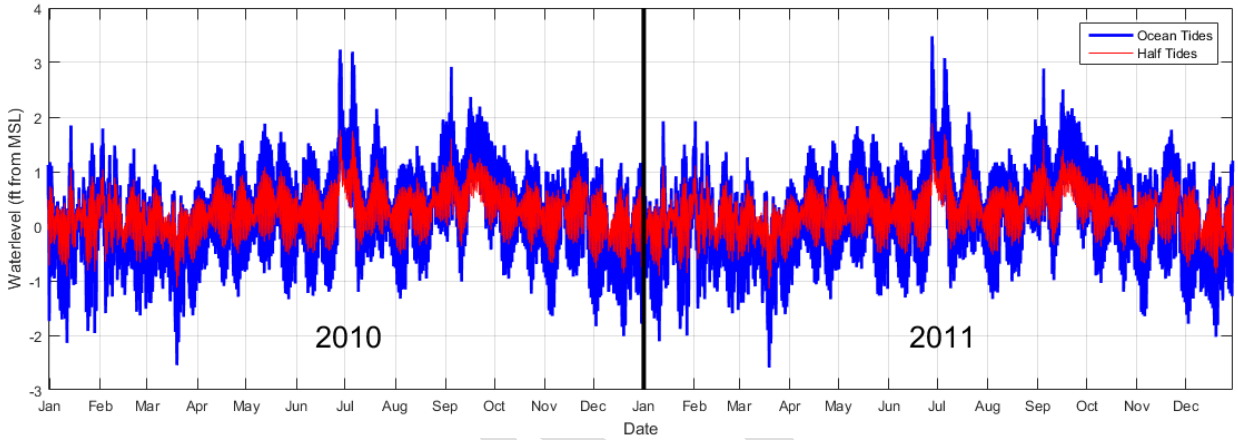


Figure 6 – Input water levels for the Gulf of Mexico (Ocean Tides), and the Packery Channel and Fish Pass (Half Tides)

Modeled temperature and salinity at the tidal boundary locations were obtained from the sensor at 5.5m depth within the Corpus Christi Ship Channel adjacent to The University of Texas Marine Science Institute (UTMSI). Data from this sensor was used to validate the SUNTANS model (Furnans, 2019). In this modeling effort with EFDC+, however, the UTMSI data was used to drive the model, and therefore was not available for use in model verification. The tidal input salinity and temperature time series data are presented in Figure 7.

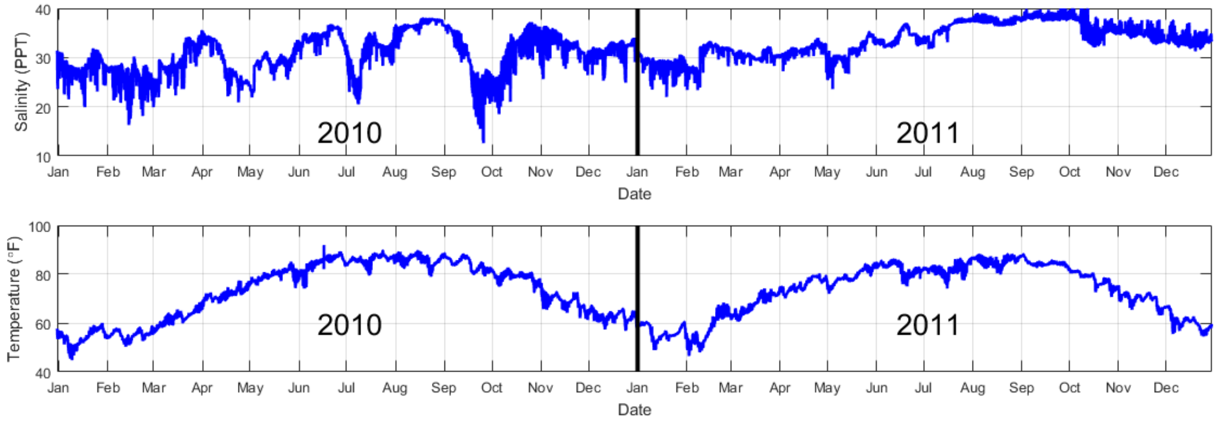


Figure 7 – Modeled Salinity (Top) and Temperature (Bottom) for the Gulf of Mexico, Packery Channel, and Fish Pass . From UTMSI data collected within the Corpus Christi Ship Channel.

Unlike in the previously created SUNTANS model (Furnans, 2019), the EFDC+ model of the Corpus Christi Bay system utilizes open boundaries along its northern and southern edges (Figure 1). To the north, the model simulates an open boundary across Aransas Bay, approximately 500 m (1,640 ft) south of where HW 35 crosses over the intersection between Copano Bay and Aransas Bay. To the south, the model simulates the portion of Laguna Madre which extends from the sourthern edge of Corpus Christi Bay to a point 26.4 km (16.4 miles) southward. The southern boundary of the EFDC+ model is therefore north of Baffin Bay, and Baffin Bay is excluded from the EFDC+ model.

At modeled open boundaries, water is simulated as being able to flow into or out of the modeled domain, as determined by modeled conditions and directed by water levels specified at the open boundaries. Water levels (Figure 8) at the northern boundary were obtained from the Mission Aransas National Estuarine Research Reserve (available as of April 12, 2023). Water levels at the southern boundary were obtained from the NOAA tides and currents database, station S. Bird Island, TX (ID 8776139).

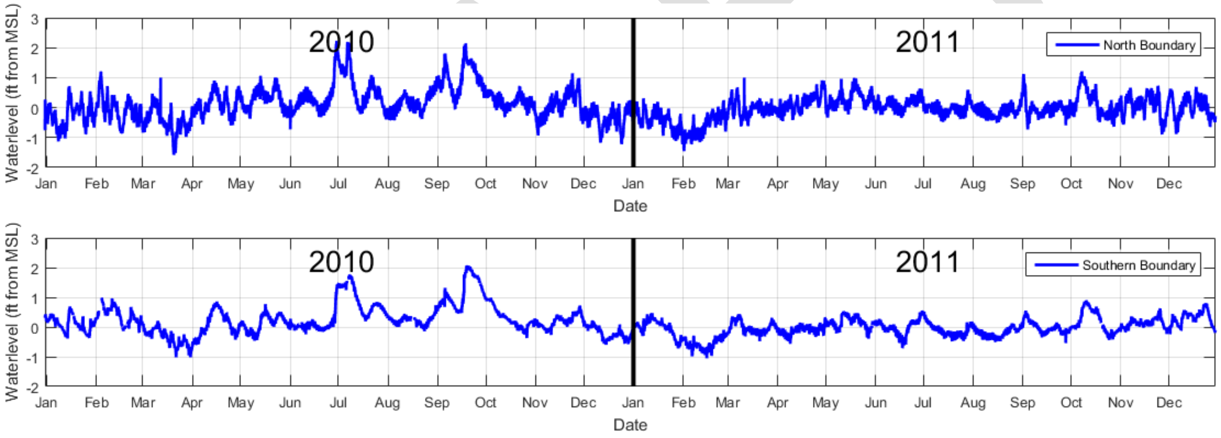


Figure 8 – Water levels at the northern (top) and southern (bottom) open boundaries of the EFDC+ model domain

The EFDC+ model also included the simulation of known water inputs and transfers within and around the Corpus Christi Bay system. Such inputs include the permitted discharges from facilities located adjacent to parts of the system, as listed in and mapped in Figure 9 and Figure 10. These discharges were simulated as constant discharges at the rate, salinity, and temperature specified in Table 1. All inflows in

Table 1 were modeled as defined “Flow Boundary Conditions” within EFDC+.

Table 1– Model Constant inflows to the Corpus Christi Bay System – Base Model

		Flow Rate			
#	Description	Million Gallons Per Day (MGD)	Cubic Meters Per Second (m^3/s)	Salinity (PPT)	Temperature (°C/°F)
1	CC Alison	25.88	1.134	1	30/86
2	Flint Hills Resources	2.97	0.13	2	35/95
3	CC Polymers	38.57	1.690	55	30/86
4	Valero Refinery West	1.83	0.08	2	30/95
5	Equistar Chemicals	0.91	0.04	2	35/95
6	CITGO East Refinery	2.28	0.10	2	35/95
7	Valero Refinery East	1.37	0.06	2	35/95
8	Nueces Bay Power	335.48	14.700	30	36/97
8	City of Corpus Christi – New Broadway	4.11	0.18	1	30/86
9	GCGV	6.00	0.263	4	40/104
10	Voestalpine	8.44	0.370	40.5	35/95
11	Chemours	2.28	0.100	50	35/95
12	Oxy	2.28	0.10	2	35/95
13	City of Corpus Christi – Laguna Madre	1.87	0.082	1	30/86
14	Barney Davis Power Plant	235.07	10.30	36	40/104

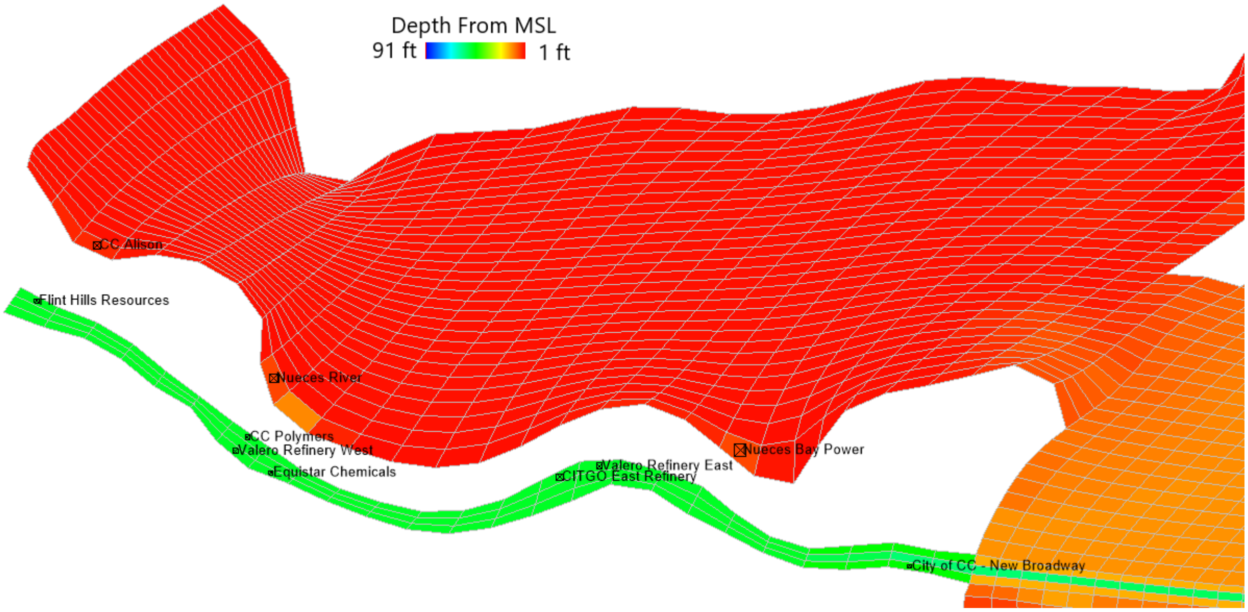


Figure 9 – Model Grid & Bathymetry of Nueces Bay and the Inner Harbor, showing modeled discharge locations

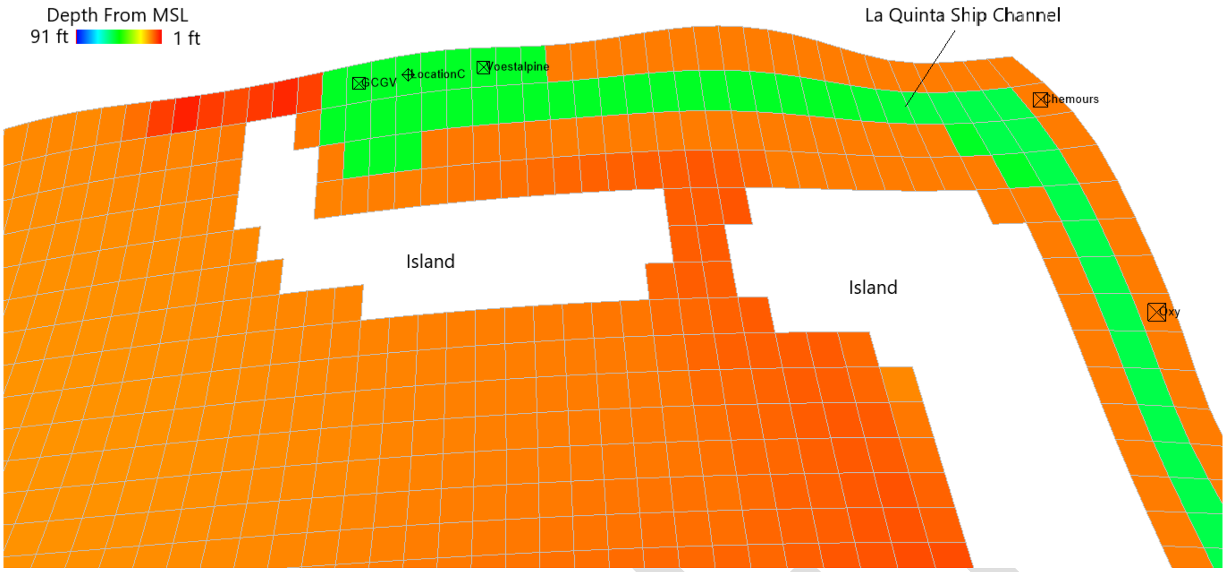


Figure 10 – Model Grid & Bathymetry of the La Quinta Channel area showing modeled discharge locations.

The EFDC+ model was unable to numerically simulate the actual operation of the Barney Davis Power Plant, which withdraws water from Laguna Madre, uses the water in its cooling processes for power generation, and then discharges the water into Oso Bay. Attempts were made to have EFDC+ simulate an outflow of water from Laguna Madre, with the withdrawn water then discharged at the same model timestep into Oso Bay, with the same computed salinity and temperature at both the withdrawal and discharge locations. Such a numerical simulation would better represent the actual physical processes occurring within the Corpus Christi Bay system, and would result in a dynamic discharge into Oso Bay (with respect to both modeled salinity and temperature). The EFDC+ model, however, would not run successfully under such a setup, and would "crash" due to numerical errors after only a few timesteps. As such, only the Barney Davis Power Plant discharge was included within the EFDC+ model, simulated under the static conditions provided in Table 1.

The EFDC+ model was similarly unable to numerically simulate the actual operation of the Nueces Bay Power Plant, which withdraws water from the Corpus Christi Bay Inner Harbor, uses the water in its cooling processes for power generation, and then discharges the water into Nueces Bay. Attempts were made to have EFDC+ simulate an outflow of water from the Inner Harbor, with the withdrawn water then discharged at the same model timestep into Nueces Bay, with the same computed salinity and temperature at both the withdrawal and discharge locations. Such a numerical simulation would better represent the actual physical processes occurring within the Corpus Christi Bay system, and would result in a dynamic discharge into Nueces Bay (with respect to both modeled salinity and temperature). The EFDC+ model, however, would not run successfully under such a setup, and would "crash" due to numerical errors after only a few timesteps. As such, only the Nueces Bay Power Plant discharge was included within the EFDC+ model, simulated under the static conditions provided in Table 1.

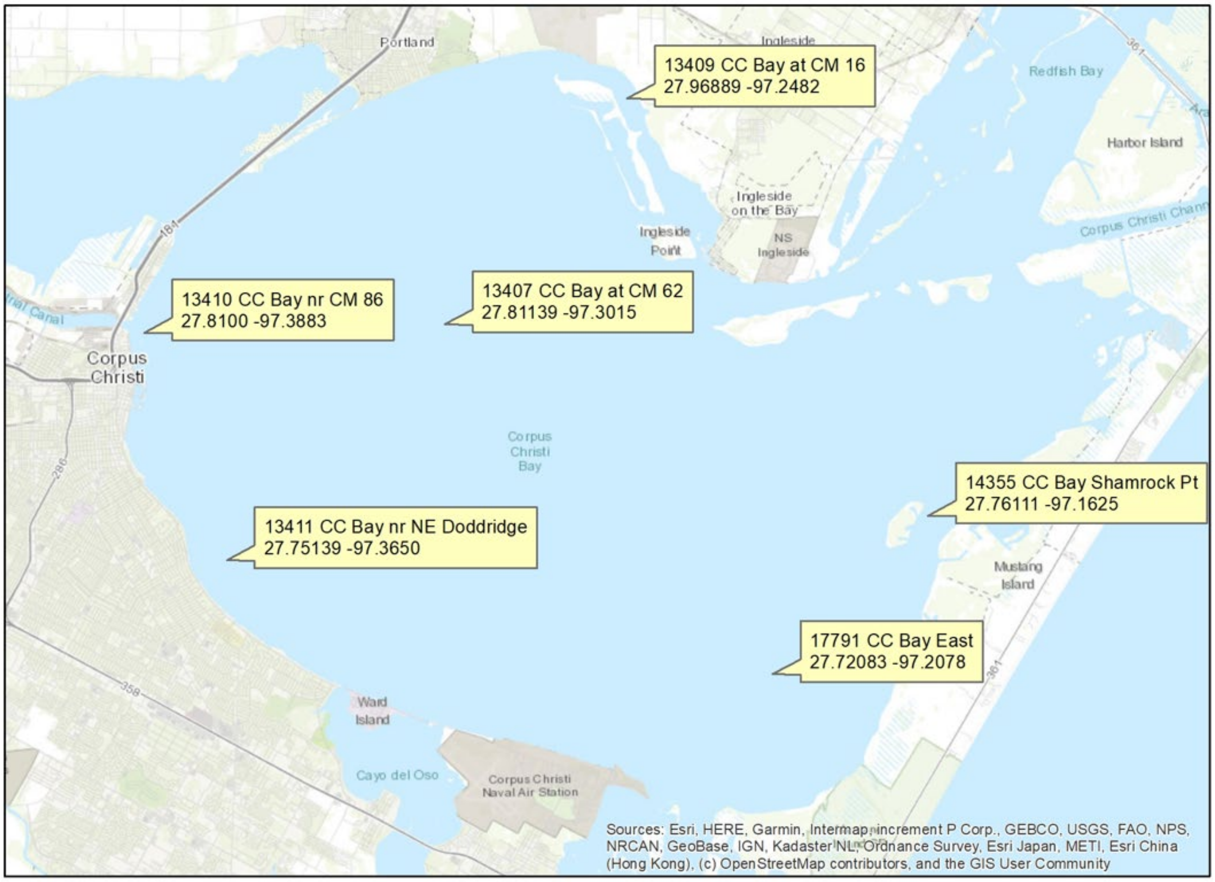
Initial conditions specified for the entire simulated EFDC+ model domain were a temperature of 27.4° C (81.3 °F) and a salinity of 40.0 PPT. The initial water level elevation was set to 0 m (0 ft) above Mean Sea Level (MSL). These initial conditions were specified for the first model timestep corresponding to November 1, 2009, and were based on conditions observed at the long-term salinity and temperature monitoring stations within Corpus Christi Bay and Nueces Bay. The EFDC+ model simulations include both November and December 2009 as the model "spin-up" period where the initial conditions of the model provide the most impact on the computed model results. As the initial conditions specified were 100% uniform across the model domain, and as this is an unrealistic condition within the modeled system, the modeled "spin-up" period is included in order to eliminate the effect of initial conditions on the computed and reported model results.

EFDC+ Base Model Validation/Verification

Prior to assessing EFDC+ base model results with regard to the proposed desalination brine discharge within the vicinity of the La Quinta Channel, it is necessary to establish that the model is capable of reasonably representing the physical conditions driving water circulation, salinity, and temperature distribution within the Corpus Christi Bay system. Model validation often requires detailed comparison between modeled and measured parameters, should sufficient measured data be available. The goal of the model validation effort is to establish that the EFDC+ model is capable of reproducing results (i.e. water velocities, temperatures, and salinities) that are reasonably accurate with respect to measured results.

To validate the EFDC+ model's ability to simulate temperature, base case simulations were performed and simulated data was compared to data collected at long-term monitoring stations within the Corpus Christi Bay system, as maintained by the Texas Commission on Environmental Quality (TCEQ). Monitoring station locations, names, and GPS coordinates are shown in Figure 11.

Figure 12 through Figure 17 show modeled salinity and temperature at each TCEQ long-term monitoring location, along with the measured data collected at each location over the 2010-2011 modeled timeframe. In general, the model excellently reproduces the observed trends in both temperature and salinity, yet commonly over-predicts water temperature throughout the year. Figure 15 presents modeled and measured data for the monitoring location closest to the proposed discharge locations. At this location, the EFDC+ model accurately predicts the magnitude and trends in salinity for 2010, yet under-predicts the salinities observed in 2011. The increase in salinity from February to September 2011 was, however, captured by the model. The agreement between measured and modeled temperature, however, was not as strong. The EFDC+ model did not "cool off" as much during the winter months, and generally over-predicted temperatures by 3-7 degrees Fahrenheit. It did accurately predict temperatures in April 2010 and June 2011, however.



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Figure 11 – Map showing locations of long-term TCEQ water monitoring stations within Corpus Christi Bay.

The general agreement between measured and modeled salinity and temperature at the six TCEQ monitoring stations provides sufficient confidence that the EFDC+ model is reasonably accurate at reproducing conditions within Corpus Christi Bay.

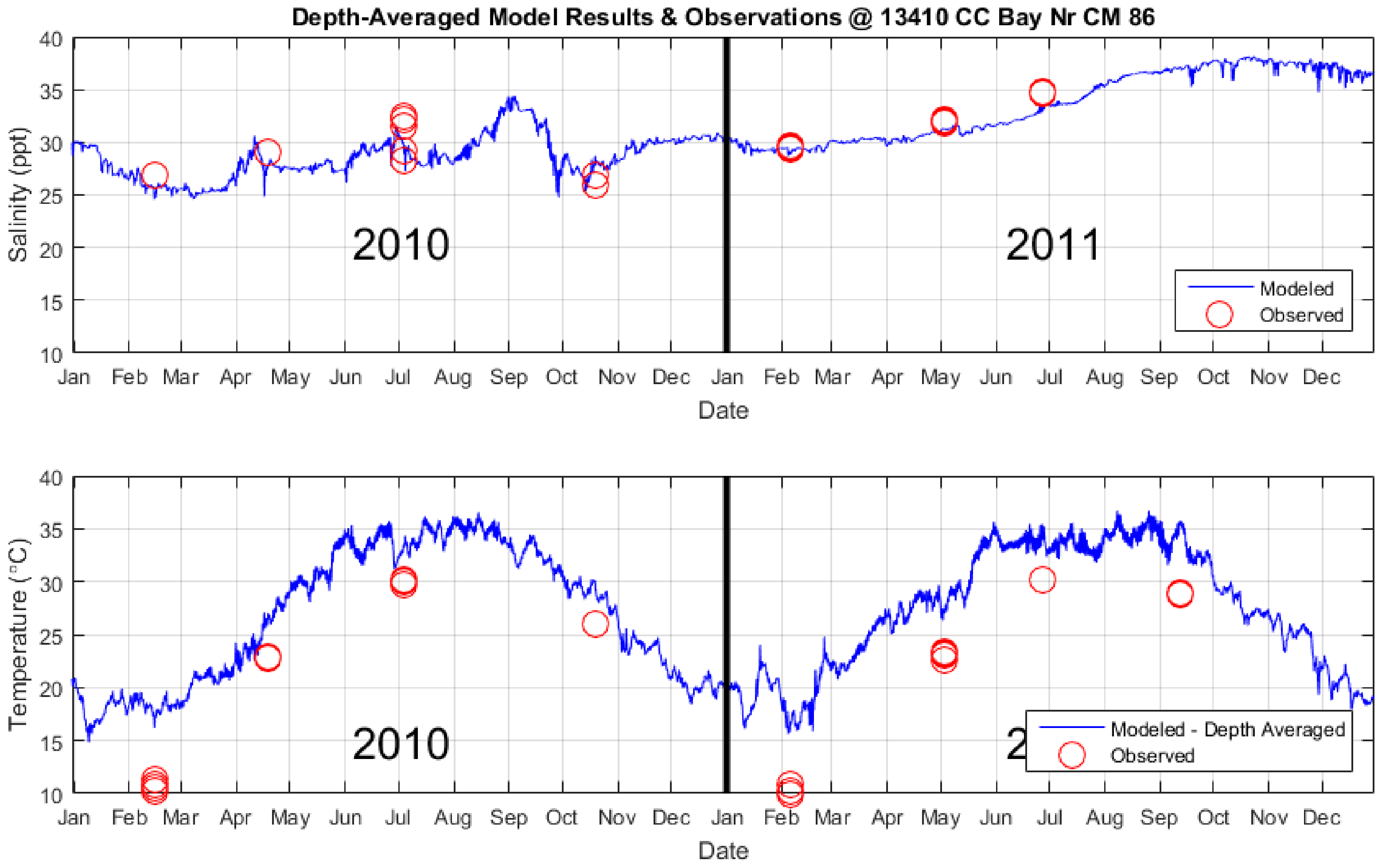


Figure 12 – Measured and modeled salinity and temperature at TCEQ monitoring station 13409 CC Bay at CM 16

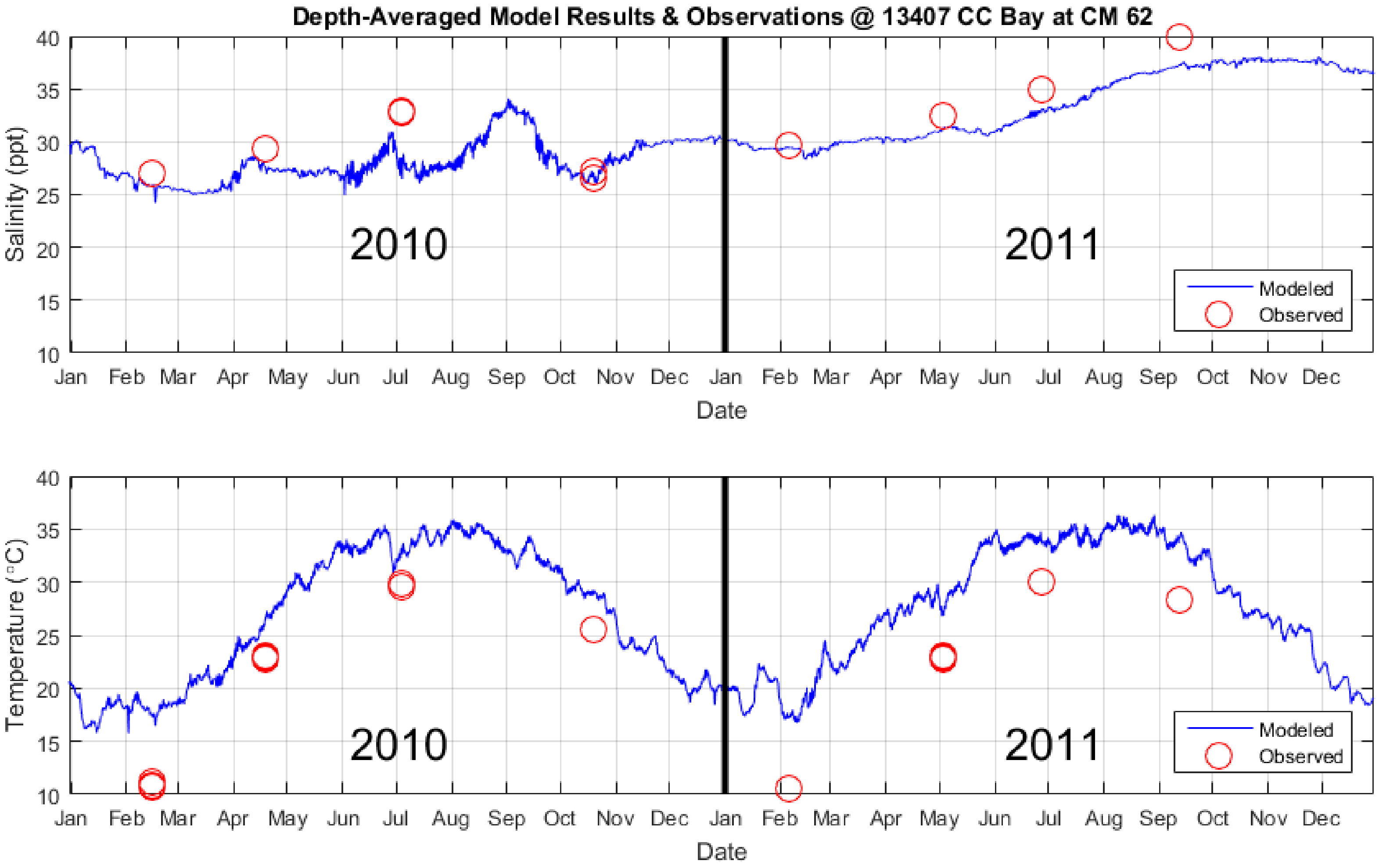


Figure 13 – Measured and modeled salinity and temperature at TCEQ monitoring station 13407 CC Bay at CM 62

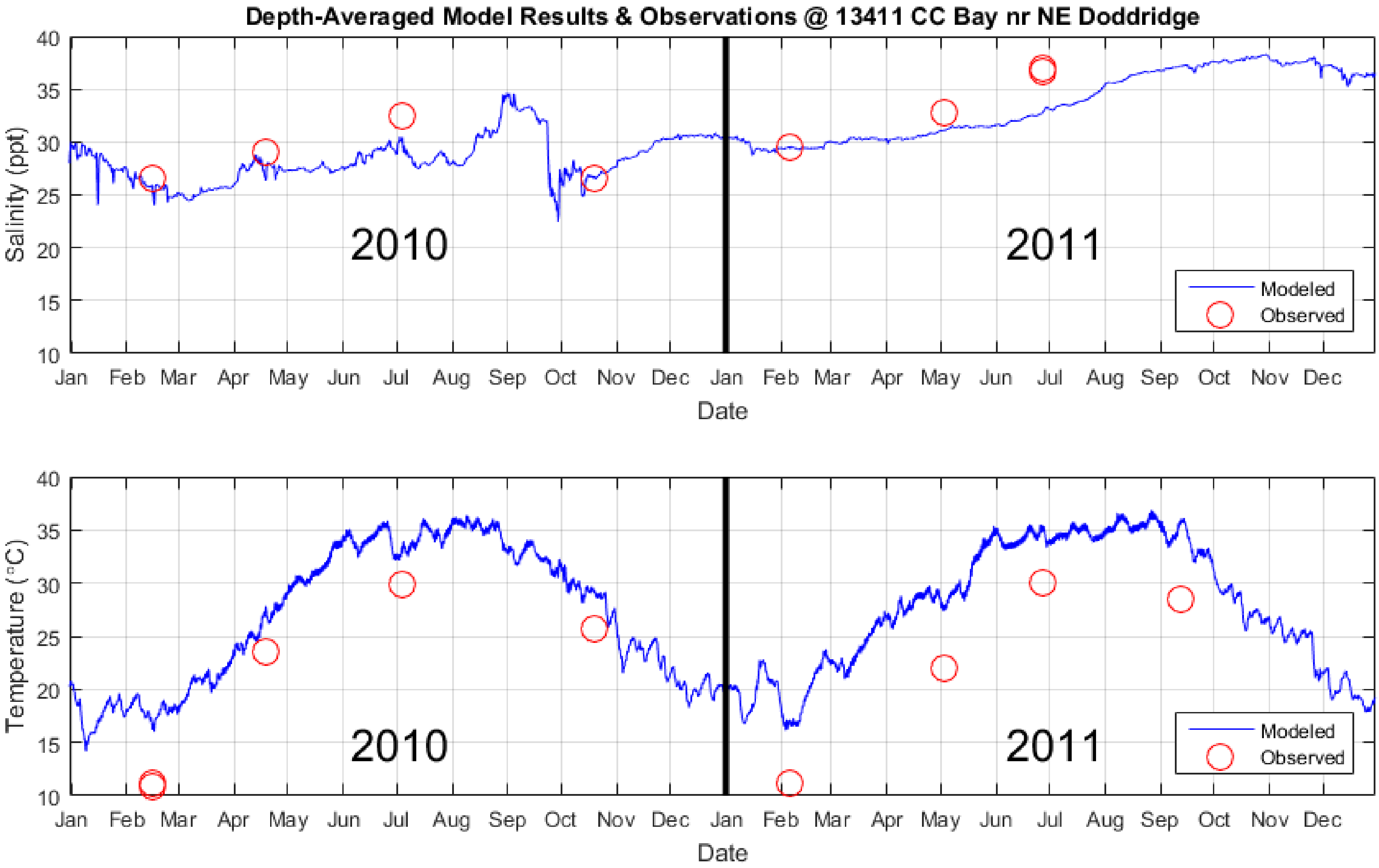


Figure 14 - Measured and modeled salinity and temperature at TCEQ monitoring station 13411 CC Bay nr NE Doddridge

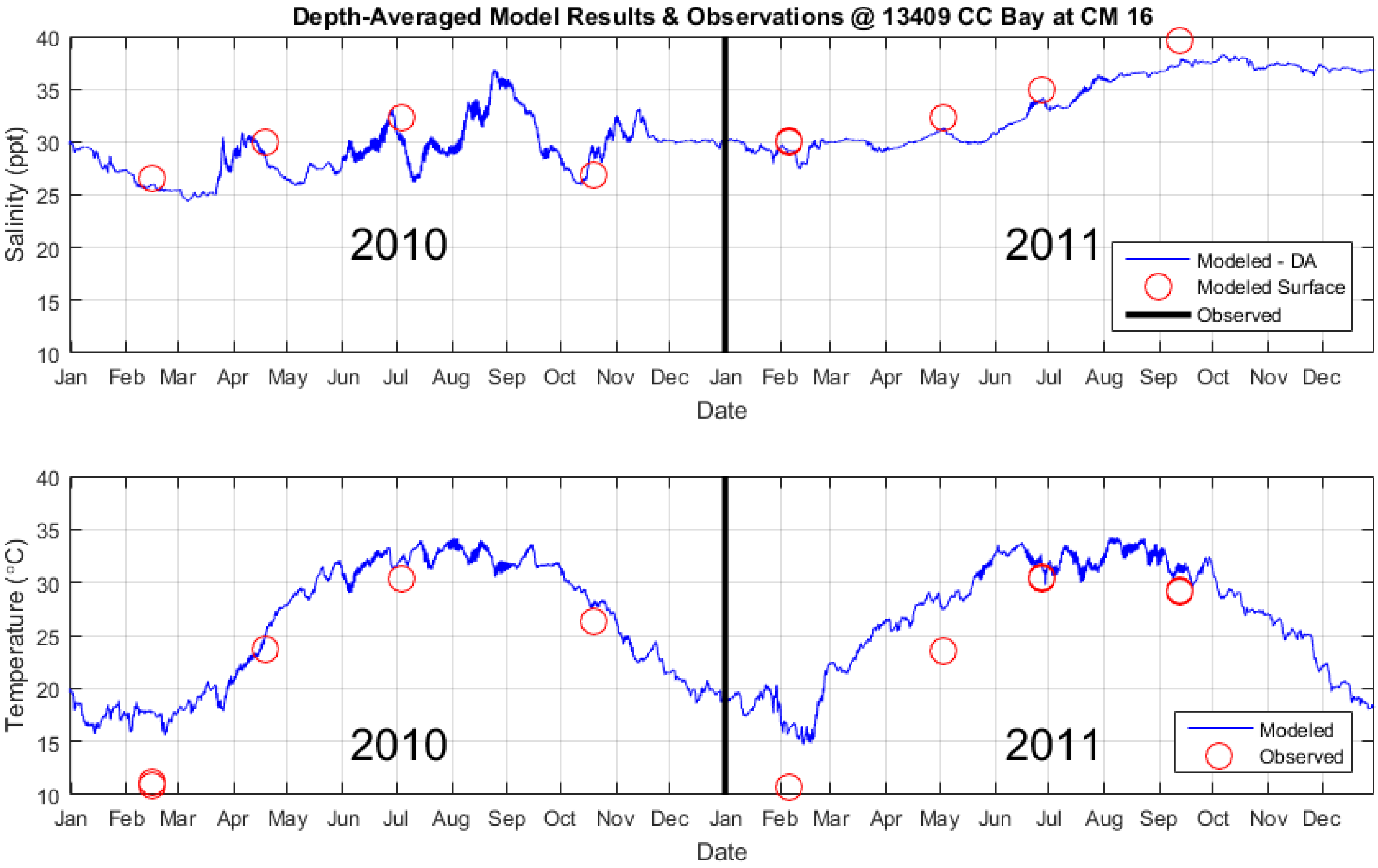


Figure 15- Measured and modeled salinity and temperature at TCEQ monitoring station 13409 CC Bay at CM 16

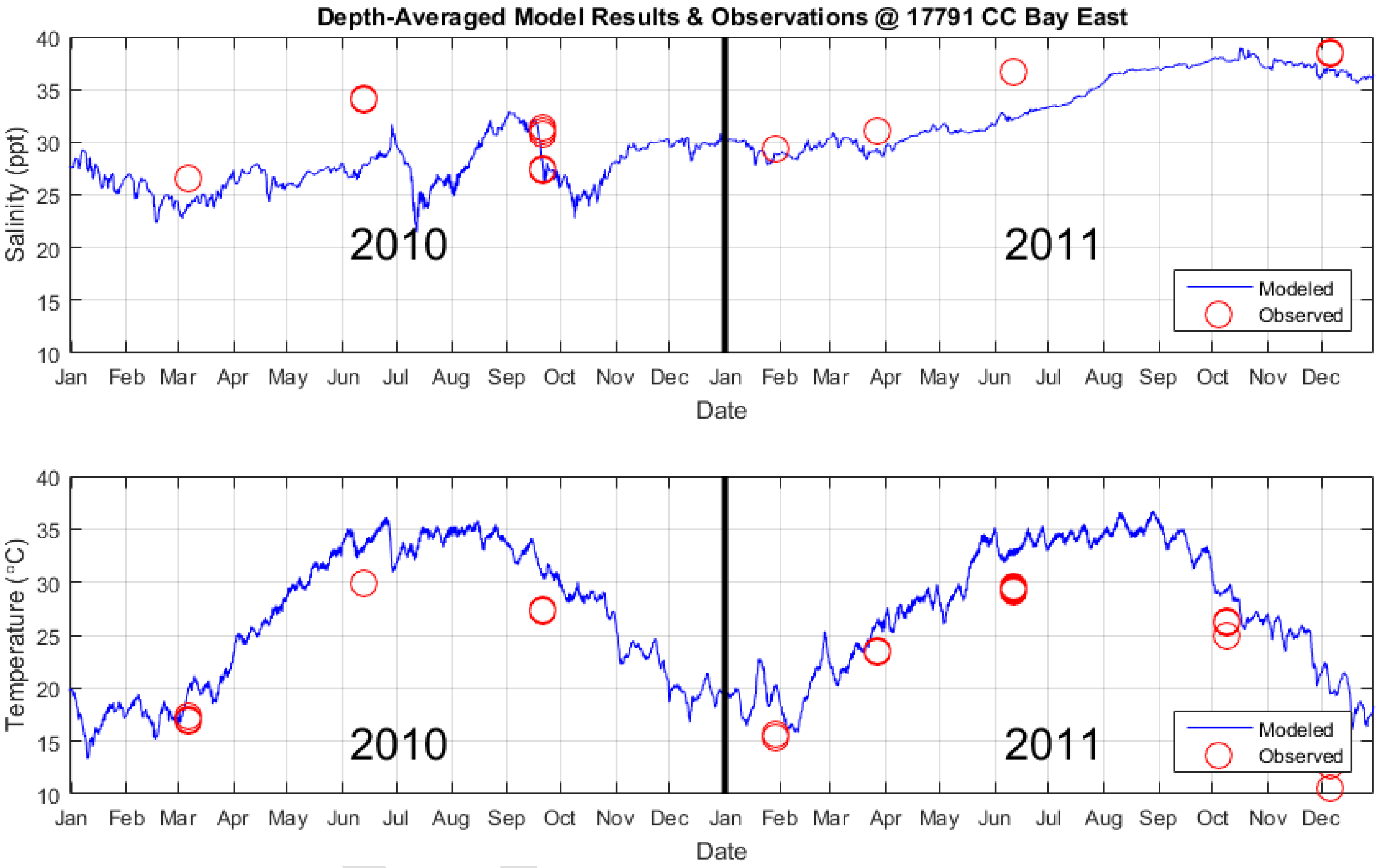


Figure 16 - - Measured and modeled salinity and temperature at TCEQ monitoring station 17791 CC Bay East

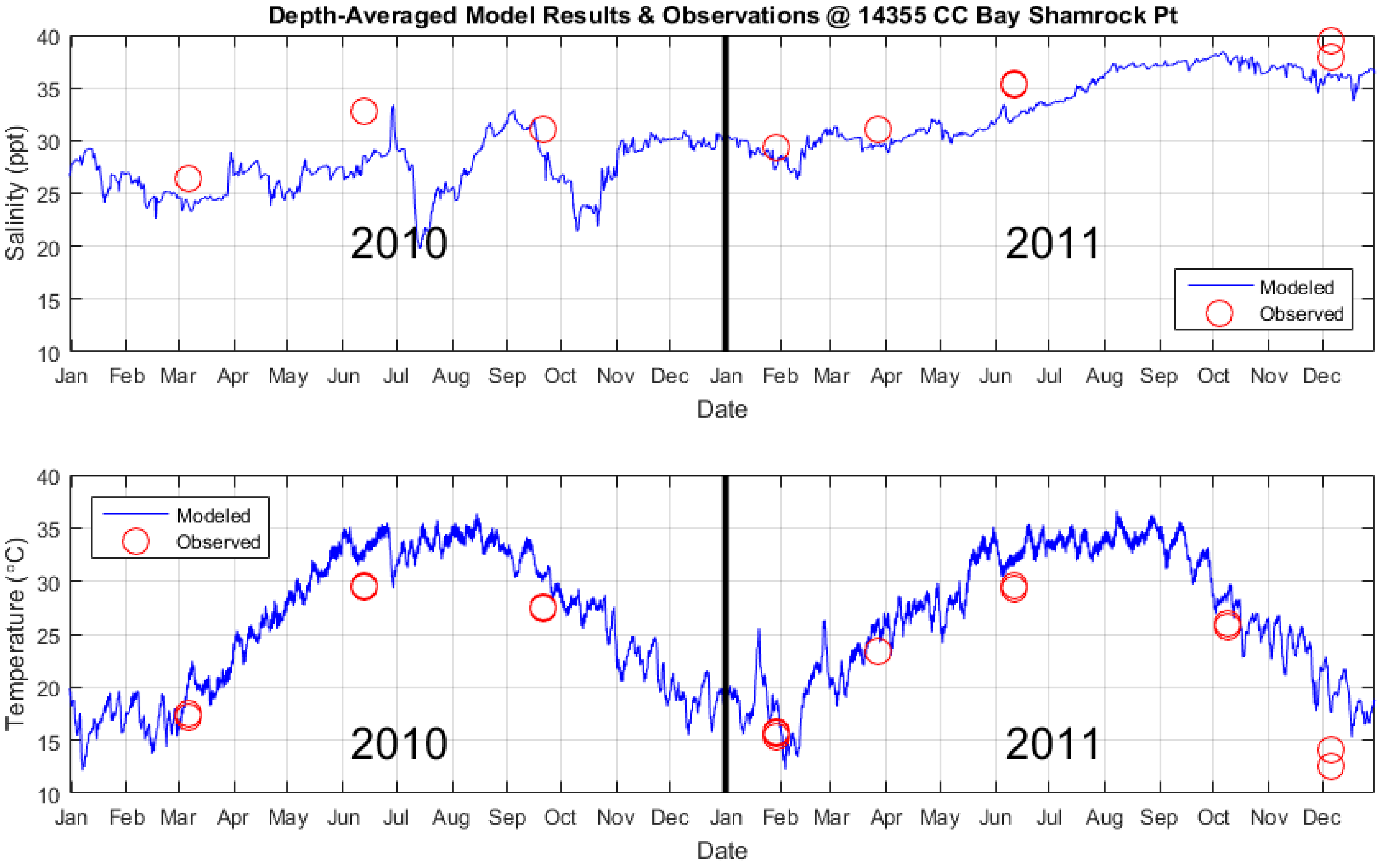


Figure 17 - - Measured and modeled salinity and temperature at TCEQ monitoring station 14355 CC Bay Shamrock Pt.

EFDC+ Modeling Results – Discharge Scenarios

To assess the expected impact of desalination brine discharges into the Corpus Christi Bay System, the Baseline EFDC+ model was modified to investigate numerous potential scenarios. In each scenario, modifications were limited to:

- Inclusion or Exclusion of brine discharges from the Harbor Island Location
- Inclusion or Exclusion of brine discharges from other proposed future desalination facilities currently being considered by the City of Corpus Christi
- Variations in the Port of Corpus Christi's brine discharges, including
    - Location of the Discharge
    - Volume of the Discharge
    - Salinity Concentration of the Discharge

Table XY lists all of the model simulations that were performed and completed for this effort. All model files are stored within an external hard drive maintained by LRE Water, with a copy provided to the Port of Corpus Christi along with this report. Viewing and processing of the model data requires a software license from www.eemodelingsystem.com.

When modeling included discharges from planned City of Corpus Christi desalination plants, the simulated discharges included:

- Inner Harbor:
    - Flow: 51.5 MGD (2.26 m^3/s)
    - Salinity: 49.9 PPT
    - Temperature: 30 °C
- La Quinta Channel:
    - Flow: 68.7 MGD (3.01 m^3/s)
    - Salinity: 50.0 PPT
    - Temperature: 30 °C

Preliminary model simulations suggested that originally proposed location B would not be advantageous compared with Location A or Location C. As such, no full simulations of discharges at Location B were completed.

For each modeling simulation, depth-averaged results were analyzed to assess the following:

- Maximum salinity concentration increases within 500 ft and 1000 ft from the discharge location, over time, and
- Concentration increases at each of the long-term monitoring stations from Figure 11, over time.

Table 2 – EDFC+ Model Runs – Simulated Discharge Descriptions

				Port of Corpus Christi Discharge			
		Other Discharges		Location A		Location C	
Run #	Name	Harbor Island	Corpus Christi	Flow (MGD)	Salinity (PPT)	Flow (MGD)	Salinity (PPT)
0	Baseline	NA	NO	NA	NA	NA	NA
1	Baseline with HI, NoCC	95 MGD, 48 PPT	NO	NA	NA	NA	NA
2	C-1, NoCC	95 MGD, 48 PPT	NO	NA	NA	57	48
3	A-1, NoCC	95 MGD, 48 PPT	NO	57	48	NA	NA
4	Split-1, NoCC	95 MGD, 48 PPT	NO	28.5	48	28.5	48
5	C-3, NoCC	95 MGD, 48 PPT	NO	NA	NA	40	71
6	A-3, NoCC	95 MGD, 48 PPT	NO	40	71	NA	NA
7	Split-3, NoCC	95 MGD, 48 PPT	NO	20	71	20	71
8	Baseline with HI, CC	95 MGD, 48 PPT	YES	NA	NA	NA	NA
9	C-1, CC	95 MGD, 48 PPT	YES	NA	NA	57	48
10	A-1, CC	95 MGD, 48 PPT	YES	57	48	NA	NA
11	Split-1, CC	95 MGD, 48 PPT	YES	28.5	48	28.5	48
12	C-3, CC	95 MGD, 48 PPT	YES	NA	NA	40	71
13	A-3, CC	95 MGD, 48 PPT	YES	40	71	NA	NA
14	Split-3, CC	95 MGD, 48 PPT	YES	20	71	20	71
15	C-1, NoCC, 40% Recovery, 30 MGD	95 MGD, 48 PPT	NO	NA	NA	57	Variable
16	C-1, NoCC, 50% Recovery, 30 MGD	95 MGD, 48 PPT	NO	NA	NA	57	Variable
17	C-1, NoCC, 40% Recovery, 20 MGD	95 MGD, 48 PPT	NO	NA	NA	38	Variable
18	C-1, NoCC, 40% Recovery, 20 MGD	95 MGD, 48 PPT	NO	NA	NA	26.6	Variable

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To assess concentration increases, it was necessary to compare the difference in modeled salinity between a given discharge scenario and the appropriate baseline scenario. For example, to assess the impact of modeling a 50 MGD discharge at 48 PPT from Location A, it is necessary to compare the results of model run #3 with those from model run #1. This comparison excludes the modeled impact of any desalination brine discharges proposed by the City of Corpus Christi but not permitted, constructed, or active. In contrast, to determine the impact of the same modeled discharge while also simulating planned discharges from the City of Corpus Christi plants, it is necessary to compare results between run #10 and run #8.

The EFDC+ model computes salinity and temperature at the center of gridcells, and modeled output is available at each grid cell location and timestep. To assess the salinity concentrations at distances of 500 ft and 1000 ft from each modeled discharge, data is output for each of the model gridcells within 1500 ft of a modeled discharge location. Using customized MATLAB data processing scripts, the output data is bi-linearly interpolated to locations at 500 ft and 1000 ft radial distances from the discharge location, at 1-degree of arc intervals around the discharge. Thus for each output model timestep, 360 salinity values are interpolated at 500 ft and 1000 ft from the discharge location. Of these interpolated salinity values, the largest value is compared to the corresponding value from the baseline simulation (Runs 0, 1, or 8), to result in the computed salinity increase for the given output timestep. This allows for desalination brine plumes to travel about the discharge location per the prevailing current, which may not be constant in time depending upon wind and tidal conditions. The resulting salinity comparison, however, is likely to provide the maximum modeled salinity increase resulting from a simulated brine discharge.

The following figures and discussion detail modeling results comparing EFDC+ runs excluding the proposed City of Corpus Christi discharges. Results are based on comparisons between Run #1 and the runs discussed/displayed in each section. Results presented are representative of the results obtained through comparisons of all model runs.

Figure 18 presents the modeled salinity increases computed due to discharges at Location A (top figure) and Location C (bottom figure) over the modeled 2010-2011 period. Results are depth-averaged maximum increases computed at radial distances of 500 ft (blue) and 1000 ft (green) from each discharge location. Results are shown using a 30-minute model output time interval. Location A is within the generally shallow portion of Corpus Christi Bay south of the upper end of the La Quinta Ship Channel, and south of the spoil island separating the La Quinta Ship Channel from the rest of Corpus Christi Bay. Location C, in contrast, is located within the La Quinta Ship Channel, approximately 1500 feet east of the channel's western terminus.

As shown, salinity increases vary with time at either location, yet only occasionally exceed 1.5 PPT. Increases are generally larger at location C, yet are also more variable, especially during 2010. During 2010, the system experienced larger freshwater inflow events, and these inflow events may have affected the modeled discharge at Location C more than they affected the discharge at location A. It is also notable that computed salinity increases around the Location A discharge are slightly larger at the 500 ft distance than at the 1000 ft distance, which is expected due to the mixing and dispersion patterns prevalent in the open bay. At location C, however, computed salinities at 1000 ft and 500 ft distances are nearly identical. This is because of the discharge's proximity to the western terminus of the La Quinta Ship Channel, where higher salinity water tends to accumulate. Figure 18, however, demonstrates that salinity is not steadily accumulating with time as a result of the discharge at either Location A or Location C.

Figure 19 presents the same computed salinity increase at location A as in Figure 18, but instead provides (in the bottom graph) the computed increase resulting from splitting the brine discharge equally between Location A and Location C. Salinity increases from the split discharge (Figure 19 bottom) are always lower than those from having the full discharge at Location A.

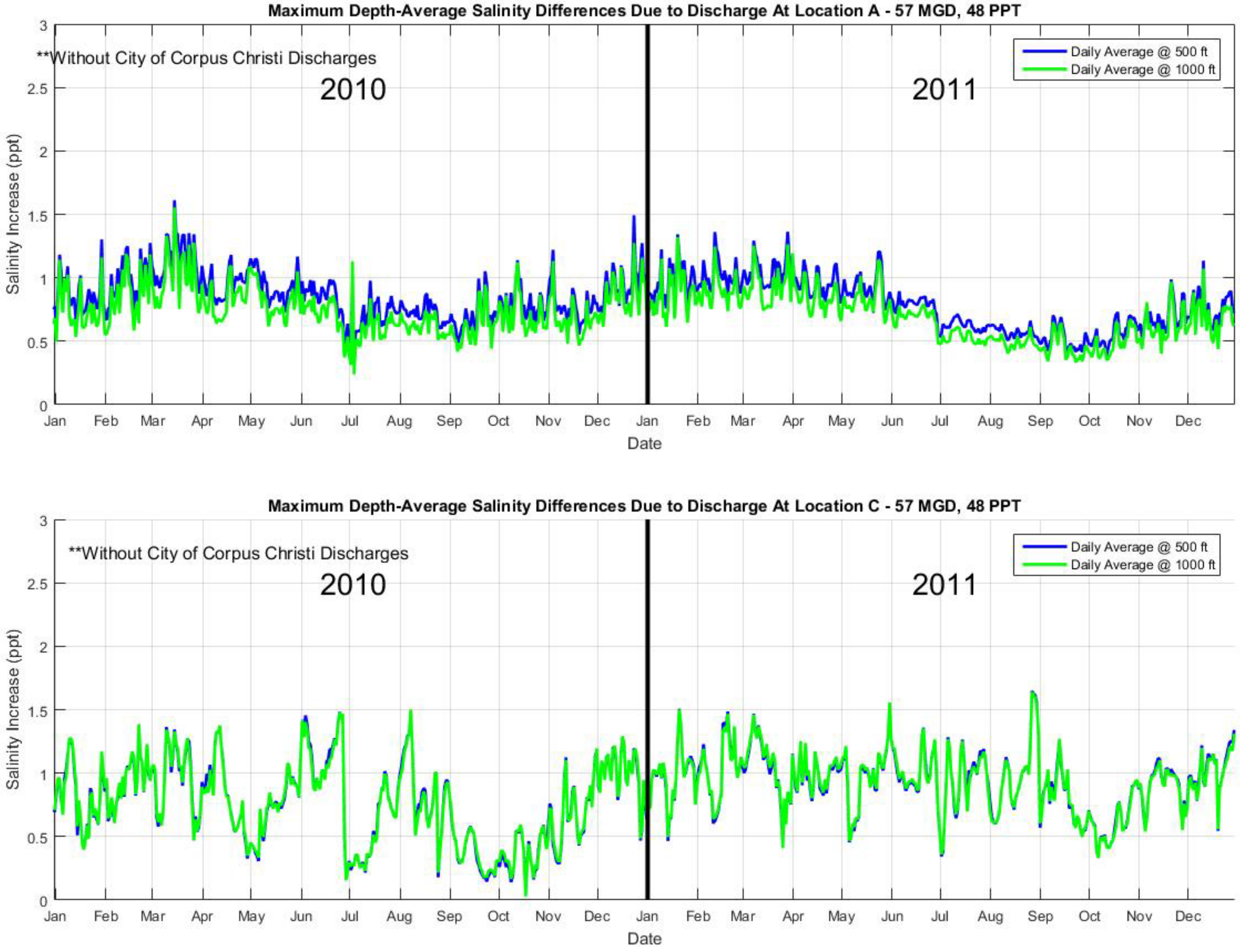

Figure 18 – EFDC+ Model Results - Computed depth-averaged salinity increases resulting from discharges of 57 MGD at 48 PPT at (Top) Location A (Comparing runs 1 and 3), and (Bottom) Location C. (Comparing runs 1 and 2)

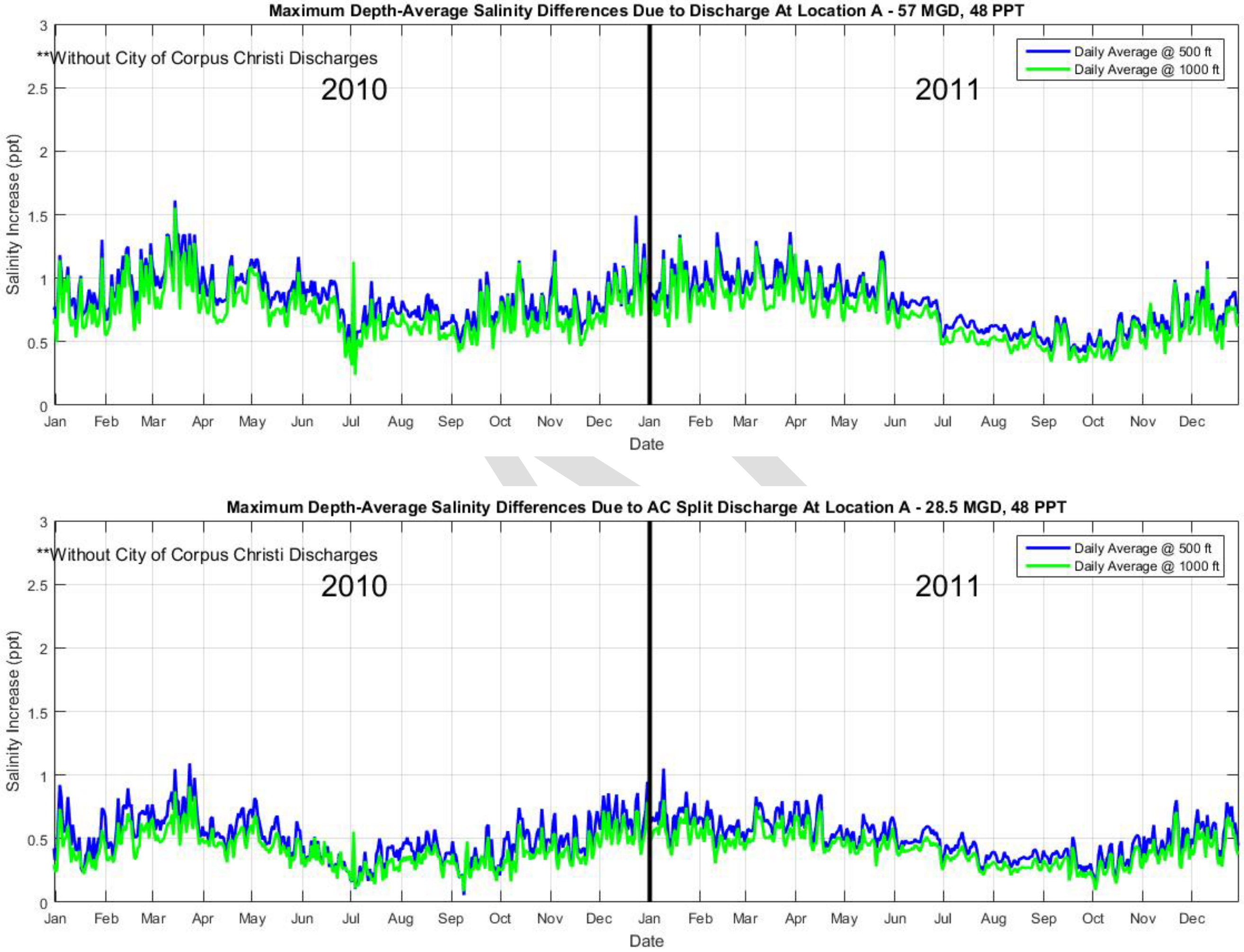

Figure 19– EFDC+ Model Results - Computed depth-averaged salinity increases resulting from discharges at Location A of A) 57 MGD at 48 PPT (Comparing runs 1 and 3), and B) 28.5 MGD at 48 PPT (Comparing runs 1 and 4)

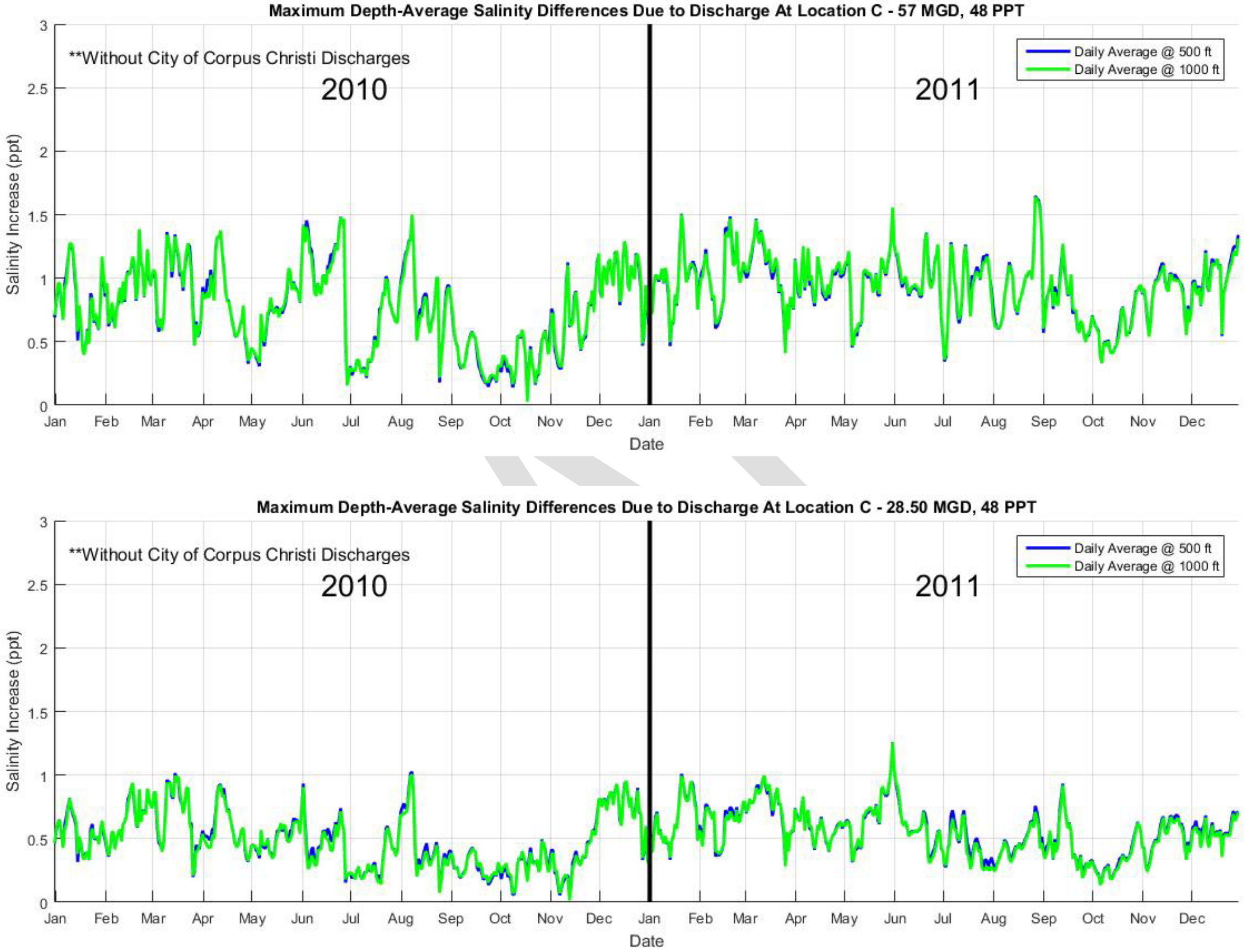

Figure 20– EFDC+ Model Results - Computed depth-averaged salinity increases resulting from discharges at Location C of A) 57 MGD at 48 PPT (Comparing runs 1 and 2), and B) 28.5 MGD at 48 PPT (Comparing runs 1 and 4)

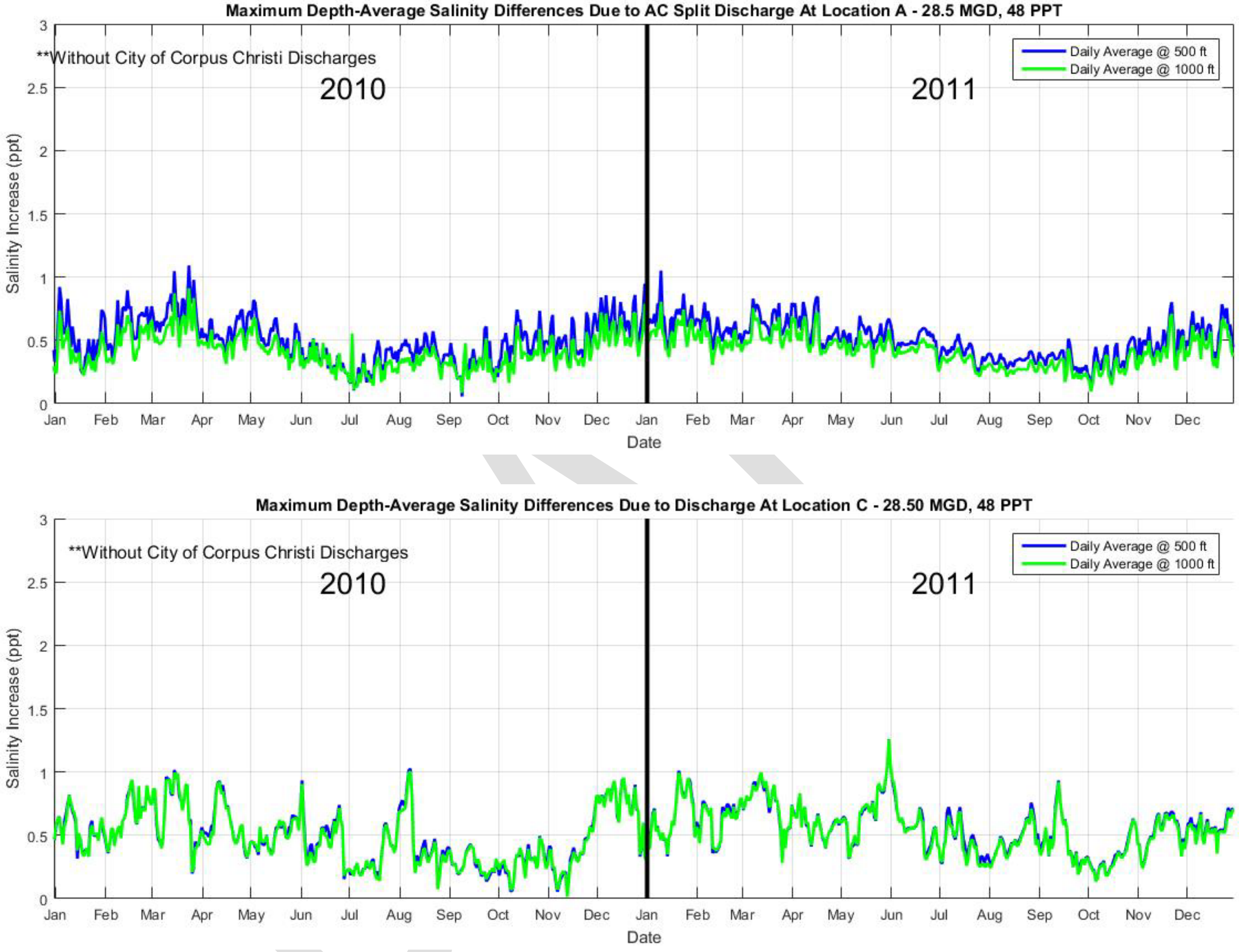

Figure 21– EFDC+ Model Results - Computed depth-averaged salinity increases resulting from discharges of 28.5 MGD at 48 PPT at A) Location A (Comparing runs 1 and 4), and B) Location C. (Comparing runs 1 and 4)

Figure 20 presents the same computed salinity increase at location C as in Figure 18, but instead provides (in the bottom graph) the computed increase resulting from splitting the brine discharge equally between Location A and Location C. Salinity increases from the split discharge (Figure 20 bottom) are always lower than those from having the full discharge at Location C, yet exhibit the same temporal pattern.

Figure 21 presents the same computed salinity increases at Location A (Top) and Location B (Bottom) as shown in Figure 19 and Figure 20, respectively. Figure 21 demonstrates that splitting the discharge volume between locations A and B results in lower salinity increases at both locations, often with the increases less than 1 ppt.

Figure 22 presents the model results from the baseline "No Discharge" scenario (run #1), discharge of 57 MGD with 48 PPT salinity at location C (run #2) and location A (run #3), and results from splitting this same discharge between locations A and C (run #4). Results are computed for the lon-term monitoring location closes to the proposed discharge locations, specifically site 13409 CC Bay at CM 16. The top graph in Figure 22 presents the absolute modeled salinity, and the bottom graph provides the salinity increase resulting from the modeled desalination brine discharges. Data is shown at the 30-minute output time intervals from the EFDC+ models.

Review of Figure 22 shows that the greatest salinity increase at this monitoring point within the vicinity of the La Quinta Ship Channel occurs with brine discharges at Location C (within the ship channel). Discharges at location A also yield increasing salinity results, although not to the same degree and often lead to lower depth-averaged salinity at the monitoring location. Splitting the discharge between the two proposed outfall locations results in an intermediate increase in salinity.

Overall, the inclusion of discharges from the proposed desalination facility near the La Quinta Ship Channel will result in salinity changes at the monitoring location of less than 1 PPT. There are occasional times where the increases temporarily exceed 1 PPT. Of note in Figure 22 is that the variation in modeled salinity resulting from the brine discharge is small relative to the seasonal and temporal variations in modeled salinity overall (Top graph). For example, in early 2010, salinity increases due to the C-discharge approach 1 PPT. This occurs at a time when the ambient salinity was approaching 25 PPT. Toward the end of 2011, when the modeled salinity reached its peak near 38 PPT, the increase in salinity due to the modeled discharges was less than 0.5 PPT.

Temporal averaging of modeled results on daily (Figure 23), monthly (Figure 24) and seasonal timeframes (Figure 25) highlight the small influence the proposed discharges have on salinity at this long-term monitoring location. Monthly averaging suggests salinity increases no greater than 0.5 PPT, and these increases tend to occur at times when bay waters are generally fresher.

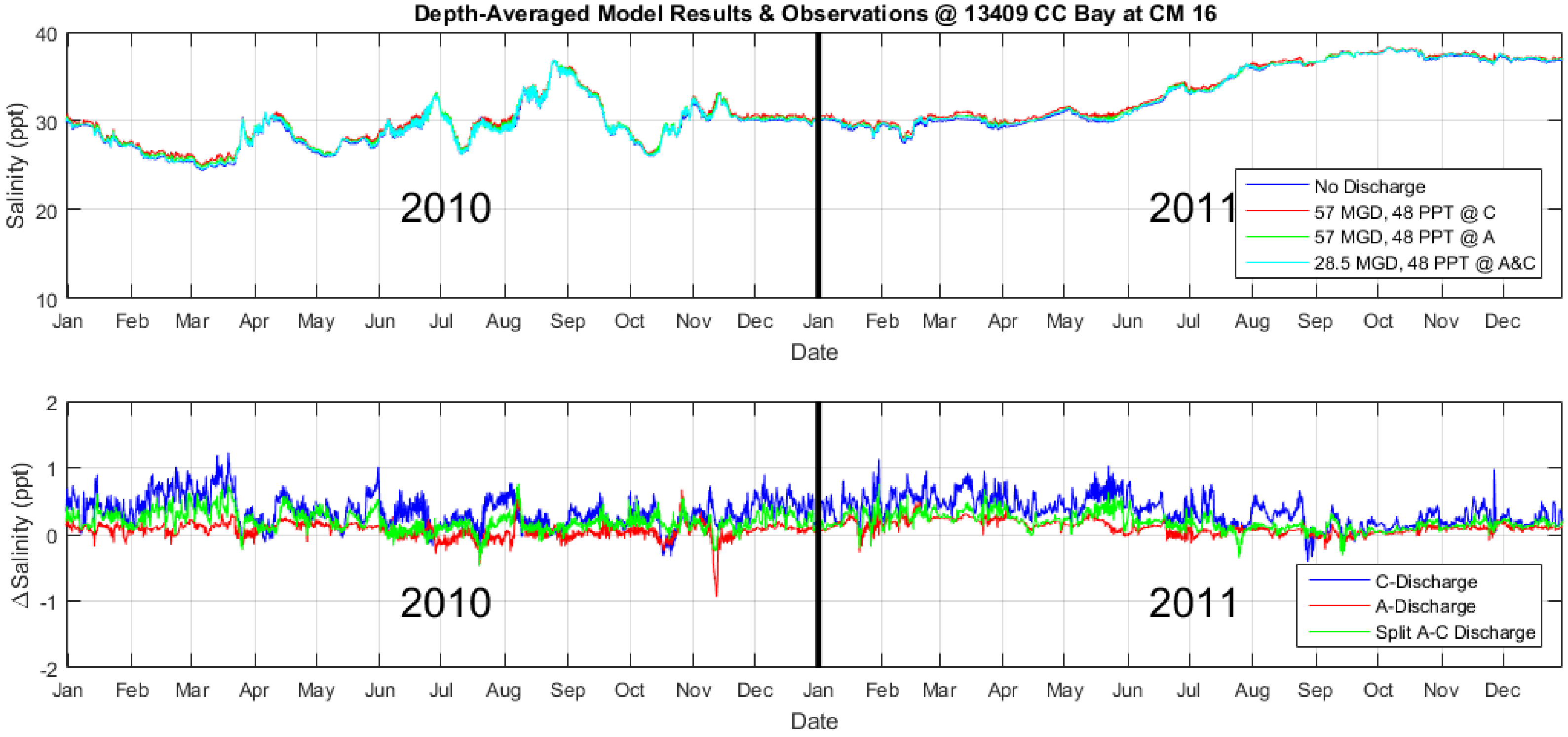

Figure 22 – Computed Salinity Increases at Monitoring Point 13409, nearest Location A and Location C, shown on a 30-minute time interval. Top: modeled salinity. Bottom: salinity change due to the inclusion of the desalination brine discharge.

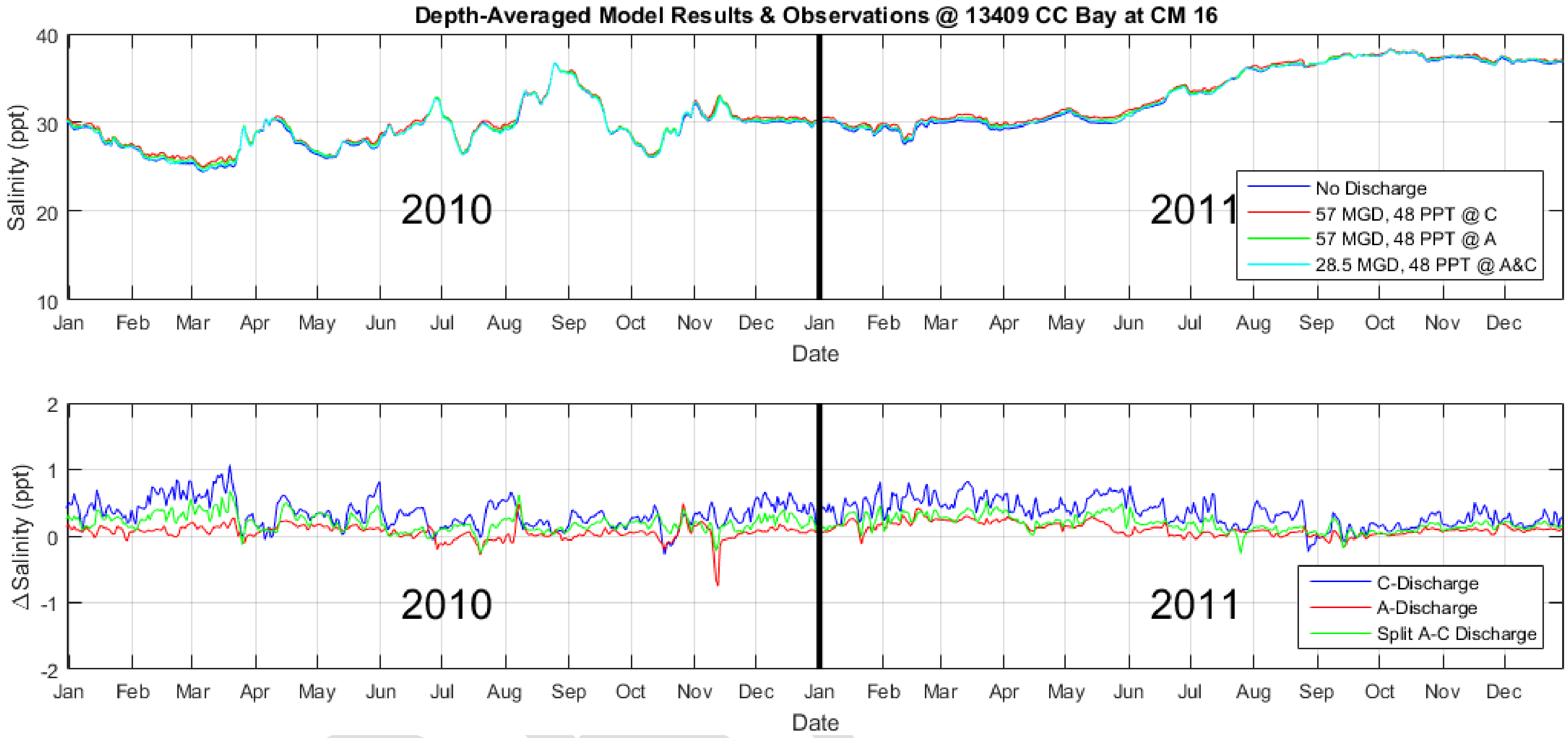

Figure 23 – Computed Salinity Increases at Monitoring Point 13409, nearest Location A and Location C, shown on a Daily-Averaged time interval. Top: modeled salinity. Bottom: salinity change due to the inclusion of the desalination brine discharge.

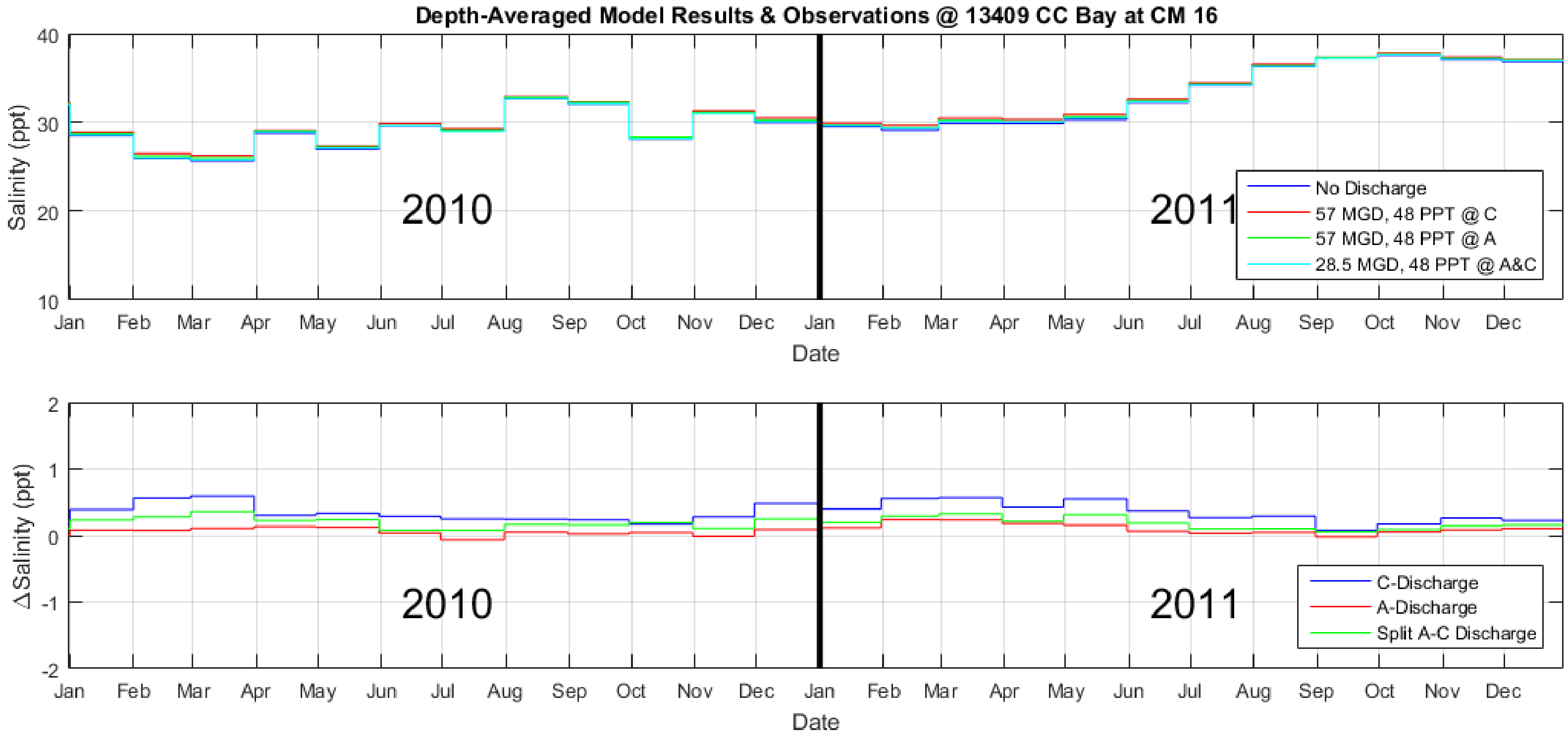

Figure 24 – Computed Salinity Increases at Monitoring Point 13409, nearest Location A and Location C, shown on a monthly-Averaged time interval. Top: modeled salinity. Bottom: salinity change due to the inclusion of the desalination brine discharge.

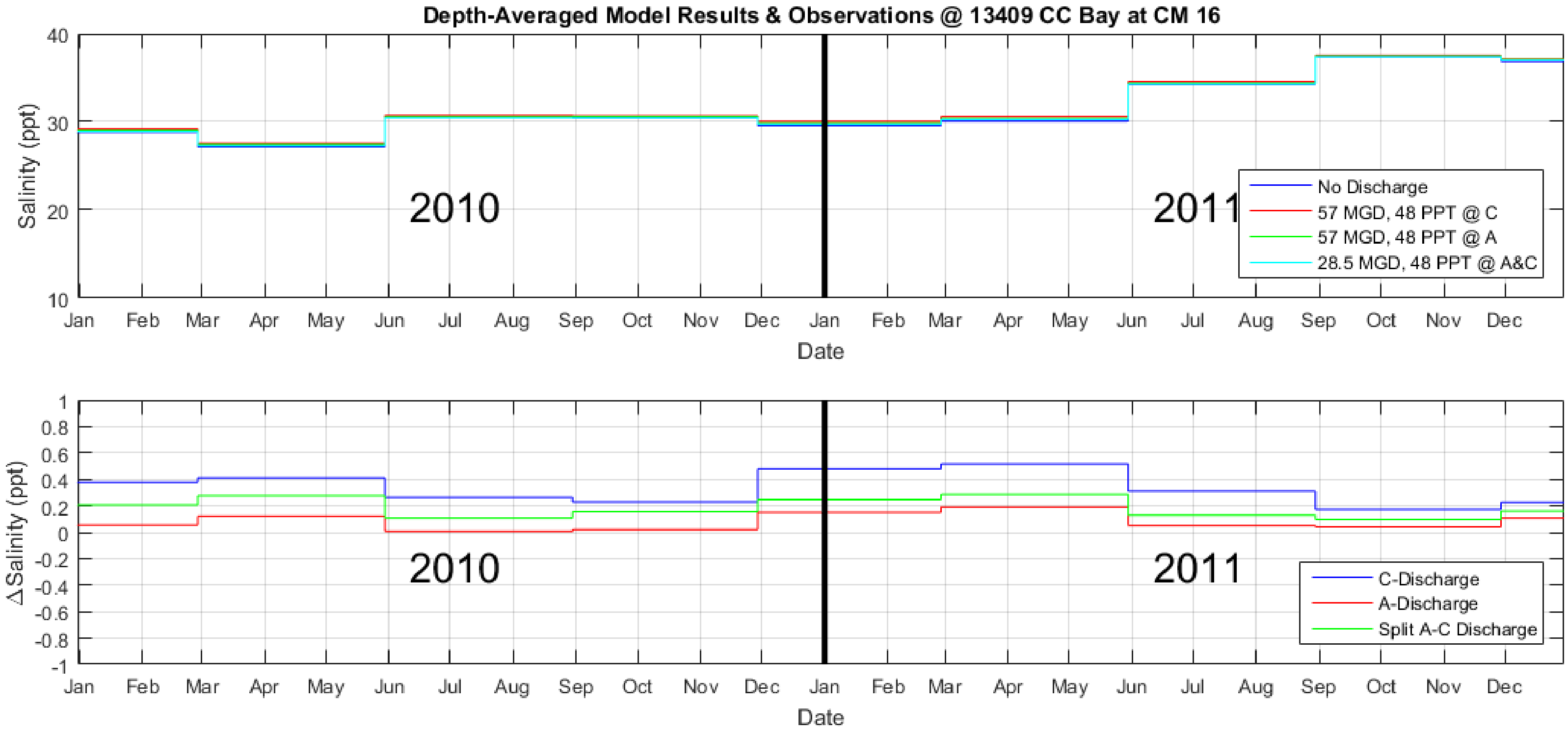

Figure 25 – Computed Salinity Increases at Monitoring Point 13409, nearest Location A and Location C, shown on a seasonally-averaged time interval. Top: modeled salinity. Bottom: salinity change due to the inclusion of the desalination brine discharge.

Model runs #15-#18 (

Table 2) differed from all other model runs as they included a variable salinity concentration within their constant rate discharges. These simulations were designed to reflect the plant operation, which takes in ambient seawater at whatever salinity concentration it has, and then concentrates the salinity within the discharge water from the desalination plant. The discharge concentration essentially becomes a function of the input concentration to the plant. To calculate the discharge concentration, results from run #1 were extracted for the cell corresponding to the location of the proposed plant intake. This salinity time series was then mathematically adjusted to mimic expected discharge concentrations. The same adjustment factor was applied to each inflow assuming the, based on the percentage of intake water recovered (40% or 50%), irrespective of the volume of water produced by the plant. The 20 MGD production volume simulated in runs #17 and #18, however, produce less volume of high salinity water discharged to the bay system.

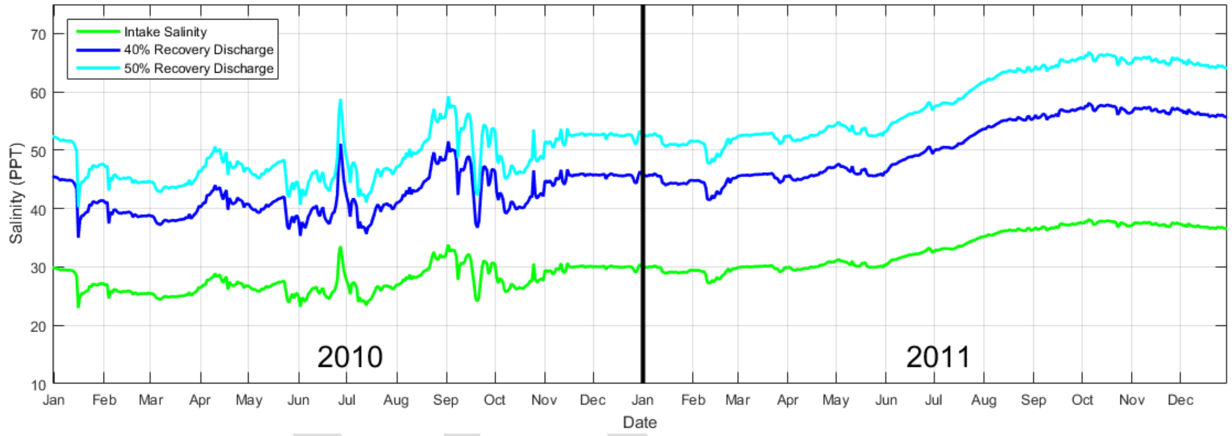

Figure 26 – Variable salinity from the intake location, along with resulting variable salinity discharges.

Figure 26 presents the variable modeled salinity concentration at the proposed intake location, as well as the computed discharge salinity when assuming 40% and 50% recovery from the desalination process. As shown, the intake salinity ranged from approximately 25 PPT to 39 PPT, which resulted in discharge salinities between 35 and 58 ppt for the 40% recovery scenario, and 41 and 65 PPT for the 50% recovery scenario.

Figure 27 presents the modeled salinity and salinity increase, averaged monthly, at the TCEQ long-term monitoring station at the center of Corpus Christi Bay. Results show the 40% recovery scenario assuming a 30 MGD and 20 MGD plant production capacity. Salinity increases due to the discharge do not exceed 0.2 PPT, and less increase occurs with the 20 MGD plant.

Figure 28 presents similar results, yet with salinities and increases calculated at the location of the long-term monitoring station within the La Quinta Channel. This location is closer to the modeled discharge (at Location C), and this proximity is the explanation for the larger salinity increase. The maximum increase (0.6 PPT) occurs in early 2010 when modeled salinity is low, and then again in early 2011 when the modeled salinity is around 30 PPT.

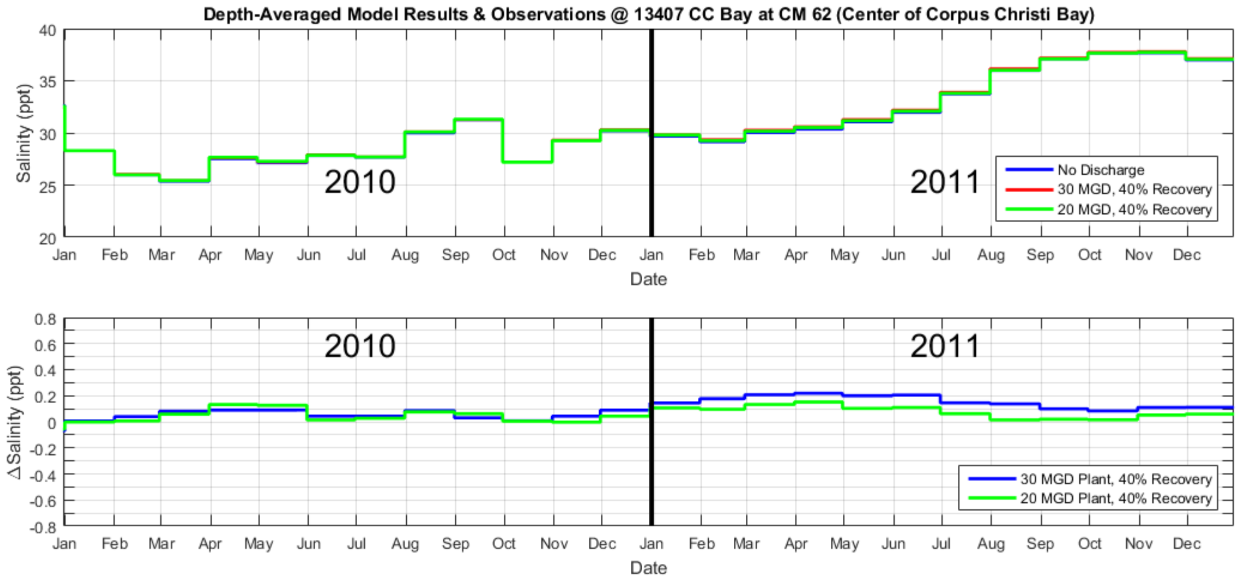

Figure 27 – Modeled salinity and salinity increases at Site 13407 CC Bay at CM 62 (Center of Corpus Christi Bay) resulting from variable concentration discharges at Location C.

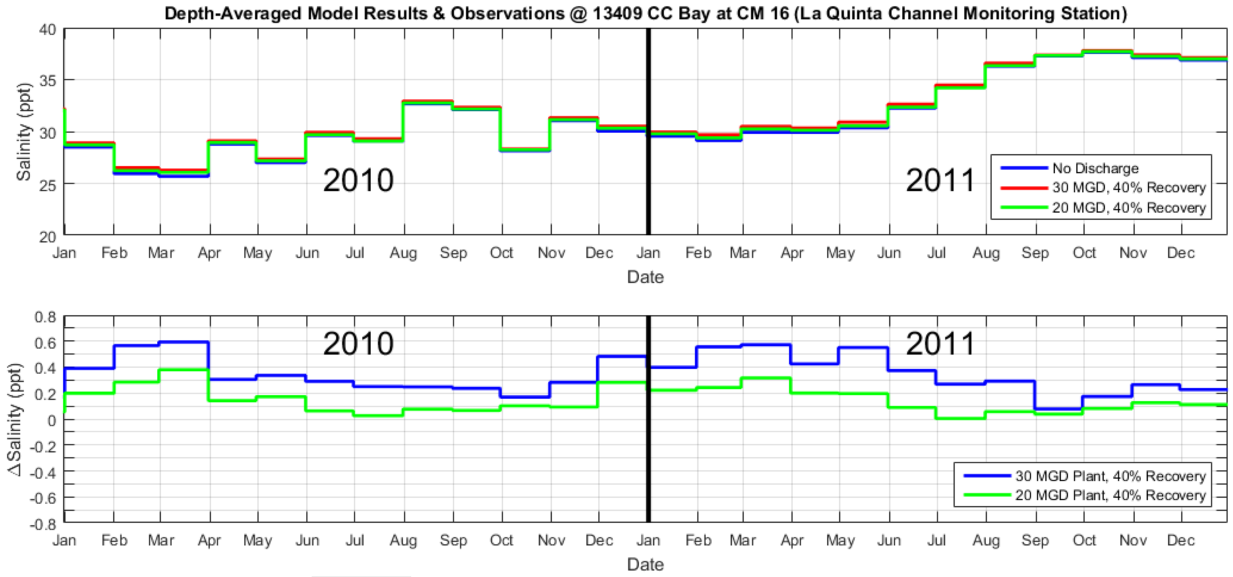

Figure 28 – Modeled salinity and salinity increases at Site 13409 CC Bay at CM 16 (La Quinta Channel) resulting from variable concentration discharges at Location C.

Further Modeling Recommendations

The baseline EFDC+ model presented herein is a well-developed model capable of determining the likely impact of the proposed desalination brine discharge(s) into the vicinity of the La Quinta Ship Channel. The model is a refined representation of the Corpus Christi Bay system presented in Furnans (2019), which used the SUNTANS model to simulate discharges from the proposed Harbor Island facility.

Further model improvements may yield greater agreement between modeled and observed parameters, including salinity, temperature, and water velocity. Spatial variations in wind forcing may impact computed water flows and therefore alter brine mixing. Similarly spatial variations in atmospheric forcing may improve the heat transfer calculations, resulting in improved computed temperature regimes throughout the bay. Overall, however, LRE Water expects such changes to result in minimal improvements to the presented EFDC+ model, and we expect such improvements would not significantly alter overall circulation and mixing of the proposed brine discharge(s).

LRE recommends continued development of the EFDC+ model of the Corpus Christi Bay system, including expanding the possible modeled period of record to include the full period from 2010 through Present, subject to the availability of suitable model forcing data. This will allow for greater model verification and validation, as there are additional measured data points against which the EFCD+ model results may be reviewed.

References

Furnans, J. 2019. “Desalination Brine Discharge Modeling – Corpus Christi Bay System.” Port of Corpus Christi Contracted Report. October 21.

Longley, W.L. ed. 1994. “Freshwater inflows to Texas bays and estuaries: ecological relationships and methods for determination of needs.” Texas Water Development Board and Texas Parks and Wildlife Department, Austin, TX. 386 pp.