LREWater, LLC
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Integrated Water Resources Engineering
Innovative Solutions for Water and Land

Desalination Brine Discharge Modeling – Corpus Christi Bay System

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Executive Summary

The objective of this modeling project was to determine whether the proposed discharge of brine from desalination operations would likely result in environmental conditions that are potentially damaging to the Corpus Christi Bay ecosystem. Specifically, we strove to determine whether a proposed desalination brine discharge within the Corpus Christi Ship Channel near Harbor Island would result in either the formation of a high-salinity water layer along the channel bottom, or would result in an overall or accumulating increase in salinity throughout the Corpus Christi Bay system.

To meet this objective, LRE Water, LLC in conjunction with researchers at The University of Texas at Austin, developed a SUNTANS hydrodynamic model of the Corpus Christi Bay system. The model was modified from an existing system model used to predict the fate and transport of oil spills, and it was specifically designed to simulate the cumulative salinity impacts of a proposed desalination brine discharge into the Corpus Christi Ship Channel near Harbor Island. The SUNTANS model assumes the discharge diffuser will produce a 1% increase in salinity relative to ambient conditions at 400’ from the discharge as per the modeling performed and detailed in the representative permit application.

The SUNTANS model was applied to the January 1, 2010-December 31, 2011 period. This 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(2010-2011) included in this study would have provided sufficient duration for all water within the bay system to have been replaced by inflows.

Limited field data were available for use in validating the SUNTANS model results. Comparisons between observed and measured salinity profiles (collected in 2010 within the center of the Corpus Christi Bay system 13.5 miles from the proposed Harbor Island discharge location) suggest the model tends to over-predict salinity yet reasonably predicts water column stratification. The

SUNTANS model also tends to suggest more uniform vertical mixing than indicated by field data. Comparisons between modeled and observed salinity and temperature time series data from the Corpus Christi Ship Channel adjacent to The University of Texas Marine Science Institute indicate that SUNTANS reasonably predicts changes in salinity over time, yet under-predicts the observed variations in salinity data. The model also tends to over-predict water temperatures during winter months. Analysis of the salinity and temperature time-series comparisons indicates that the SUNTANS model likely under-determines the extent of mixing and water circulation within the Corpus Christi Bay system, at least in the vicinity of the proposed Harbor Island discharge location.

Simulation results during both the 2010 “wet” year and 2011 “dry” years indicate that the desalination brine discharge increases computed salinity by 0-1 ppt in the vicinity of the discharge and throughout the Corpus Christi Bay system, with daily tidal fluctuations continuously mixing the discharge so that stratification is never persistent. This increase is small relative to the 8 ppt modeled variation in salinity resulting from seasonal fluctuations, alternating dry and wet periods, and periods with longer-term variations in tidal elevations. This indicates that inflows, tidal fluctuations, evaporation, and other natural features of the Corpus Christi Bay system play a larger role in determining local salinity than does the proposed desalination brine discharge.

Freshwater inflow events were shown to impact the salinity at the Harbor Island location, with larger inflow events resulting in generally system-wide reductions in computed salinity. However, the inflow events had equal effects on salinities computed with and without simulating the Harbor Island desalination brine discharge, thus indicating that the discharge did not affect the modeled response to the inflow events.

Modeled salinity stratification resulting from the freshwater inflows is prevalent throughout the Corpus Christi Bay system, especially soon after larger freshwater inflow events. Modeled stratification, however, diminishes over time during periods of relatively low freshwater inflows, suggesting that surface winds and tidal fluxes are sufficient to keep the system well mixed from the surface to the bay bottom. Salinity stratification does occur near the Harbor Island discharge, yet only as a result of larger freshwater inflow events. Tidal forcing from the Gulf of Mexico drives much of the diurnal flux of water through the Corpus Christi Ship Channel, and the flux is often stronger near the discharge location due to the relative proximity with the Gulf of Mexico. The stronger tidal flux typically keeps the water column well mixed near the proposed Harbor Island discharge location and tends to rapidly eliminate any stratification that arises after larger freshwater inflow events.

SUNTANS modeling results indicate that within the vicinity of the Harbor Island discharge, vertical mixing of the water column is sufficient to prevent the formation of a persistent high-salinity water layer along on the channel bottom. Results also indicate that the diurnal tidal mixing and water circulation patterns within the Corpus Christi Bay system are such that bottom salinity values increase by 0-1 ppt as a result of the modeled discharge, yet this increase in salinity remains stable over time and does not accumulate. Large freshwater inflow events will tend to cause salinity stratification within the water column near the Harbor Island discharge location, yet the daily, tidally-driven flow of water through the channel tends to rapidly reduce and eliminate stratification resulting from the large freshwater inflow events. The SUNTANS modeling results do NOT indicate that large freshwater inflow events are needed to maintain a vertically-well mixed water column in the vicinity of the proposed Harbor Island discharge.

Based on the SUNTANS modeling presented herein, the Harbor Island discharge location appears suitable in that the saline discharge as proposed in the permit application will not lead to a continual increase in ambient salinity over time in the Corpus Christi Bay System and will not cause the formation of a high-saline layer of water along the channel bottom. Modeling suggests that the proposed discharge will increase ambient salinities by 0-1ppt, and that increases are mitigated by the strong tidal forcing constantly driving water movement within the vicinity of the discharge location. Large freshwater inflow events are not needed to prevent salinity build-up due to the proposed discharge, as daily tidal fluctuations are sufficient for such purposes.

Refinements to the SUNTANS model are recommended if the model is to be used to simulate potential brine discharges at other locations throughout the Corpus Christi Bay system. The proximity of the Harbor Island discharge to the Gulf of Mexico makes these recommended refinements unnecessary for simulating the likely effects of the Harbor Island desalination brine discharge.

Based on the SUNTANS model results presented in this document, LRE Water, LLC concludes that the proposed Harbor Island desalination brine discharge will not lead to the formation of a highly-saline water layer along the channel bottom, nor to an ever-increasing average bottom salinity within the Corpus Christi Bay system. We conclude that the Harbor Island desalination brine discharge, if properly constructed and maintained, will not likely result in environmental conditions that are potentially damaging to the Corpus Christi Bay ecosystem.

Introduction

The objective of this modeling project was to determine whether the proposed discharge of brine from desalination operations would likely result in environmental conditions that are potentially damaging to the Corpus Christi Bay ecosystem. To assess this objective, we revised a previously existing SUNTANS model of the Corpus Christi Bay System (Figure 1) so that the model better represents salinity transport through the bay, including both open water and channel locations. The original SUNTANS model of the Corpus Christi Bay System was developed by researchers at The University of Texas at Austin to support oil spill modeling. SUNTANS was similarly applied to model circulation within Galveston Bay, as documented in Rayson et al (2015).

We simulated the proposed discharge at Harbor Island (Figure 1) to determine: 1) the extent to which the discharge increases the ambient salinity over time, 2) the spatial extent of any salinity increases resulting from the discharge, and 3) the temporal extent of any salinity increases, including the determination of whether the discharge would result in the accumulation of salt over time in the vicinity of the discharge. We also attempted to identify how factors driving bay circulation (namely freshwater inflows and tidal forcing) dictate the fate and transport of the desalination brine discharge. For all simulations, we modeled the discharge as being a constant 95 MGD ("Million Gallons per Day") with a salinity of 48 PPT ("Parts Per Thousand"). Within the permit application for the Harbor Island discharge, the depth of the diffuser is stated to be 63 ft, with the rise to the ports equaling 12 ft. We simulated the depth of the discharge to be 53 ft, which is the current average depth of the Corpus Christi ship channel in the vicinity of the modeled discharge.

Simulations were run for the time 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 desalination brine discharge.

Model simulations were performed both with and without including the desalination brine discharge. Comparing model results therefore allows for the discernment of salinity variations resulting solely from natural environmental conditions, as well as those resulting from the brine discharge.

The remainder of this report details the revision of the SUNTANS Corpus Christi Bay system model, and our analysis regarding potential impacts of the proposed desalination brine discharge.

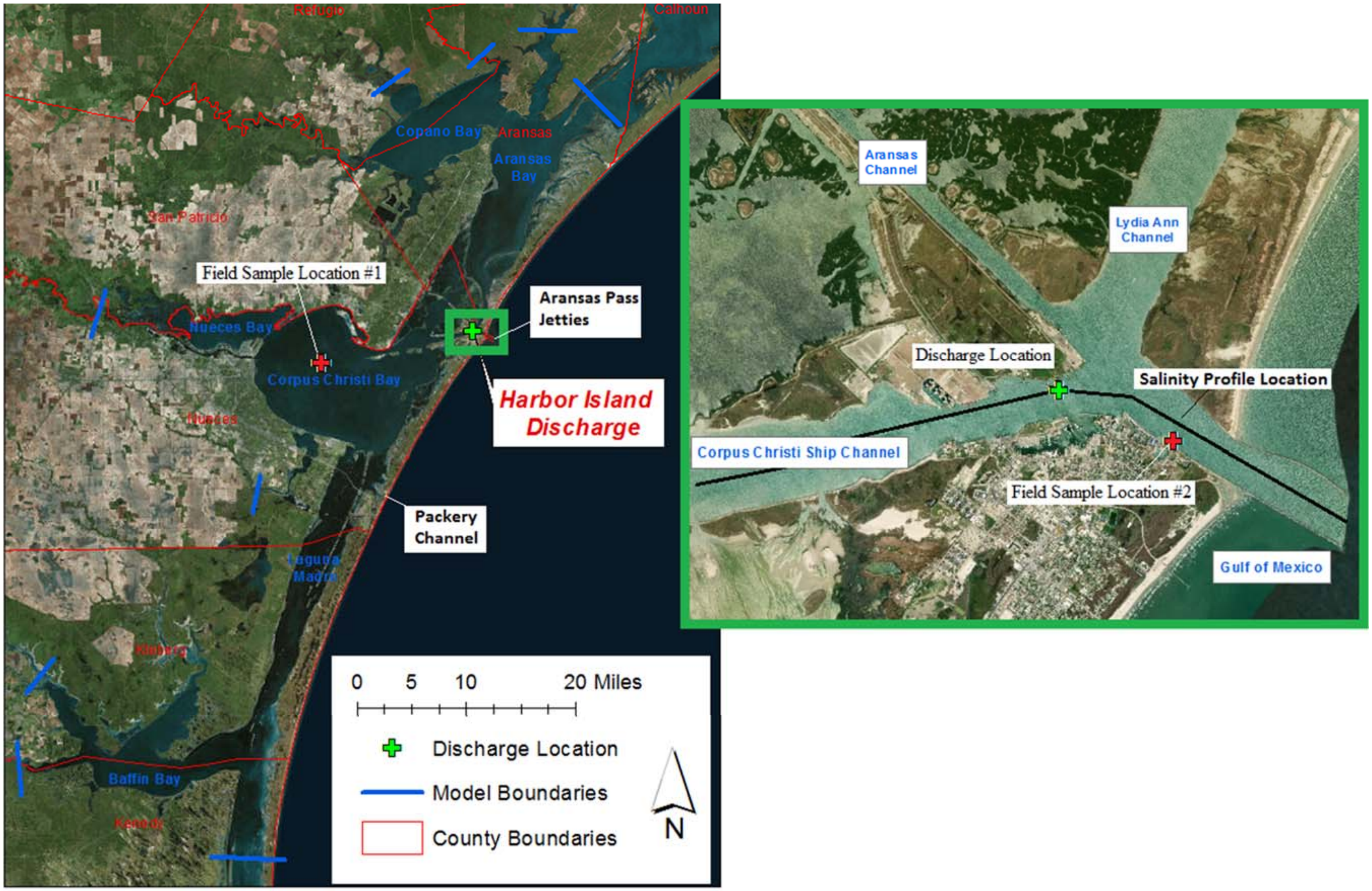


Figure 1 – Corpus Christ System Model Domain showing model boundaries and the location of the Harbor Island desalination brine discharge.

SUNTANS MODEL – Corpus Christi Bay System

As shown in Figure 1, the SUNTANS model of the Corpus Christi Bay system extends from the Northern end of Aransas Bay to Laguna Madre south of Baffin Bay. It simulates water movement through the following bays/waterbodies: Copano Bay, Aransas Bay, Redfish Bay, Corpus Christi Bay, Nueces Bay, Oso Bay, Laguna Madre, and Baffin Bay. 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 developed for oil spill analysis purposes. The SUNTANS model code is open source, and can be freely obtained from the github page maintained by the model developer, Dr. Oliver Fringer of Stanford University (https://github.com/ofringer/suntans as of 7/1/2019).

SUNTANS Model Modifications

To properly model the proposed desalination brine discharge within the Corpus Christi Bay ship channel, the SUNTANS model required multiple modifications. These modifications included both alterations to the Corpus Christi Bay system representation in the model, as well as alterations to the SUNTANS model code itself. In the following sections, we detail modifications made both to the SUNTANS algorithms, as well as to the model setup for the Corpus Christi Bay system.

SUNTANS Model Modification – Point Source Discharges

The grid cell size surrounding the proposed diffuser site is too large to resolve the complex fluid dynamics in the near field mixing with SUNTANS – that is, near the diffuser the model cannot actually solve how the mixing is occurring, but instead represents the net effects of mixing assuming the diffuser is operating as specified in the instructions LRE was given. We added a new algorithm to SUNTANS to represent the diffuser inflow using the design specification that it always mixes to 1% above ambient, with ambient being defined as the salinity at 51 ft above the bottom for the Harbor Island discharge. In each time step, the additional salinity is handled in a mass-conservative, layer-based mixing routine that serves to mix the incoming salinity with the ambient to achieve the salinity target in the near field. Note that the SUNTANS model cannot predict failure of the diffuser to meet its design specifications when the flow around the diffuser is inadequate. If such conditions occur, the SUNTANS model will predict more mixing than will actually occur. Understanding the interactions of flow with the near-field and far-field will require more comprehensive modeling than undertaken in this project.

SUNTANS Model Modification – Hotstart Capabilities

Prior to use on this project, the SUNTANS model did not have the capability to start in "hotstart" mode. Model "hotstarts" allow for simulations to start using results obtained at the end of previous simulations. Without hotstart capabilities, models are started using assumed initial conditions (water levels, temperatures, salinities, velocities, etc), and then the model is "spun-up" over multiple timesteps until computed model results become independent upon the assumed initial conditions. Results obtained during the "spin-up period" are not to be considered accurate and should not be used in reporting and analyses. For example, when spinning-up the SUNTANS model on the Corpus Christi Bay system, it is necessary to run the model for 2-4 simulated days before results may be trusted. As such, to model January 1-30, for example, it is first needed to model December 27-31, even though the results from the December modeled time period are not to be reported. Adding 2-4 days of spin-up time to each model simulation requires large amounts of physical time, and is both wasteful and inefficient.

To avoid the spin-up problem, researchers at The University of Texas at Austin revised the SUNTANS model source code so that model runs would be initiated with results from previous simulations. This "hotstart" capability now allows for the efficient execution of multiple models that combine to simulate a longer time period. As reported herein, SUNTANS was used to simulate water circulation for the period from January 1, 2010 through December 31, 2011. Having the hotstart capability reduced model execution times by between 20% and 25%.

Corpus Christi Bay System Setup Modifications - Bathymetry

A major driving force in determining water circulation patterns within the Corpus Christi Bay system is the shape of the system, defined by the numerical grid and bathymetric data within the SUNTANS 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 2, which also depicts the entire model domain.

Bathymetry used within the SUNTANS model of the Corpus Christi Bay system is largely identical to that included in the similar SUNTANS model developed for oil spill modeling purposes. However, modifications to the oil spill model bathymetry were needed to make the revised model suitable for desalination brine discharge modeling.

As shown in Figure 2, the SUNTANS model bathymetry contains representations of all channels located within the Corpus Christi Bay system. This includes modeling of the Corpus Christi Ship Channel, La Quinta Channel, Gulf Coast Intracoastal Waterway (GIWW), Aransas Channel, and Lydia Ann Channel. These channels provide conduits for the movement of water, especially in transferring tidal fluxes into and from the Gulf of Mexico. Bathymetry used in depicting the system channels was derived from hydrographic survey data publically available from the U.S. Army Corps of Engineers.

Specific bathymetric modifications included:

- Increasing the depth of the Corpus Christi Ship Channel to 16.08m (52.75 ft)
- Increasing the depth of the La Quinta Channel to 15.0m (49.2 ft)
- Incorporating the GIWW into the model bathymetry, from Aransas Bay southward through Laguna Madre
- Improved connectivity between model grid cells representing the various ship channels
- Improved generalized bathymetry with the bay systems immediately adjacent to the various ship channels.

Figure 3 provides a comparison of the original and revised bathymetry for the portion of the bay system in the vicinity of the Harbor Island discharge location. As evident within Figure 3A, the original bathymetry included a disjointed representation of the Corpus Christi Ship channel, with a depth of only 45 ft (on average). The original bathymetry also did not include the La Quinta Channel, the GIWW, Aransas Channel, or the Lydia Ann Channel. Within the revised bathymetry (Figure 3B), all channels are incorporated into the model, with channel depths reflective of the recent surveys conducted by the USACE. The depth of the Corpus Christi ship channel was increased to 52.75 ft, and the La Quinta Channel was deepened to 49.2 ft. The GIWW was modeled with a depth of approximately 16 ft, and similar depths were imposed within the Aransas and Lydia Ann Channels.

Figure 4 presents the bathymetry of the Corpus Christi ship channel in the vicinity of the proposed Harbor Island discharge location, as measured during 2019 USACE hydrographic surveys. As shown, depths range from 50-60 ft to the west of the discharge, then increase to 90 ft near the discharge location, and return to 50-60 ft to the east of the discharge. These depth changes occur over a distance (west to east) of approximately 2,000 feet.

Within Figure 4, SUNTANS model grid cells (black triangles) are overlain on the bathymetry, with the modeled discharge location located at the center of the horizontal extent representing a single grid cell. In developing the SUNTANS model, each grid cell is assigned a single depth value, and the depths are constant along the entire horizontal extent of the grid cell. For the cell containing the discharge, actual physical depths (based on the available bathymetric data) range from 0 ft to 92 ft. and the depth of the actual bathymetric surface represented by the grid cell is not well-defined using a single depth value. Figure 5 presents the depth options considered when assigning a depth to the cell containing the modeled discharge.

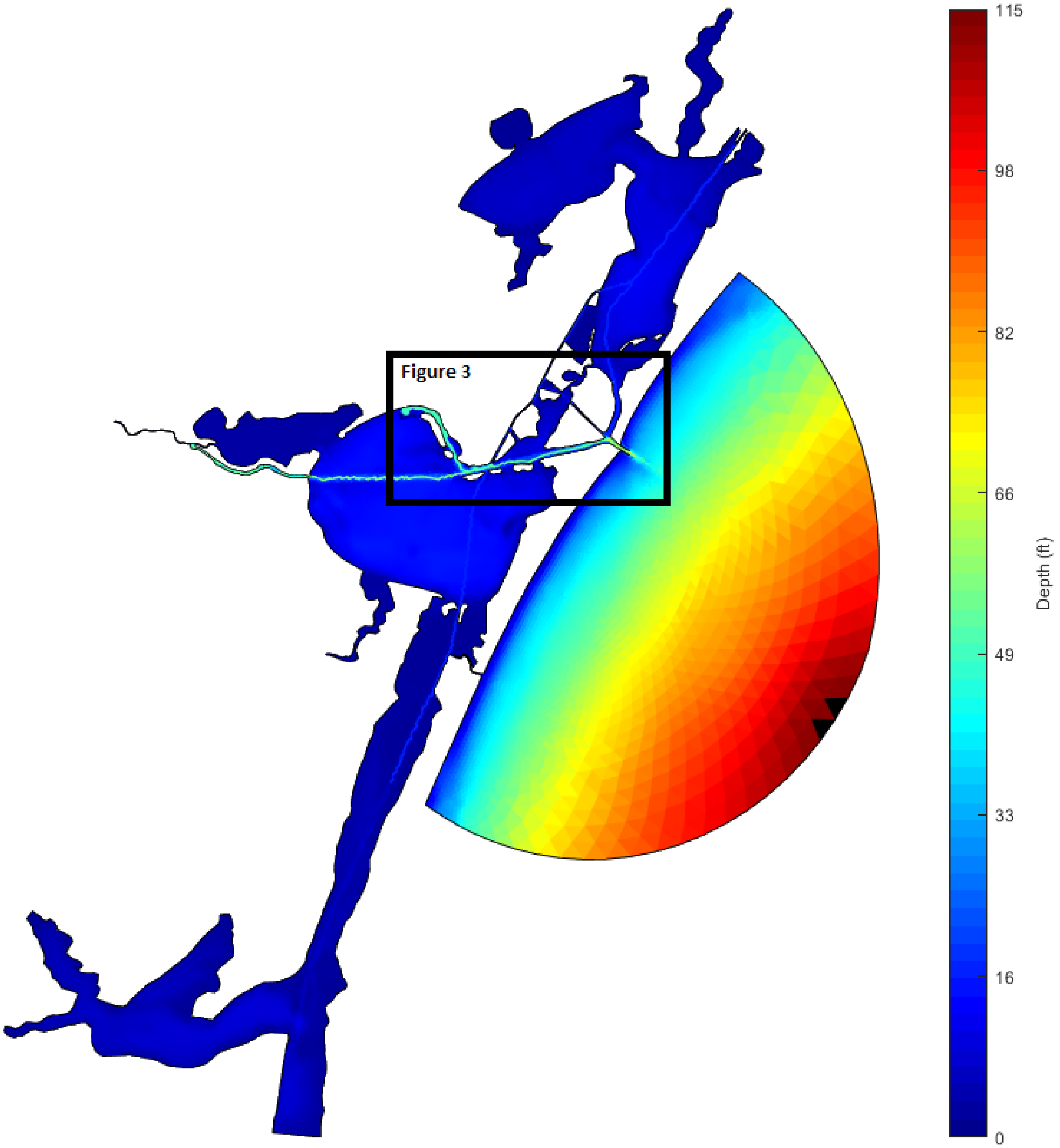
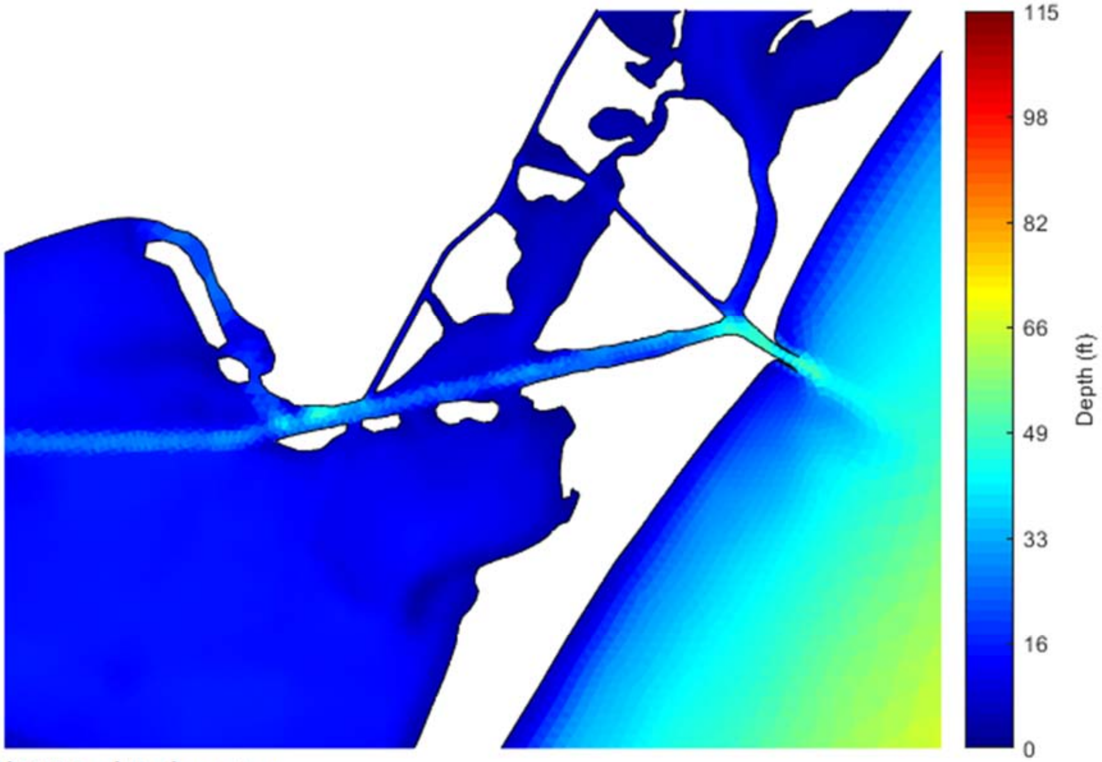
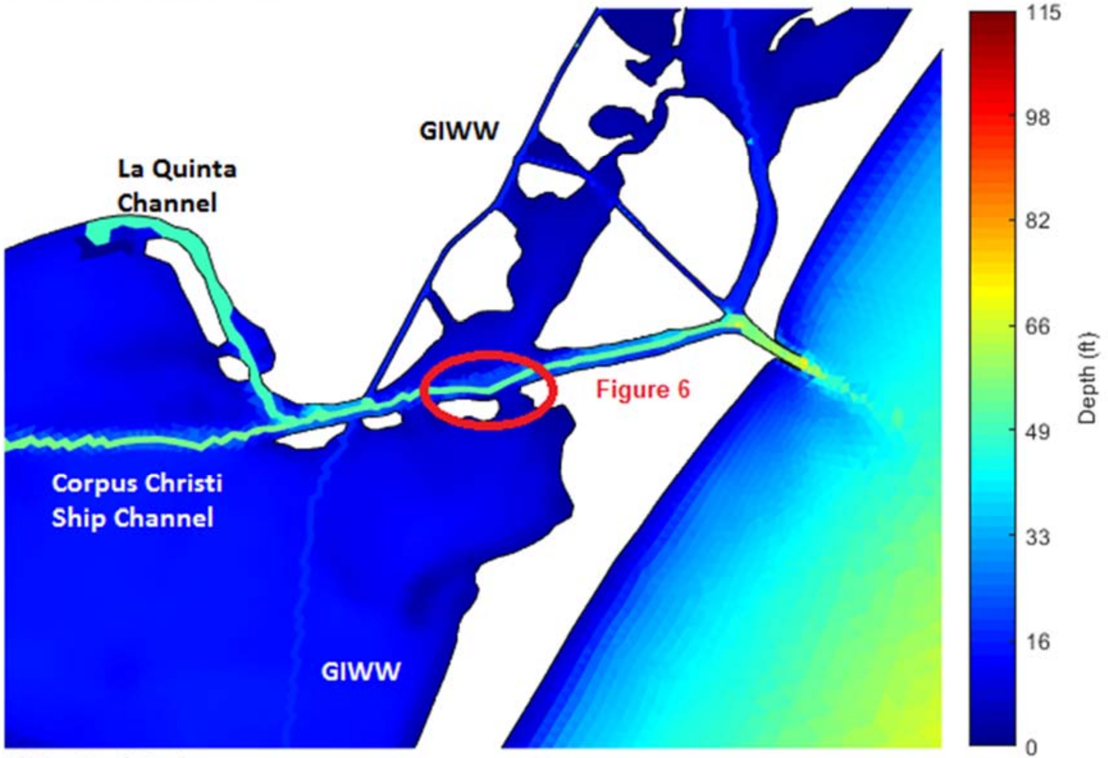


Figure 2 – Final Model Bathymetry for the Corpus Christi Bay System. Bathymetry includes existing ship channels, including the Gulf Intracoastal Water Way (GIWW), the Corpus Christi Ship Channel, and the La Quinta channel. Channel depths were based on hydrographic survey data from recent U.S. Army Corps of Engineers (USACE) surveys, yet modeled channel locations were modified to conform with the existing SUNTANS model grid. Channel widths within the SUNTANS model are generally comparable to the physical widths of the channels, thereby maintaining equality between the modeled and physical conveyance capacity of the channels.



A) Original Bathymetry



B) Revised Bathymetry

Figure 3 – Original and Revised Bathymetry revisions within the vicinity of the Harbor Island Discharge. A) Original bathymetry from the oil spill model, B) revised bathymetry better representing various ship channels.

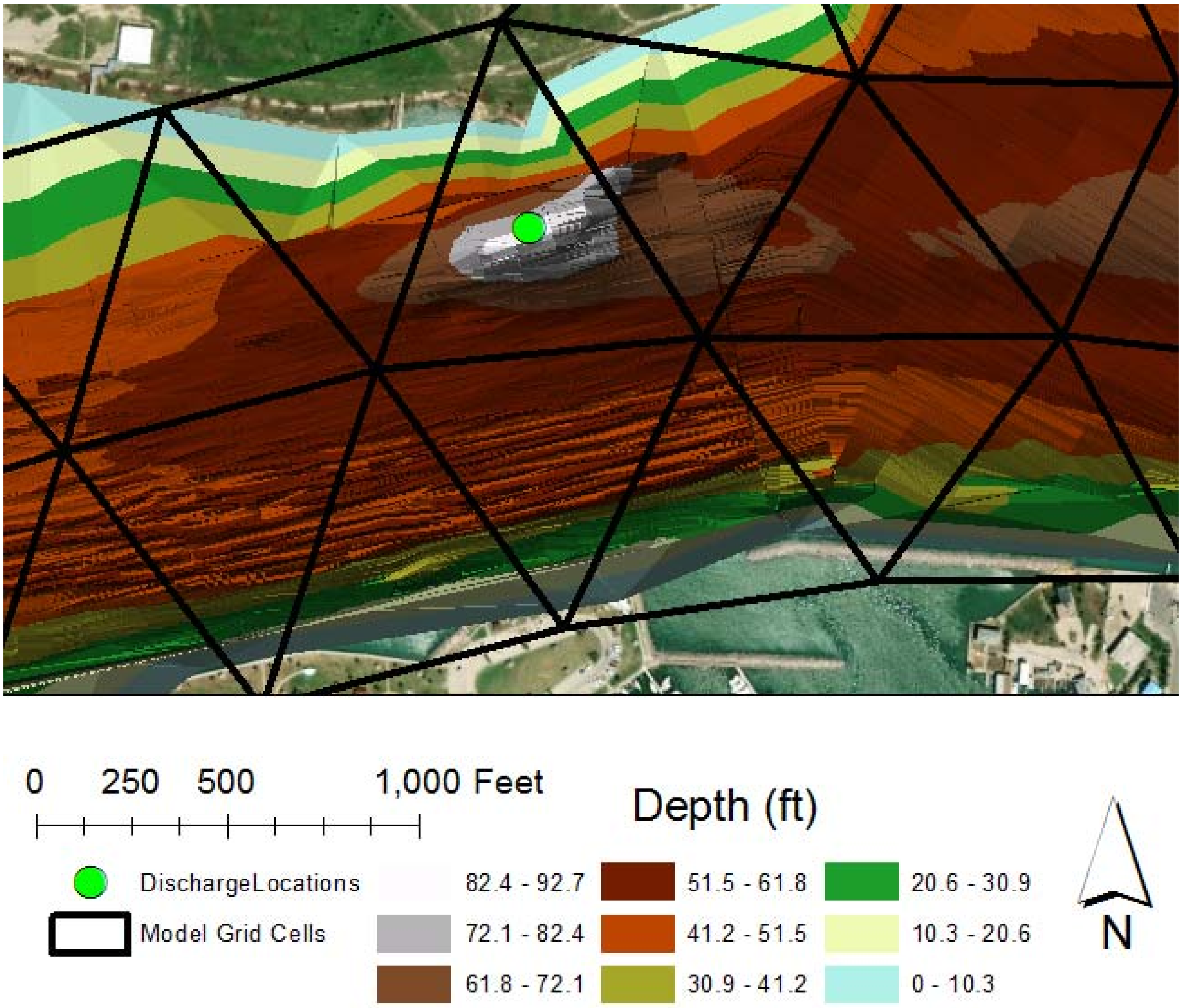


Figure 4 – Bathymetry and model grid cells in the vicinity of the Harbor Island discharge location, from 2019 USACE survey data.

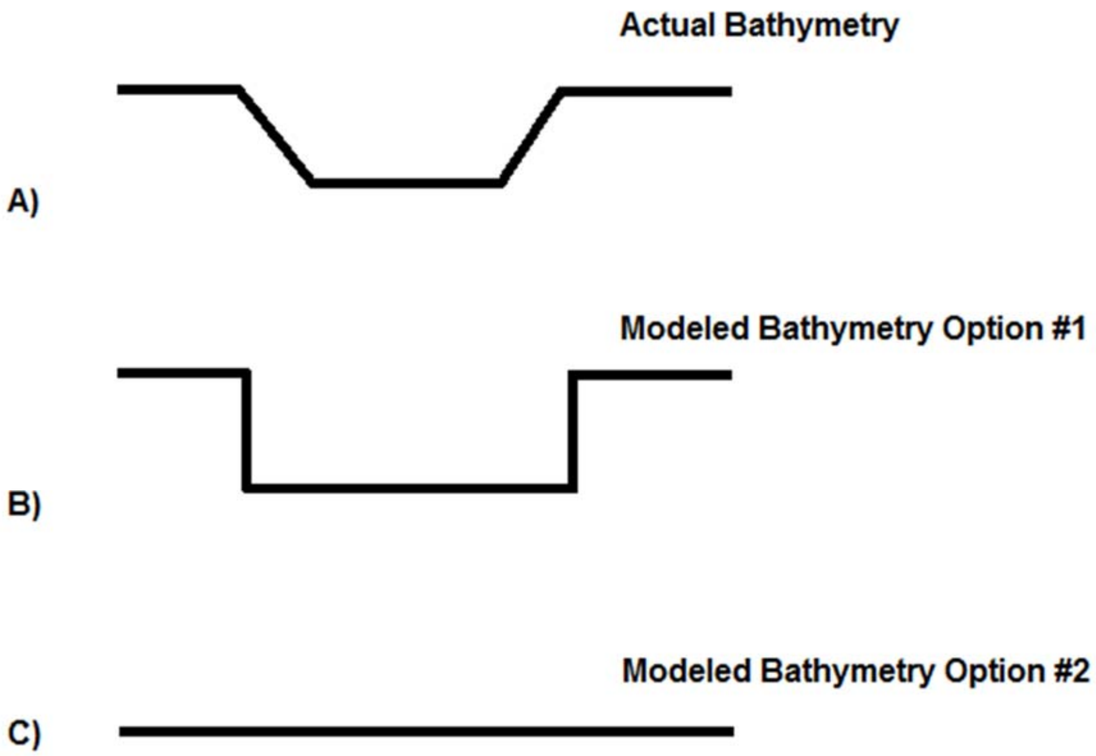


Figure 5 – Possible bathymetric configurations for a W-E cross section through the proposed discharge location. A) the actual bathymetry with a basic trapezoidal shape, B) modeled bathymetry option #1 with vertical walls along the edge of the grid cell containing the discharge, and C) modeled bathymetry option #2 which keeps the channel depth constant and ignores the increase in depth within the terrain spanned by the discharge cell.

The true bathymetry through the discharge location follows an approximate trapezoidal pattern similar to that shown in Figure 5A. It is likely that actual water movement across this portion of the channel is highly turbulent, with flows first decelerating across the depth expansion and then accelerating across the depth contraction. Such accelerations and decelerations would work to enhance vertical mixing of any saline plume from the discharge location, and would lead to plume dispersal throughout both the horizontal and vertical extent of the water column. Modeling this true bathymetry would require significant refinement to the numerical grid used in SUNTANS, and would necessitate decreasing the triangular grid cell size by a factor of 10 (at minimum) to properly simulate the trapezoidal shape. Such grid refinement would have been required throughout the entire model domain, and (while possible) would have resulted in significantly slower model run-times. Such grid refinement was outside the scope of this project.

To better represent the true bathymetry, LRE also considered “Modeled Bathymetry Option #1,” which consists of modeling the cell containing the discharge as having a depth approximately 30 ft greater than the depths of the surrounding grid cells. In such a scenario (Figure 5B), water flowing through the channel would simply pass over the deeper portion of the grid cell, and negligible circulation is to be expected within the portion of the discharge-cell's water column that extends below the depths of the neighboring cells. Modeling the discharge in this deeper portion of the water column, however, would still show vertical mixing across the water column, per the methodology developed to simulate the discharge. It is possible that higher salinity water would accumulate in the isolated bottom waters within the deeper discharge cell, yet LRE believes this unlikely due to the diffuser design and rapid horizontal transport of water through the ship channel at this location.

LRE selected "Modeled Bathymetry Option #2" (Figure 5C) as the best option for simulating the Harbor Island discharge conditions. This option included assigning the discharge cell a depth equal to that of the surrounding grid cells making up the Corpus Christi Bay Ship Channel. With a uniform cross section, vertical mixing is only enhanced by any vertical shear (i.e. differences in velocities with depth) within the channel water column. This vertical mixing likely under-represents the actual mixing that would occur as a result of both the vertical shear in the water column and the flow acceleration and deceleration resulting from the true bathymetry (trapezoidal shape – Figure 5A). Thus by modeling a bathymetry likely to under-represent the extent of vertical mixing within the vicinity of the Harbor Island discharge, model results are likely to under-represent processes that will lead to the prevention of saline layer formation along the benthos. LRE selected Modeled Bathymetry Option #2 as the conservative approach to simulating the vicinity of the discharge. This approach also did not require refinement of the model grid.

Along with adjusting the channel depths, bathymetric revisions required continuity in depths between adjacent model grid cells representing ship channels, as well as continuity in depths of cells immediately adjacent to the ship channels. This ensures that the channels are represented in the model as efficient conduits of water movement, rather than as adjacent shallow and deep cells included within the original bathymetry.

To ensure continuity between adjacent cells representing ship channels, it was often required to adjust the channel locations within the SUNTANS model grid. This is evident in Figure 6, which shows the separation between the modeled and physical location of the Corpus Christi ship channel. The separation was required in order to keep the width of the modeled ship channel approximately equal to the physical ship channel width, and to maintain a rather uniform width along the channel length.

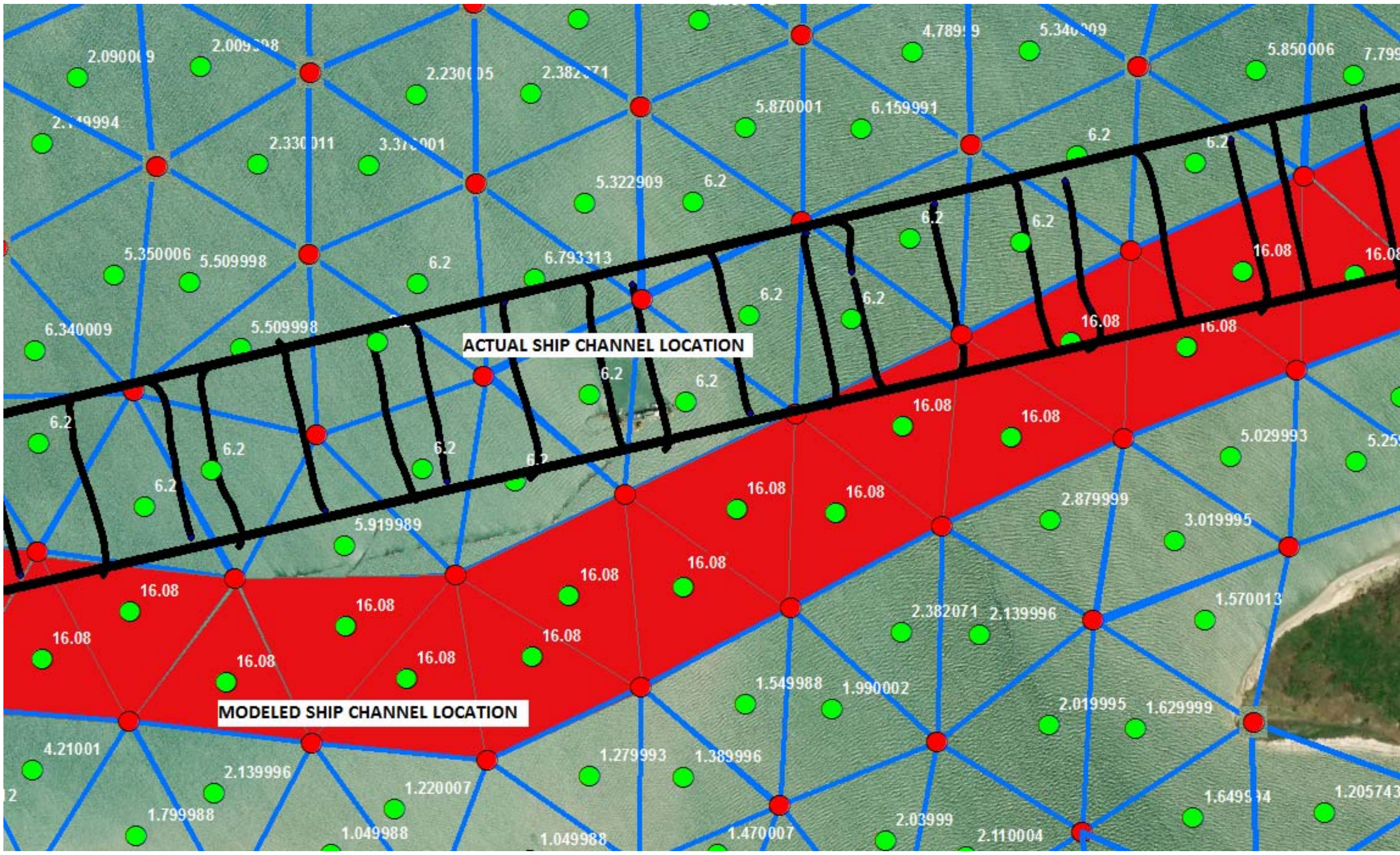


Figure 6 shows the surveyed location of the Corpus Christi Channel (Black lines), in comparison with the modeled channel location (Red Triangular polygons). In the right side of the image (closer to the Gulf of Mexico), the modeled channel location and width coincides well with the surveyed location and width. However, upon moving to the right across the image, the deviation between modeled and physical channel location increases, yet the modeled width remains constant. This separation was required based on the location of the triangular grid cells used to model the SUNTANS bathymetry. Forcing the modeled ship channel to be located at the physical channel location would have required either a substantial revision to the model grid, or would have resulted in an artificially wide and irregularly shaped channel. The artificially wide and irregularly shaped channel would not have accurately represented the physical movement of water within the channels. By maintaining consistency between the modeled and physical channel widths, we ensure that the modeled channel will convey approximately equal quantities of water as the physical channel. Water velocities within the modeled channel, however, are likely to be lower than those in the actual physical channel, as a result of energy loss due to the modeled channel bends.

Revising the model grid to better incorporate ship channel locations was outside the scope of this project, yet is recommended should further modeling efforts be undertaken.

LRE Water does not expect that grid revisions will significantly alter the computed fate and transport of the Harbor Island desalination brine discharge. However, an improved model grid will be important in accurately representing flow through the La Quinta, Aransas, and Lydia Ann channels. As modeled herein, these channels are generally wider than their physical counterparts, which would result in lower modeled in-channel velocities and could impact computed mixing and salinity profiles.

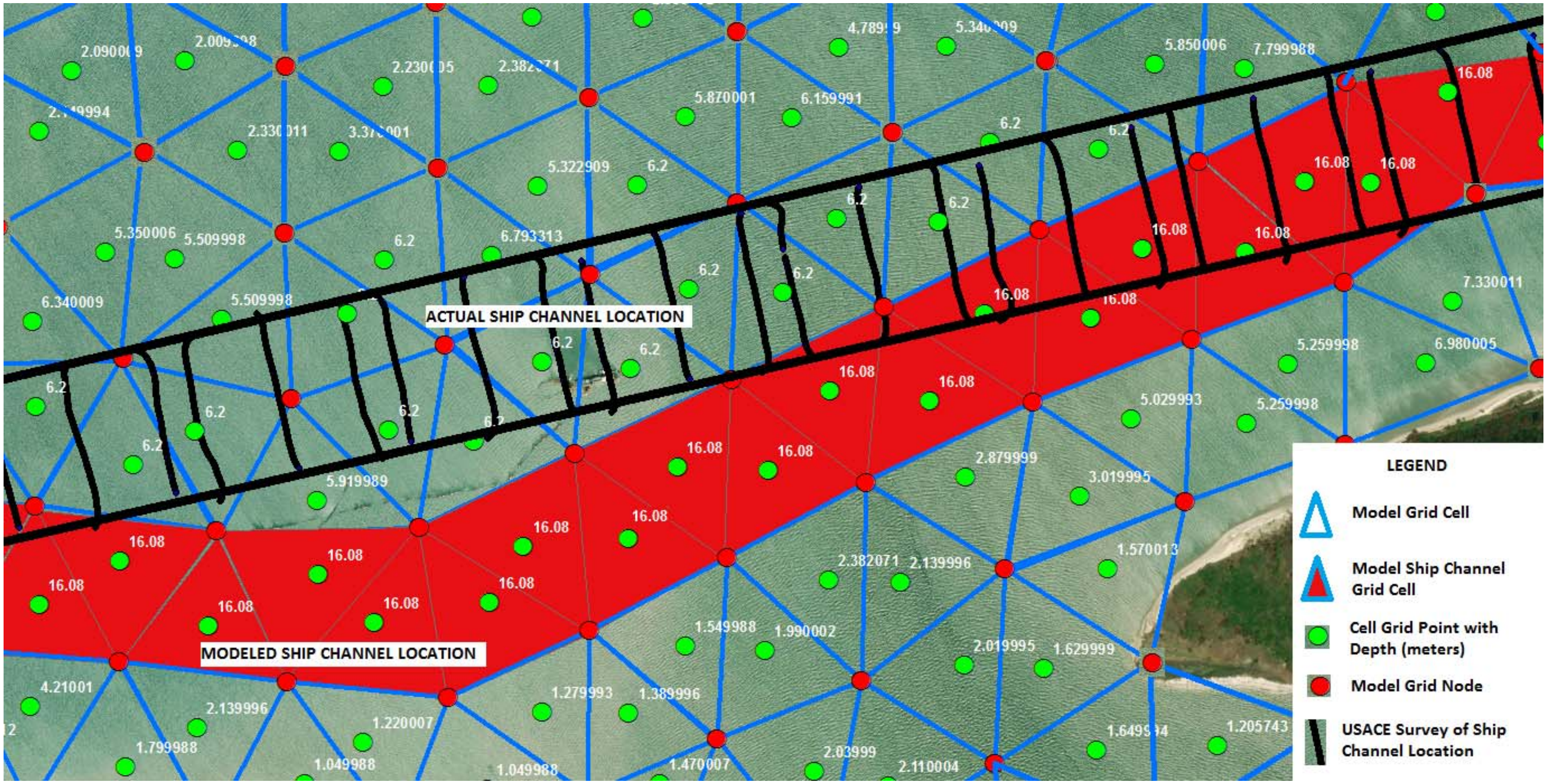


Figure 6 - – Modeled vs. Actual location of the Corpus Christi Ship Channel. The modeled channel (red cells) are located slightly to the south of the actual ship channel, and the modeled channel includes bends not present within the actual channel. The separation between modeled and actual channel locations, as well as the bends in the model channel, result from the coarse triangular model grid used within SUNTANS. The modeled channel retains the approximate width of the actual channel, which ensures that the modeled channel will convey similar quantities of water as the actual channel. Bends in the channel, however, will result in reduced velocities in the modeled channel compared to those expected to exist in the actual channel.

SUNTANS 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 SUNTANS Corpus Christi Bay system the following inflow sources are included:

- Oso Creek at Corpus Christi, TX (USGS Gauge #08211520)
- Copano Creek near Refugio, TX (USGS Gauge #08189200)
- Nueces River near Mathis, TX (USGS Gauge #08211000)
- Aransas River near Skidmore, TX (USGS Gauge #08189700)
- Mission River at Refugio, TX (USGS Gauge #08189500)
- Rincon Bayou Channel near Calallen, TX (USGS Gauge #08211503)

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 7 depicts the total modeled freshwater inflows into the Corpus Christi Bay system for the modeled period from January 1, 2010 to December 31, 2011. This 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 7 contained four inflow events that approached or exceeded 4,000 cfs. These events, including the large 20,000 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.

In contrast to 2010, 2011 is often considered as the single worst drought year in recorded Texas history. Figure 7 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 Harbor Island desalination brine discharge on salinity levels within the bay system.

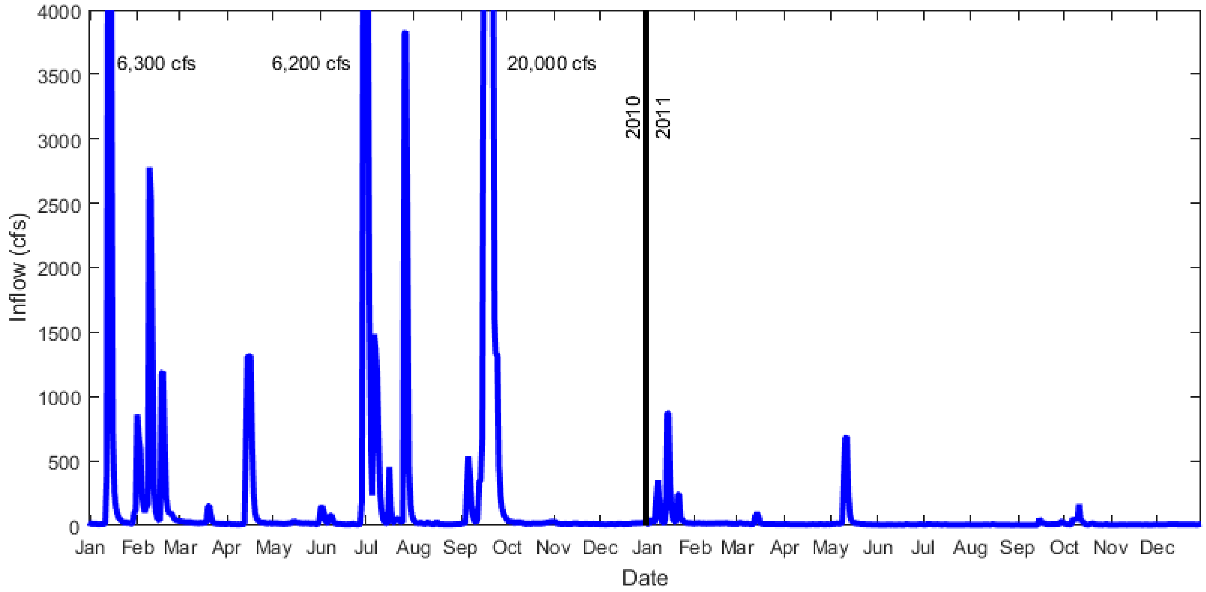


Figure 7 – Total Modeled Freshwater Inflow (2010-2011) into the Corpus Christi Bay System

SUNTANS Model Setup – Tidal Forcing

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 SUNTANS model, tidal forcing is specified as modeled input water levels at the outermost model cells representing the Gulf of Mexico (Figure 1). Water levels uses as model input were based on data recorded at Bob Hall Pier and available through the TCOON network and other sources.

Figure 8 presents the time-series of water levels driving tidal forcing within the Corpus Christi Bay System SUNTANS model. Similar to the freshwater inflow data (Figure 7), water levels in 2010 were different than those in 2011, and the contrast in levels between the two periods will likely yield differing effects with regard to the system's ability to assimilate the desalination brine discharge. Water levels in 2010 exhibit a larger seasonal variation than those in 2011, and include higher water levels generally from April through August. Higher water levels indicate periods of greater influx of seawater into the bay system, which could tend to enhance mixing within the Corpus Christi Ship Channel where the Harbor Island discharge is located. In contrast, water levels in 2011 remain fairly constant, indicating only a limited exchange of water between the bay system and the Gulf of Mexico. This limited exchange could lead to a reduction in tidal mixing and a possible accumulation of salinity resulting from the brine discharge.

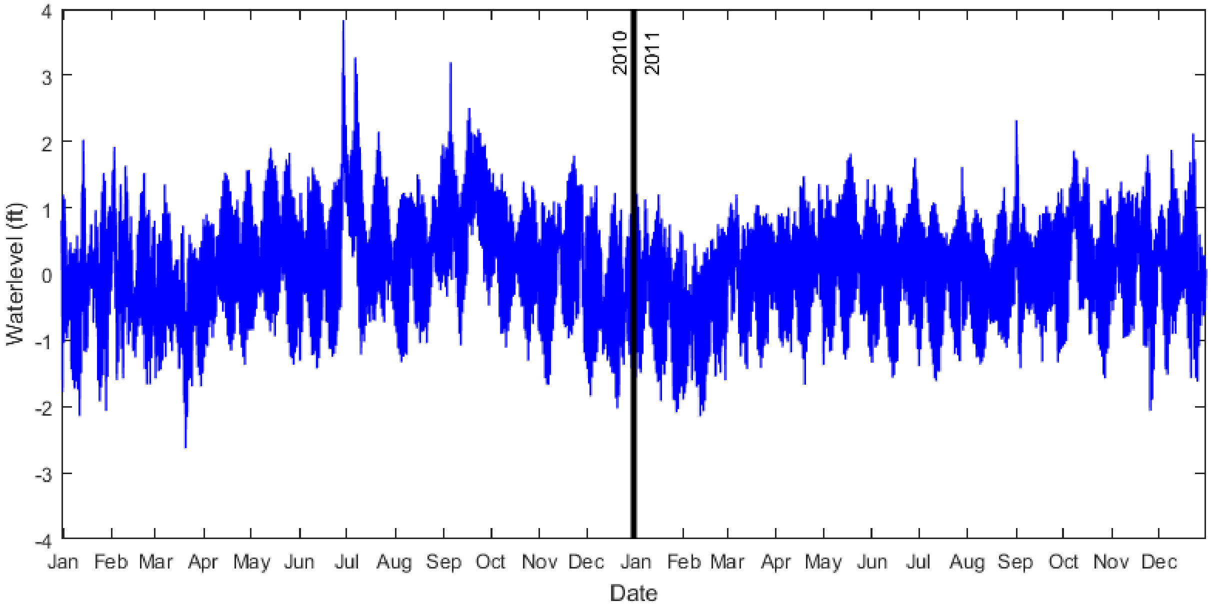


Figure 8 – Water levels used to impose tidal forcing within the Corpus Christi Bay system SUNTANS model.

SUNTANS Model Validation

Prior to assessing SUNTANS model results with regard to the Harbor Island discharge, it is necessary to establish that the model is capable of reasonably representing the physical conditions driving water circulation and salinity 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 SUNTANS model is capable of reproducing results (i.e. water velocities, temperatures, and salinity profiles) that are reasonably accurate with respect to measured results.

Model validation was not originally part of the scope of this project, as it was assumed that the SUNTANS model of Corpus Christi Bay developed for oil spill modeling (from which this model was based) had been already validated against measured field data. During the course of this project effort, LRE could not verify that the SUNTANS model had been validated in this manner, and as such we decided to perform a limited model validation exercise to provide greater confidence in the model results presented herein. The model validation exercise presented herein is to be considered "limited" because only two datasets were available for comparing modeled and measured data, and the measured field data was NOT collected within the vicinity of the proposed Harbor Island discharge.

To partially validate the SUNTANS model, LRE obtained two datasets of field measurements: 1) profiles of salinity with depth, collected from within the Corpus Christi Ship Channel in the main body of the bay by researchers during a 2011 project by the Texas Water Development Board (TWDB), and 2) a time-series of water temperature and salinity collected within the Corpus Christi

Ship Channel adjacent to The University of Texas Marine Science Institute. Both field sampling locations are shown as red crosses in Figure 1. Data from field measurements #1 are documented in TWDB contract report No. 1004831013 (Hodges, 2011). Data from field measurements #2 are publicly available at https://cdmo.baruch.sc.edu/ under the site name "MARSCWQ."

Figure 9 presents a comparison of modeled and observed salinities with depth at TWDB waypoint 30 within the Corpus Christi ship channel in the main body of Corpus Christi Bay. As shown, the SUNTANS model produced salinity values that were up to 2.5 ppt greater than measured values. Both measured and modeled data indicate salinity stratification with depth, with the difference between surface and bottom salinities each equal to 2.5 ppt. The modeled salinity profile, however, indicates larger stratification within the first few feet below the surface but greater mixing through the water column overall. The general agreement between the modeled and observed salinities at depths exceeding 45-ft is encouraging in that the SUNTANS model is reproducing the observed properties of the bay system along the benthos. A 0.75 ppt difference between observed and modeled salinities below 45 ft is less important than the fact that both profiles exhibit minimal change in values with depth below 45 ft.

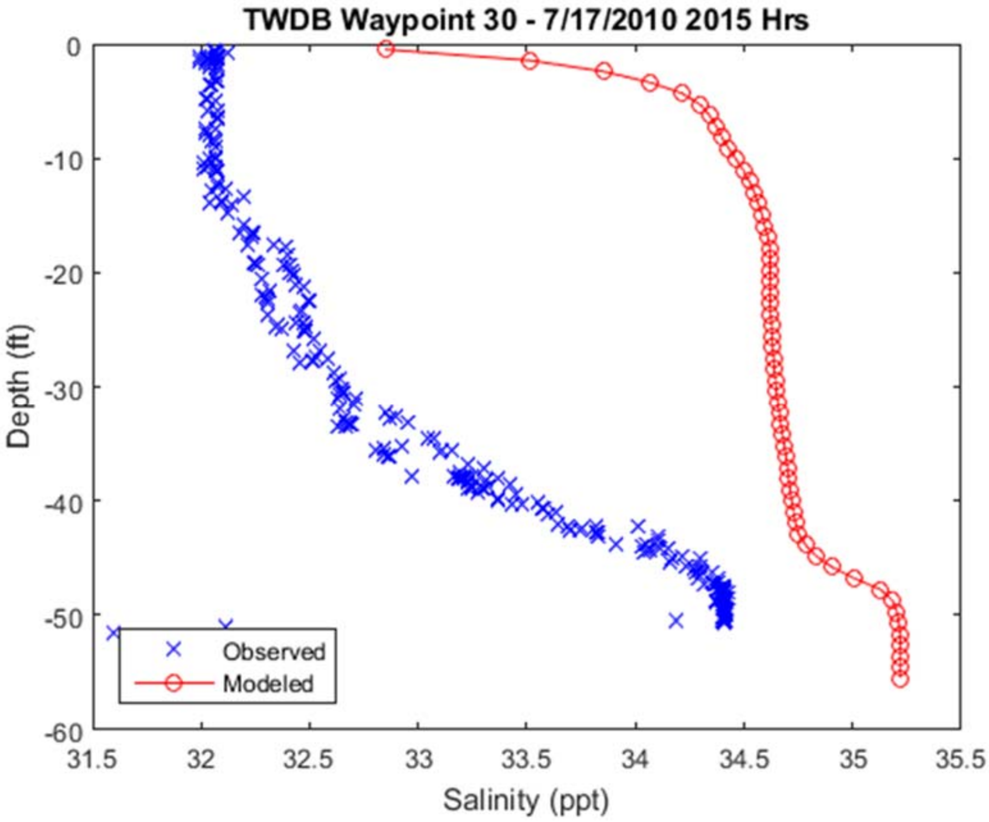


Figure 9 – Modeled and observed salinity profiles with depth from 7/17/2010 at TWDB waypoint 30 within the Corpus Christi Bay ship channel.

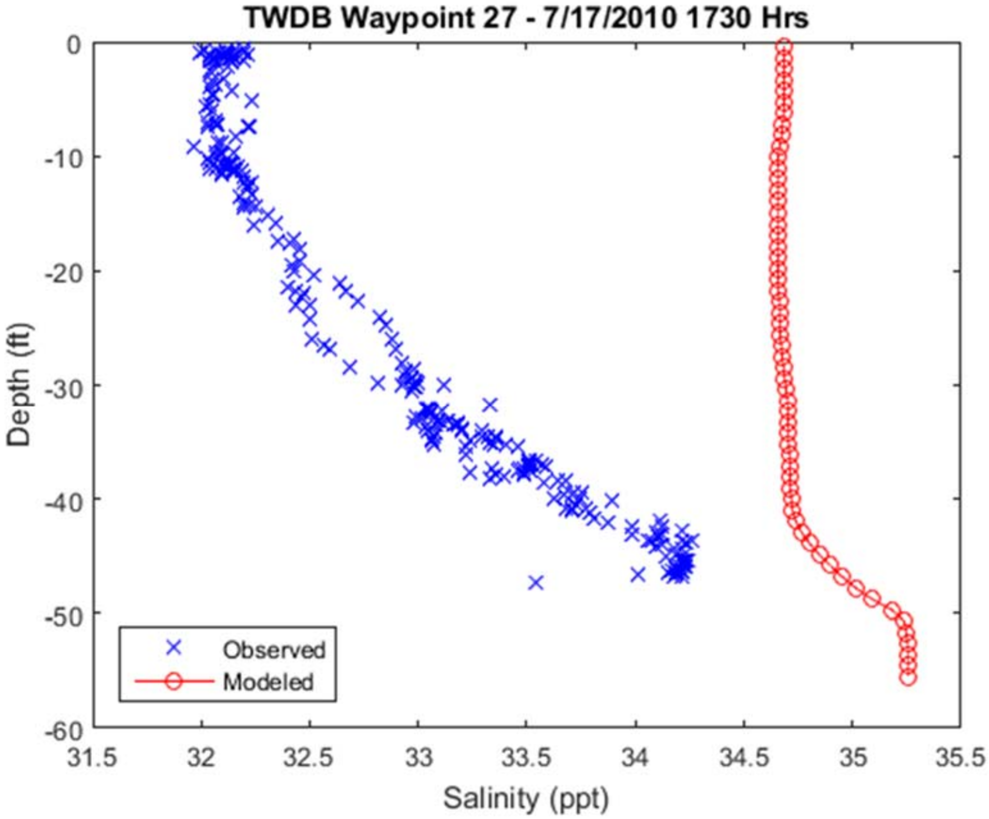


Figure 10 - – Modeled and observed salinity profiles with depth from 7/17/2010 at TWDB waypoint 27 within the Corpus Christi Bay ship channel.

Figure 10 presents a comparison of modeled and observed salinity profiles from a second location within the Corpus Christi Ship Channel, located approximately1.3 miles east of TWDB waypoint 30 (Figure 9). At this location, the SUNTANS model over-predicted the bay salinity by 2.5 ppt near the surface, and by 1.25 ppt at depth. The model also under-calculated water column stratification, as modeled stratification only occurred below 40 ft depths, whereas observed stratification began at a depth of 10 ft. Both the model and observed data demonstrated uniform salinity profiles from the surface to 10ft depths.

Given the limited extent of available field data, it is not possible to develop quantitative metrics for assessing the SUNTANS model's performance. However, comparisons between modeled and observed data from Figure 9 and Figure 10 provide confidence that the SUNTANS model is reasonably able to predict salinity stratification, and suggest that the model may over-predict actual bay salinity. It should be noted that TWDB Waypoint 30 and TWDB Waypoint 27 are 13.5 and 12.2 miles, respectively, from the Harbor Island discharge, and therefore these modeled vs. observed comparisons may not be indicative of similar comparisons that would be made at the Harbor Island discharge location (if measured data were available).

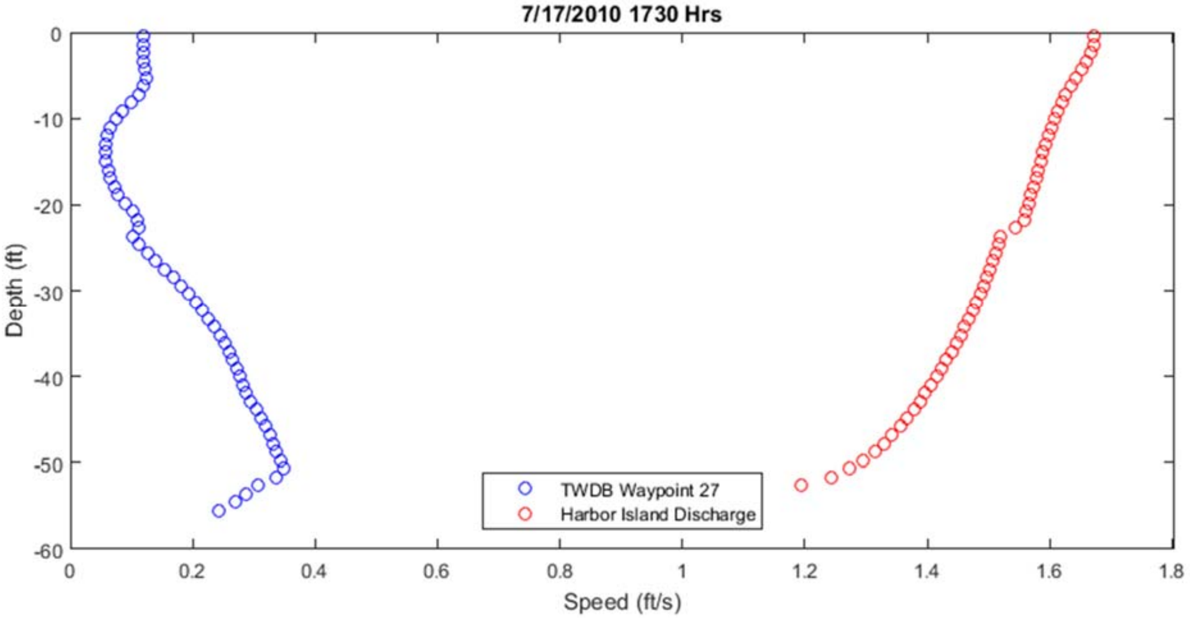


Figure 11 – Modeled water velocities at TWDB waypoint 27 (Figure 10) and at the Harbor Island discharge location.

Figure 11 presents a comparison of velocity profiles modeled at the TWDB waypoint 27 and Harbor Island discharge location. As indicated, water velocities at the discharge location range from 1.6 ft/s to 1.2 ft/s, whereas those at the TWDB waypoint range from 0.05 ft/s to 0.35 ft/s. The greater velocities at the Harbor Island discharge location are reflective of the tidal influence on water movement at that location. There is also notable velocity shear within the water columns at both locations, suggesting strong vertical mixing in both areas. The larger velocities shown in Figure 11for the Harbor Island location support the notion that model validation conclusions drawn from Figure 9 and Figure 10 may not be valid for the area in the vicinity of the proposed desalination brine discharge.

Figure 12 presents a time-series record of salinity measures at 5.5m depth within the Corpus Christi Ship Channel adjacent to The University of Texas Marine Science Institute. Data is plotted at 15-minute intervals from late 2007-late 2017. As shown, salinity variations from 15 to 40 ppt have occurred, with generally higher salinities recorded in summer months when freshwater inflows are often lower and evaporation is often higher. Figure 13 presents a comparison of the modeled and measured salinities at this location for the 2010-2011 time period. As shown, the modeled salinities are generally in-line with measured values, yet are less variant than the observed values. This suggests that the SUNTANS model is not able to capture the large temporal variations in salinity within the Corpus Christi Ship Channel. These large variations are likely due to strong freshwater inflow or tidal variations driving more water circulation than suggested from the SUNTANS model. Thus Figure 12 would indicate that the SUNTANS model generally under-predicts water mixing and movement within the Corpus Christi Bay Ship Channel.

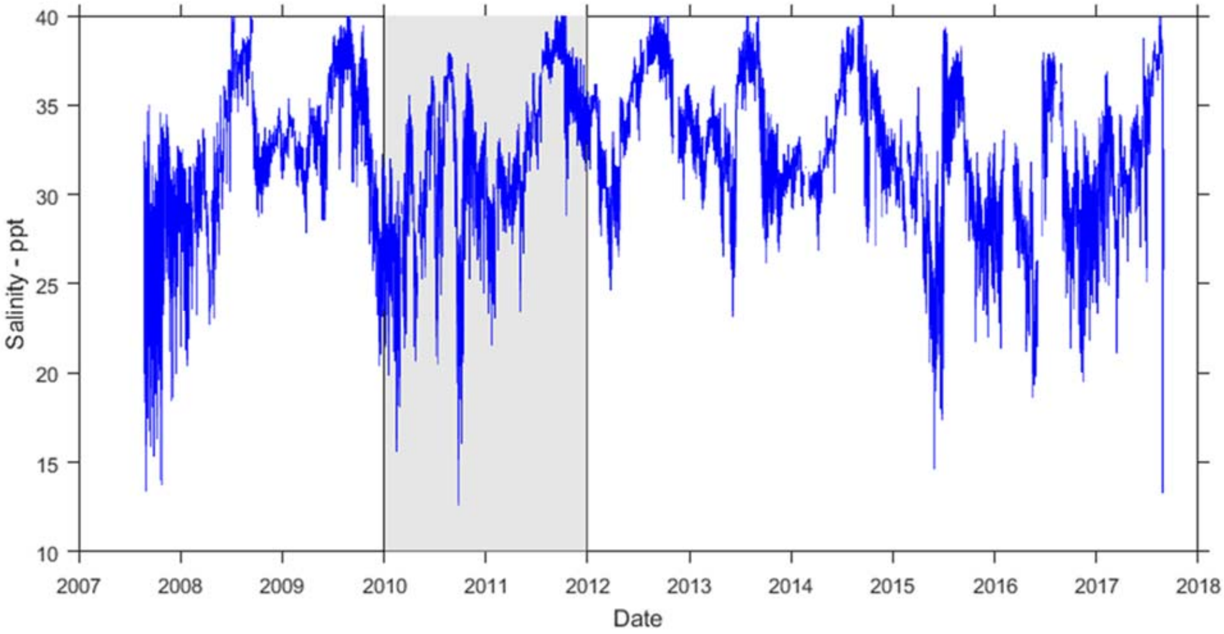


Figure 12 – Measured salinity at 5.5m depth within the Corpus Christi Ship Channel adjacent to The University of Texas Marine Science Institute. Grey area indicates the period of SUNTANS modeling.

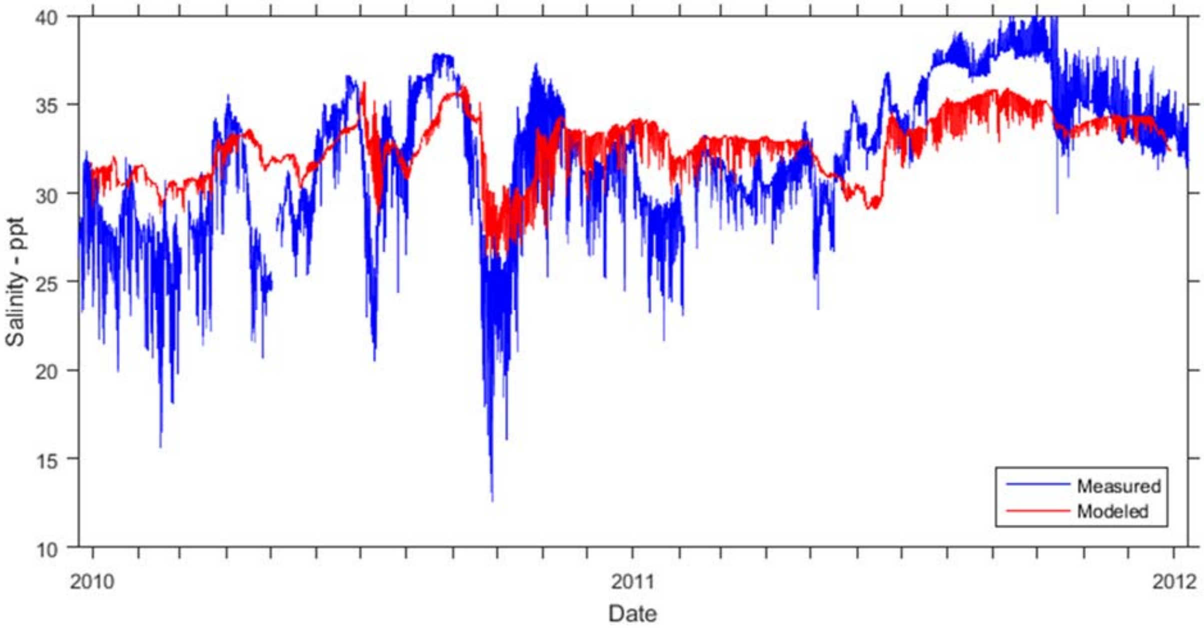


Figure 13 – Measured and modeled salinity at 5.5m depth within the Corpus Christi Ship Channel adjacent to The University of Texas Marine Science Institute.

Figure 14 presents a time-series plot of recorded temperature at 5.5m depth within the Corpus Christi Ship Channel adjacent to The University of Texas Marine Science Institute. As shown, temperatures show regular fluctuations over the calendar year, and generally range from 50 °F to 90 °F. Temperature fluctuations measured in 2010-2011 are similar in range and magnitude as for other years for which data are available.

Figure 15 presents a comparison of the modeled and measured temperatures at 5.5m depth within the Corpus Christi Ship Channel adjacent to The University of Texas Marine Science Institute for the period from 2010 to 2012. As shown, for 2010 modeled temperatures nearly always exceeded measured temperatures, yet each dataset indicated similar daily and seasonal patterns. Modeled temperatures tended to exceed measured temperatures to the greatest degree during the winter months, suggesting that the SUNTANS model does not release heat energy appropriately at these times. For 2011, measured and modeled temperatures tended to agree more (than in 2010), with modeled temperatures often 1-5 degrees below the measured temperatures. For the period in late 2011, modeled temperatures exceeded measured temperatures, providing further indication that the SUNTANS model retains too much heat energy during the cooler months.

Overall, the general agreement between measured and modeled temperatures shown in Figure 15 suggests that SUNTANS is reasonably able to model the complex thermodynamic mechanisms dictating temperature changes within the Corpus Christi Bay system. SUNTANS algorithms could likely be improved to better model the cooler months, and such modifications could influence computed salinity distributions and water circulation patterns. Such adjustments could yield more variability within the computed salinity values, and could lead to better agreement between modeled and observed salinity results (Figure 13).

Based on the limited available data for use in model validation, LRE concludes that the current SUNTANS model is likely to under-predict mixing of the proposed desalination brine discharge. This conclusion stems on the model's inability to reproduce the large salinity variations present within the Corpus Christi Ship Channel (Figure 13), as these large variations would be the result of greater mixing and circulation of water through the area around the discharge. It is also notable that while SUNTANS over-predicted salinity values within the main body of Corpus Christi Bay (Figure 9, Figure 10), this over-prediction was not constant over time and was less common near the discharge location (Figure 13). Considering the available model validation data, it is likely that any SUNTANS-computed increase in salinity as a result of the Harbor Island discharge would be overstated as field data indicates greater mixing and water movement than do model results.

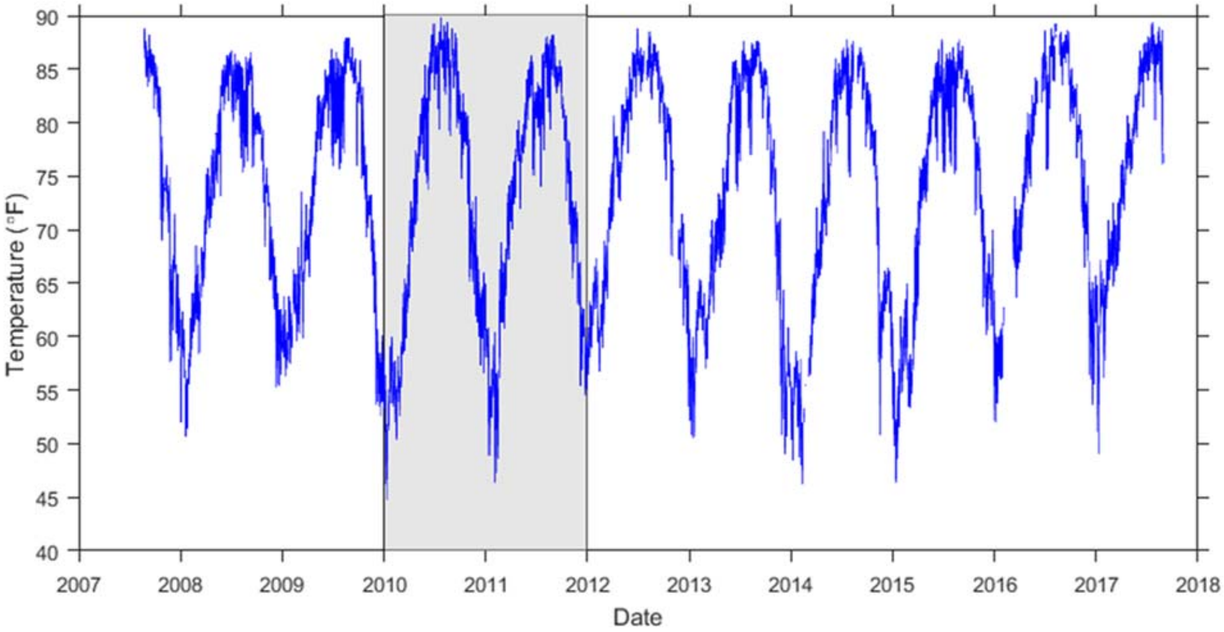


Figure 14 – Measured water temperature at 5.5m depth within the Corpus Christi Ship Channel adjacent to The University of Texas Marine Science Institute. Grey area indicates the period of SUNTANS modeling.

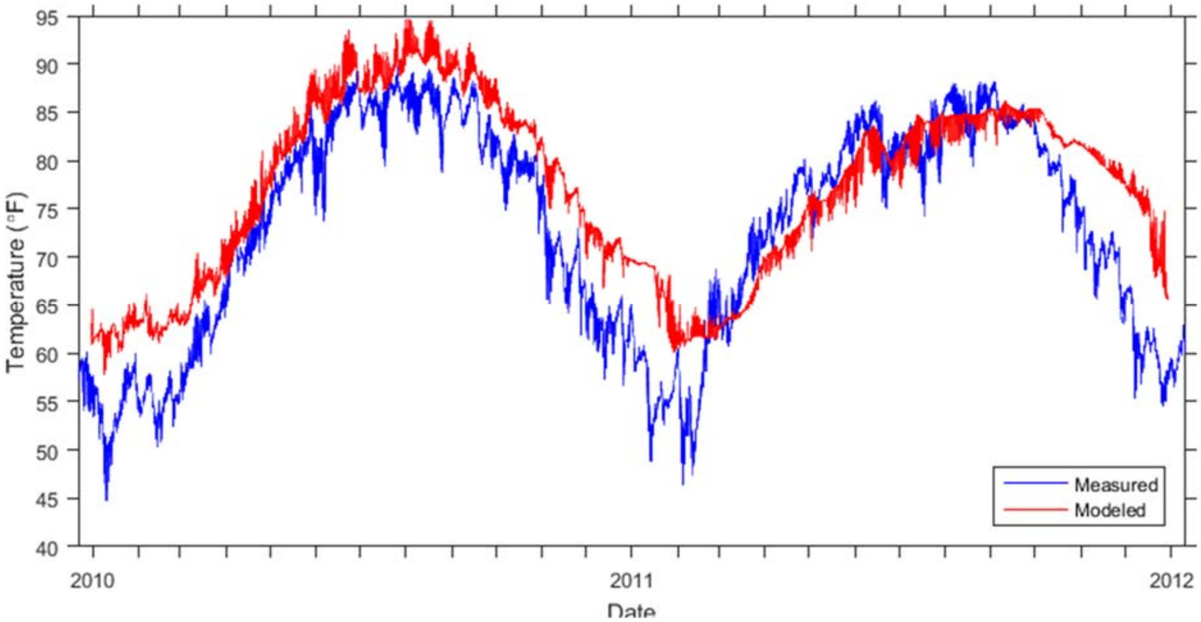


Figure 15 Measured and modeled water temperature at 5.5m depth within the Corpus Christi Ship Channel adjacent to The University of Texas Marine Science Institute.

SUNTANS Model Results

Modeled Salinity Near the Harbor Island Discharge

SUNTANS model results can be displayed in a variety of ways, and the results presented herein were chosen as they are illustrative of the impact of the desalination discharge. Figure 16 presents the computed bottom salinity at the Harbor Island discharge location for the period from January 1, 2010 to December 31, 2011. Time series of plotted results include results obtained with (red) and without (blue) the modeled discharge.

For the 2010-2011 modeled period, salinities computed with the brine discharge are generally between 0 and 1 ppt greater than those computed without the discharge (Figure 16B). This trend was evident during periods of prolonged low inflows and periodic high inflows, indicating that the salinity increase resulting from the brine discharge was not largely effected by the freshwater inflows to the bay system. However, during and after the large inflow event from September 2010, modeled salinities with the discharge would periodically be lower than those computed without the discharge. The cause for this result was not fully identified, yet is likely due to the reduced local mixing in the non-discharge scenario.

For 2010, modeled bottom salinities with and without the discharge started at approximately 31.5 ppt on January 1 and decreased to just under 30 ppt as a result of the two large inflow events in January and February. Modeled salinities increased to 34 ppt during the dry period between March and July, with a slight temporary decrease evident due to the small inflow event that occurred in mid-April. Modeled salinities decreased to under 30 ppt as a result of the 6,300 cfs inflow event in early July, then increased to 36 ppt in April. The large inflow event (20,000 cfs) in September reduced the modeled salinity to between 28 ppt and 31 ppt, where it remained during October. At the end of October, salinities rapidly increased to approximately 34 ppt, where they remained through December.

For 2011, modeled salinity values with and without the discharge continued to follow a similar pattern, with a slight decrease resulting from the small inflow event in mid-May. Modeled values increased to near 36 ppt from July through September and remained between 34 ppt and 36 ppt for the rest of the year without significant freshwater inflows to drive the salinity lower. The difference in salinity between the modeled and without-modeled discharge continuously fluctuated, but never exceeded 1 ppt for all of 2011.

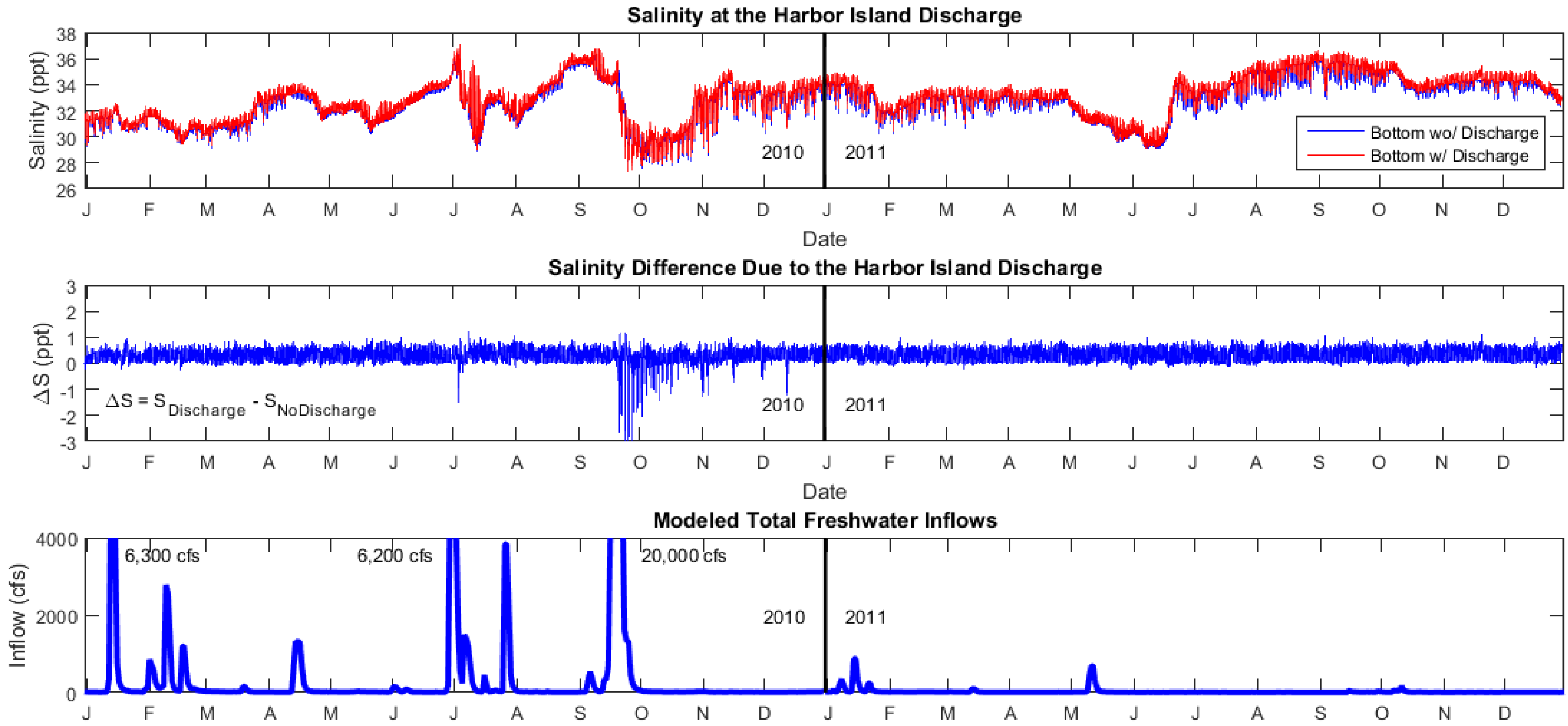


Figure 16 – Modeled Bottom Salinity values at the Harbor Island discharge location, January 1, 2010 to December 31, 2011. A) Salinity time series, including computed salinities with and without the brine discharge. B) salinity difference between simulations with and without the discharge B) Modeled freshwater inflows, repeated from Figure 7.

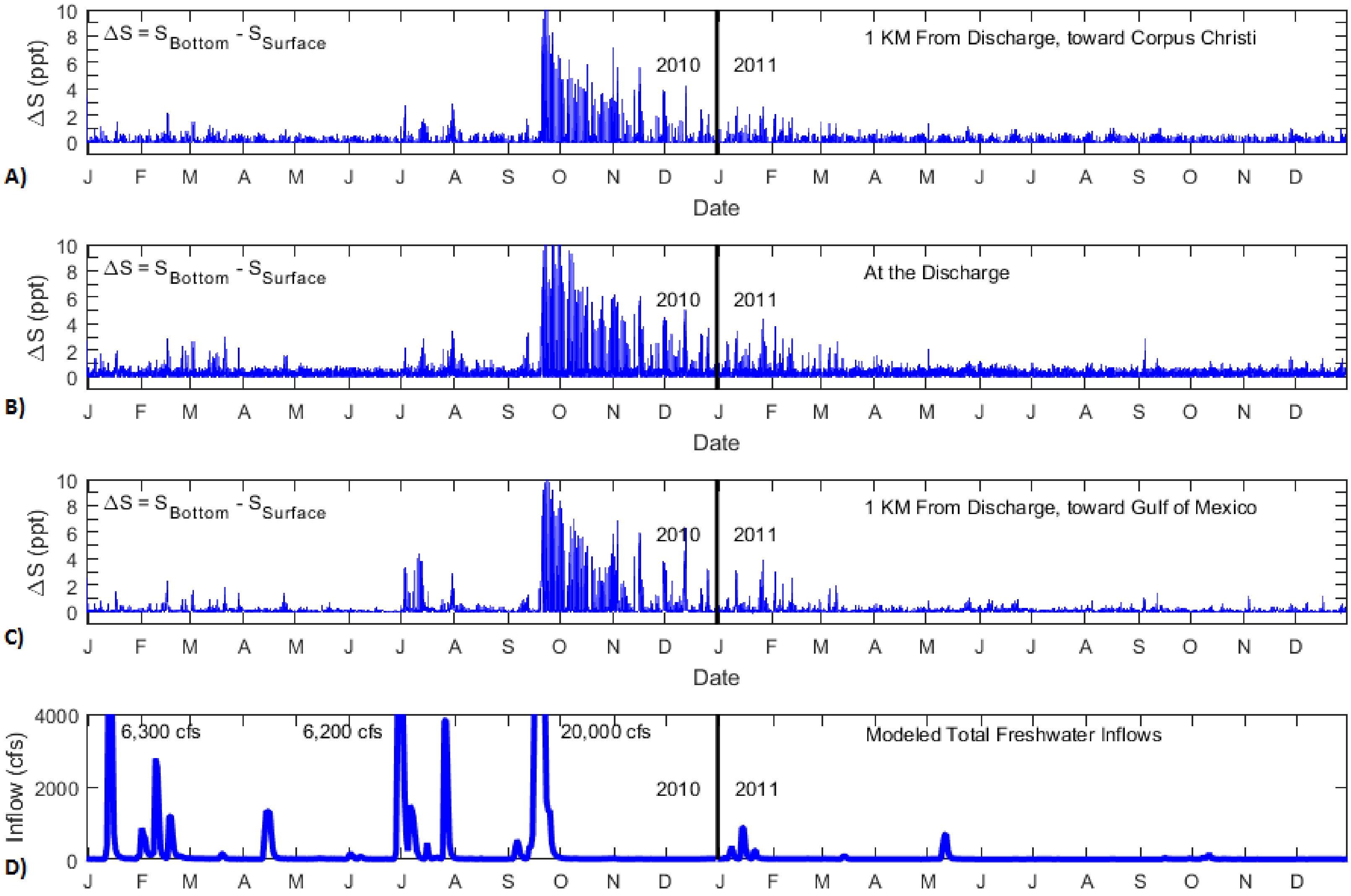


Figure 17 – Modeled salinity stratification for 2010-2010 , defined as the difference between bottom and surface salinities- A) stratification at a location 1-kilometer "up-channel" from the Harbor Island discharge (toward Corpus Christi). B) stratification at the Harbor Island discharge location. C) stratification at a location 1-kilometer "down-channel" from the Harbor Island discharge (toward the Gulf of Mexico). D) Modeled freshwater inflows, repeated from Figure 7.

Figure 17 presents model calculated salinity water-column stratification (defined as the salinity difference between the bottom and surface layers) for the modeled period (2010-2011) for locations 1 kilometer upstream (toward Corpus Christi) and downstream (toward the Gulf of Mexico) from the Harbor Island discharge, as well as at the discharge location. As shown, stratification is greatest at the discharge location, and diminishes in magnitude at the locations away from the discharge. The large inflow event in September 2010 caused a stratification of approximately 10 ppt as fresher, lower salinity water traveled along the surface on top of the denser higher salinity water near the bottom. Modeled stratification from this freshwater inflow event diminished yet persisted through March of 2011 as evident at each of the three locations plotted in Figure 17. Stratification is less pronounced toward the Gulf of Mexico, indicating that daily tidal forcing causes the water column to generally remain well mixed, thus preventing the creation of high-salinity layers along the channel bottom, and preventing the buildup of high salinity resulting from the brine discharge.

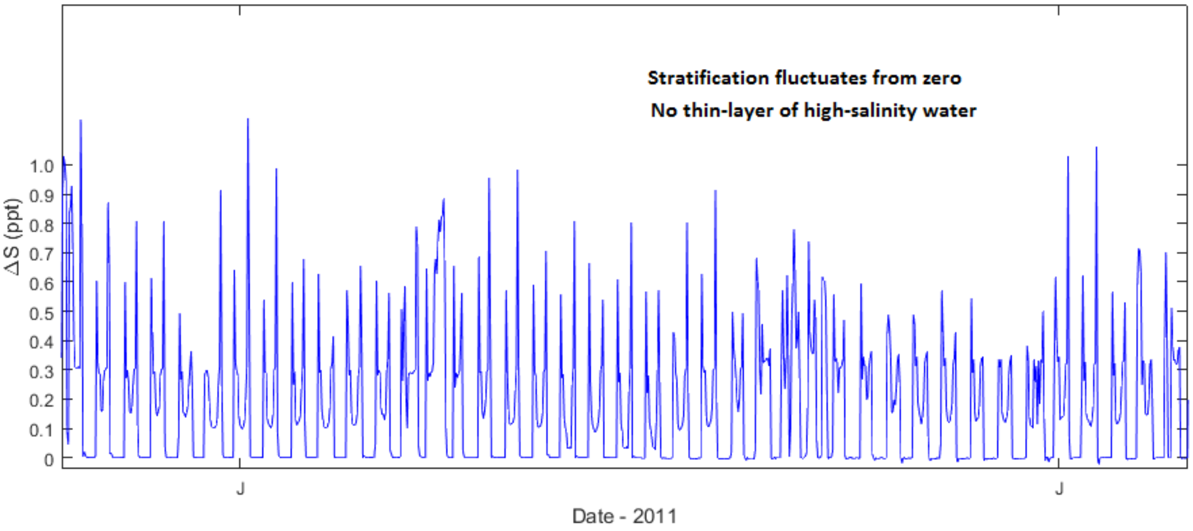


Figure 18 – Stratification at the Harbor Island discharge location for June, 2011, showing fluctuations varying based on the daily tidal influence.

Figure 18 presents a “zoomed-in” view of the computed salinity stratification at the Harbor Island discharge location for the month of June, 2011. This was a period of low freshwater inflows, and water column mixing was dominated by the diurnal tidal forcing. As shown, stratification occasionally exceeded 1.0 ppt, yet always fluctuated back to zero due to the tidal mixing. This demonstrates that the modeled brine discharge does not create a durable, persistent high-salinity layer along the channel bottom. Mixing dynamics at the discharge location are such that the brine discharge yields minimal impacts on ambient salinity.

It is notable that for the Harbor Island location, salinity values with and without the modeled brine discharge varied uniformly, with each time series increasing and decreasing at the same time and in approximately the same magnitude (Figure 16). This indicates that the brine discharge itself does not significantly affect the local salinities, and that the higher salinity resulting from the discharge does not continuously accumulate over time.

It is also notable that the 2010 variation in salinity (ranging from 28 to 36 ppt) greatly exceeds the salinity increase (0-1ppt) resulting from the brine discharge. This indicates that inflows, tidal fluctuations, evaporation, and other natural features of the Corpus Christi Bay system play a larger role in determining local salinity than does the proposed desalination brine discharge. The 2010-2011 results suggest that the discharge of high-salinity brine into the Corpus Christi ship channel does not produce an increase of over 1 ppt change in local salinity values, whether or not large freshwater inflow events periodically occur. An analysis of how a 1 ppt increase in salinity due to the brine discharge may affect the local ecosystem was outside the scope of this investigation.

Modeled Bottom Salinity Throughout the Corpus Christi Bay System

To assess the spatial and temporal impact of the modeled Harbor Island desalination brine discharge, it is necessary to compare over time how computed salinities differ from models with and without the simulated discharge. The SUNTANS model discussed within this report includes two simulated desalination brine discharges: 1) the proposed Harbor Island discharge, and 2) a "conceptual estimated" discharge from a potential desalination facility located at the northern end of the La Quinta Channel (Figure 3). Results shown in Figure 19-Figure 24 show the computed INCREASE in bottom salinity resulting from both of these modeled desalination brine discharges. LRE notes that these results will be refined in the future when the planned the La Quinta Channel desalination facility is fully designed. It is not possible within the current SUNTANS model results to distinguish between the effects of either the Harbor Island or La Quinta Channel discharges, except that computed salinity increases in the vicinity of each discharge are only the result of the modeled discharge at that location.

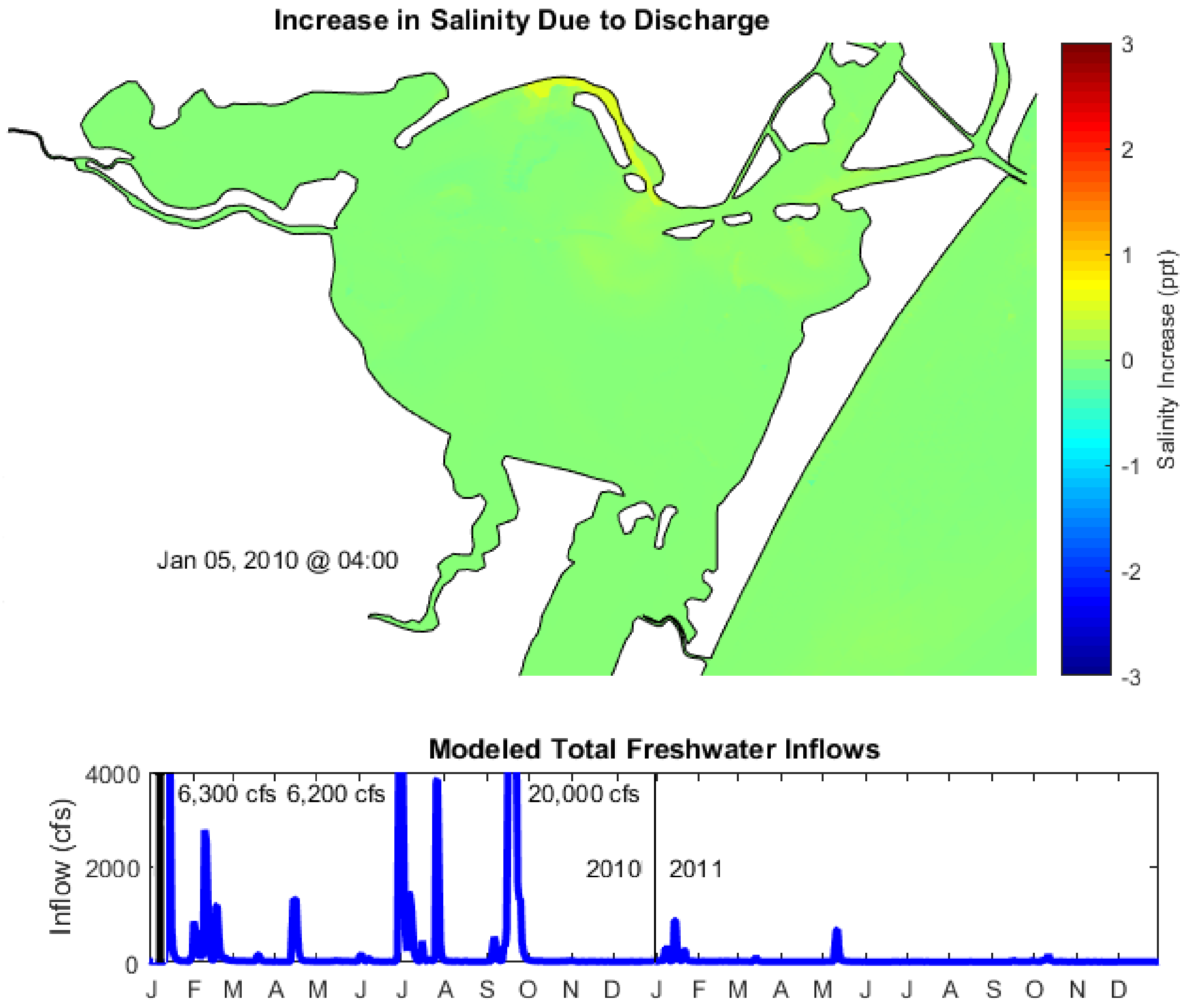


Figure 19 – Modeled Bottom Salinity Increase Resulting from Proposed Harbor Island & La Quinta Channel desalination brine discharges, shown for January 5, 2010. Increase is defined as the difference in bottom salinity between models including and excluding the desalination brine discharges. Note: the SUNTANS model does properly simulate the La Quinta Channel discharge due to the coarse model grid in the vicinity of the channel. The modeled La Quinta Channel discharge is estimated as the diffuser design for the proposed facility has yet to be finalized.

Figure 19 presents the modeled increase in bottom salinity resulting from the Harbor Island and La Quinta Channel discharges for the date of January 5, 2010. This date represents a time when the modeled discharges would have been occurring for only 5 consecutive days, and is prior to a time when any large freshwater inflow events may affect the computed salinity distribution within the bay system. As shown, bottom salinity increases are near-zero throughout the majority of the bay system. Increases approaching 1 ppt are evident around the La Quinta Channel discharge location and within the La Quinta Channel until the channel’s intersection with the Corpus Christi Ship Channel. Figure 19 does not indicate any increase in bottom salinity in the region surrounding the proposed Harbor Island discharge location.

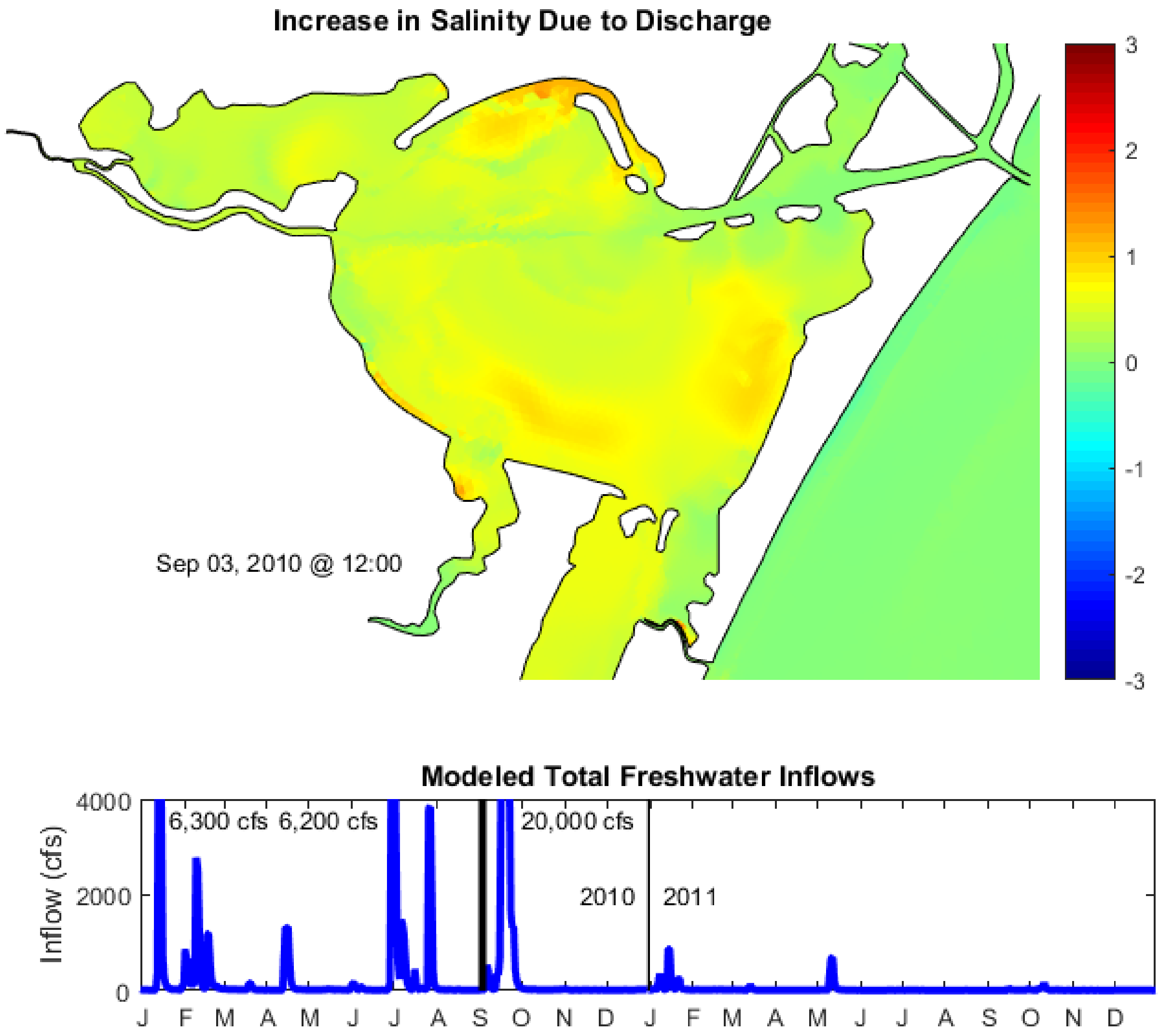


Figure 20 - Modeled Bottom Salinity Increase Resulting from Proposed Harbor Island & La Quinta Channel desalination brine discharges, shown for September 3, 2010, prior to the large inflow event. Increase is defined as the difference in bottom salinity between models including and excluding the desalination brine discharges. Note: the SUNTANS model does properly simulate the La Quinta Channel discharge due to the coarse model grid in the vicinity of the channel. The modeled La Quinta Channel discharge is estimated as the diffuser design for the proposed facility has yet to be finalized.

Figure 20 presents the modeled increase in bottom salinity resulting from the Harbor Island and La Quinta Channel discharges for the date of September 3, 2010. This date represents a time when the modeled discharges would have been occurring for 8 full months, and is prior to the large freshwater inflow event that occurred in September 2010. As shown, bottom salinity increases range from 0-1 ppt throughout the majority of the Corpus Christi Bay system, with higher salinity increases located within and around the La Quinta Channel. Figure 20 does not indicate any increase in bottom salinity in the region surrounding the proposed Harbor Island discharge location, and does not indicate any interaction between the two modeled discharges.

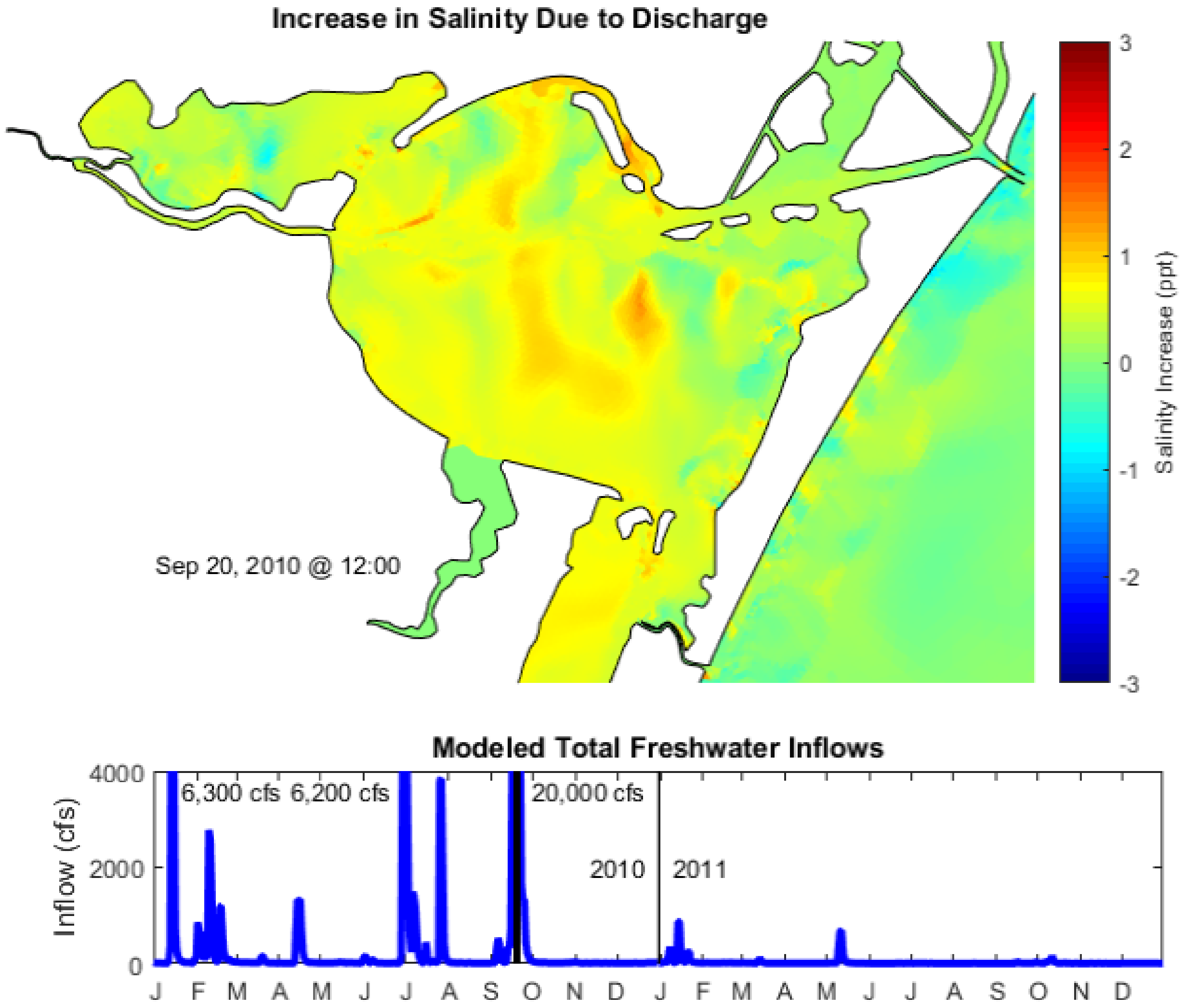


Figure 21 - Modeled Bottom Salinity Increase Resulting from Proposed Harbor Island & La Quinta Channel desalination brine discharges, shown for September 20, 2010, during the large inflow event. Increase is defined as the difference in bottom salinity between models including and excluding the desalination brine discharges. Note: the SUNTANS model does properly simulate the La Quinta Channel discharge due to the coarse model grid in the vicinity of the channel. The modeled La Quinta Channel discharge is estimated as the diffuser design for the proposed facility has yet to be finalized.

Figure 21 presents the modeled increase in bottom salinity resulting from the Harbor Island and La Quinta Channel discharges for the date of September 20, 2010, representing a time during the large freshwater inflow event that occurred in September 2010. As shown, bottom salinity increases range from 0-1 ppt throughout the majority of the Corpus Christi Bay system, and the freshwater inflows have altered the locations where higher salinity water is found. The freshwater inflows also appear to have resulted in the formation of "pockets" of higher-bottom salinity" water on both the north and south side of the Corpus Christi Ship Channel within the main body of Corpus Christi Bay. Figure 21 does not indicate any increase in bottom salinity in the region surrounding the proposed Harbor Island discharge location, and does not indicate any interaction between the two modeled discharges.

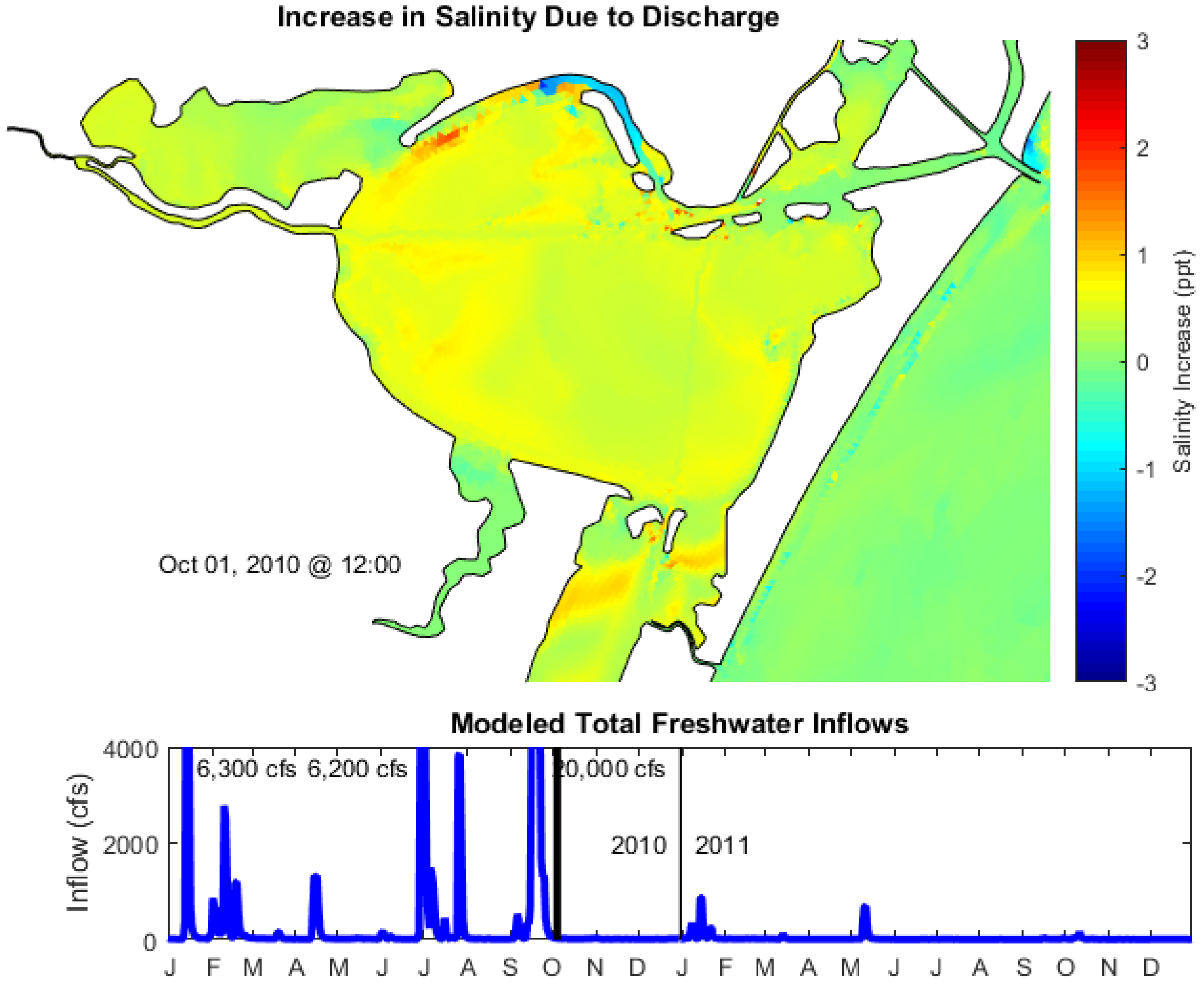


Figure 22 - Modeled Bottom Salinity Increase Resulting from Proposed Harbor Island & La Quinta Channel desalination brine discharges, shown for October 1, 2010, after the large inflow event. Increase is defined as the difference in bottom salinity between models including and excluding the desalination brine discharges. Note: the SUNTANS model does properly simulate the La Quinta Channel discharge due to the coarse model grid in the vicinity of the channel. The modeled La Quinta Channel discharge is estimated as the diffuser design for the proposed facility has yet to be finalized.

Figure 22 presents the modeled increase in bottom salinity resulting from the Harbor Island and La Quinta Channel discharges for the date of October 1, 2010, representing a time after the large freshwater inflow event that occurred in September 2010. As shown, bottom salinity increases range from 0-1 ppt throughout the majority of the Corpus Christi Bay system, yet pockets of higher increases exist near the interface with Nueces Bay and within Laguna Madre. Also evident is that the large freshwater inflow event has causes a salinity decrease within the Corpus Christi Channel (signifying the salinity with the discharges is now less than it would be without the discharges). This decrease in salinity is interesting and warrants further future investigation. Figure 22 indicates only a slight increase (<0.5 ppt) in bottom salinity in the region surrounding the proposed Harbor Island discharge location, and does not indicate any interaction between the two modeled discharges.

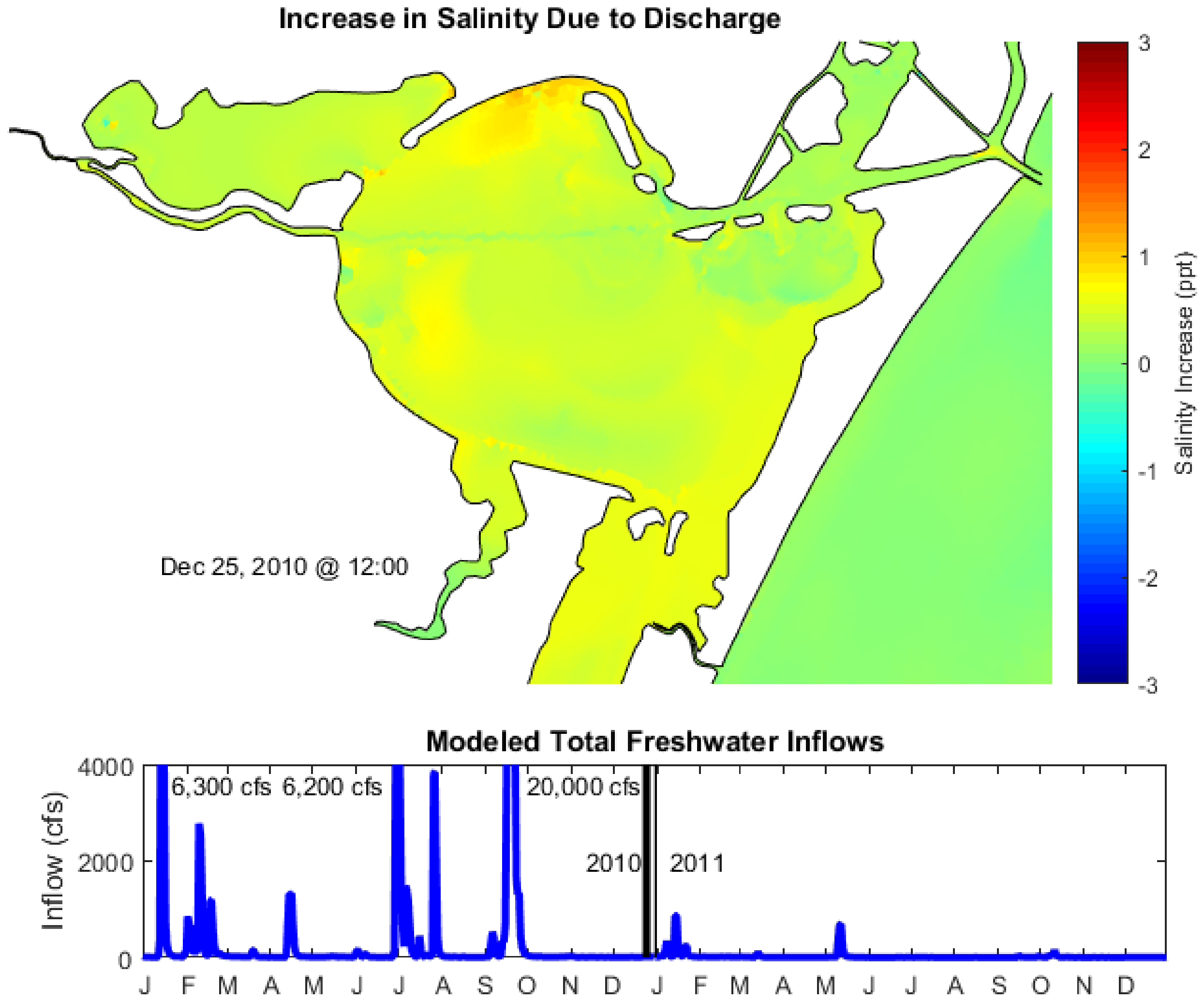


Figure 23 - Modeled Bottom Salinity Increase Resulting from Proposed Harbor Island & La Quinta Channel desalination brine discharges, shown for December 25, 2010, months after the large inflow event. Increase is defined as the difference in bottom salinity between models including and excluding the desalination brine discharges. Note: the SUNTANS model does properly simulate the La Quinta Channel discharge due to the coarse model grid in the vicinity of the channel. The modeled La Quinta Channel discharge is estimated as the diffuser design for the proposed facility has yet to be finalized.

Figure 23 presents the modeled increase in bottom salinity resulting from the Harbor Island and La Quinta Channel discharges for the date of December 25, 2010, representing a time nearly 3-months after the large freshwater inflow event that occurred in September 2010. As shown, bottom salinity increases range from 0-1 ppt throughout the majority of the Corpus Christi Bay system, pockets of lower increases (<0.5 ppt) throughout the bay (especially south of the islands separating the channel from the bay). Higher increases are evident around the La Quinta Channel discharge location. Figure 23 indicates an increase (<1.0 ppt) in bottom salinity in the region surrounding the proposed Harbor Island discharge location, yet this increase is consistent with the periodic increases shown in Figure 18, and does not indicate any interaction between the two modeled discharges.

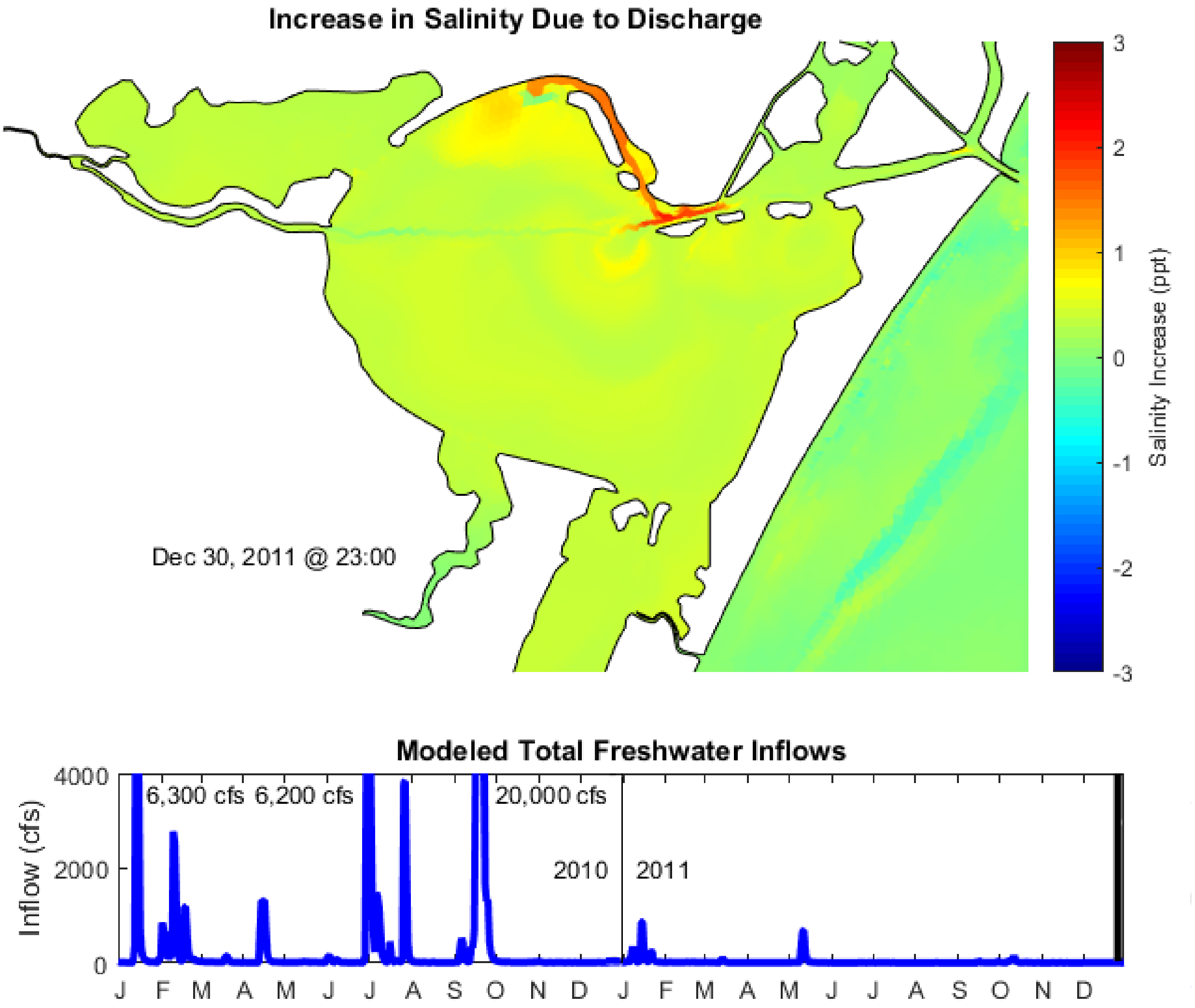


Figure 24 - Modeled Bottom Salinity Increase Resulting from Proposed Harbor Island & La Quinta Channel desalination brine discharges, shown for December 30, 2011, 15 months after the large inflow event. Increase is defined as the difference in bottom salinity between models including and excluding the desalination brine discharges. Note: the SUNTANS model does properly simulate the La Quinta Channel discharge due to the coarse model grid in the vicinity of the channel. The modeled La Quinta Channel discharge is estimated as the diffuser design for the proposed facility has yet to be finalized.

Figure 24 presents the modeled increase in bottom salinity resulting from the Harbor Island and La Quinta Channel discharges for the date of December 30, 2011, representing a time nearly 15-months after the large freshwater inflow event that occurred in September 2010. As shown, bottom salinity increases range from 0-1 ppt throughout the majority of the Corpus Christi Bay system. Increases of up to 2.5 ppt are evident within the La Quinta Channel, and in portions of the Corpus Christi Channel near the intersection with the La Quinta Channel. Figure 24 indicates an increase (<1.0 ppt) in bottom salinity in the region surrounding the proposed Harbor Island discharge location, yet this increase is consistent with the periodic increases shown in Figure 18, and does not indicate any interaction between the two modeled discharges.

Figure 19-Figure 24 demonstrate that bottom salinity values throughout the Corpus Christi Bay system will be expected to increase by 0-1ppt as a result of the combined effects of brine discharges from both the La Quinta Channel and Harbor Island desalination facilities. This accumulation level was calculated before, during, and after freshwater inflow events, including after a period in which low inflows had occurred for over 15 months. These results indicate that salt levels are not likely to continuously accumulate along the bottom of Corpus Christi Bay as a result of the modeled desalination brine discharges. These results also indicate that the distribution of higher salinity bottom water throughout the bay system changes over both time and space depending on the freshwater inflows and tidal forcing. Figure 24 does indicate a 2.5 ppt increase in salinity along and within the La Quinta Channel, yet LRE Water does not believe the current SUNTANS model bathymetry and numerical grid are properly refined to accurately determine the fate and transport of a desalination discharge in this location. It is evident, however, that after a two-year simulation, the modeled La Quinta Channel and Harbor Island discharges are not interacting within each other (Figure 24).

Modeled Salinity Stratification & Effect of Freshwater Inflow Events

Figure 25 - Figure 28 depict model results from simulations including the brine discharge, shown at specific instances before, during, and after the large inflow event in September 2010. Each image shows a map of computed salinity stratification within Nueces and Corpus Christi Bay, along with salinities versus depth along a profile running from 2 miles inland from the Harbor Island discharge to the Aransas Pass jetties at the Gulf of Mexico. This profile extent is shown on Figure 1.

Figure 25 shows results from September 3, just prior to the onset of the large inflow event that occurred for the majority of the month. As shown within the salinity profile, the Corpus Christi Ship Channel was well-mixed at approximately 36 ppt, with nearly equal salinities at all depths and locations along the profile. Salinity stratification was non-existent across most of the Corpus Christi Bay system, except in locations within Upper Nueces Bay and within the Corpus Christi ship channel upstream from the main bay-body.

Figure 26 shows results from September 20, 2010 during the middle of the high-inflow event. At this time, overall salinities along the ship channel profile decreased from 36 ppt to 32-33 ppt, yet the profile is no longer well mixed in the vertical or horizontal directions. The profile indicates pockets of higher-salinity water, including a pocket of 35-36 ppt water located 1-mile from the discharge toward the Gulf of Mexico. Higher salinity water is also visible at the discharge location. This suggests that the large freshwater inflow reduces salinities throughout the bay system, yet does not initially do so uniformly or result in a vertically well-mixed condition. The large inflow event also resulted in salinity stratification at locations within the system where the freshwater is entering the larger bays. Stratification is evident in Nueces Bay, the Corpus Christi ship channel as it enters into Corpus Christi Bay from the west, and at the mouth of Oso Bay.

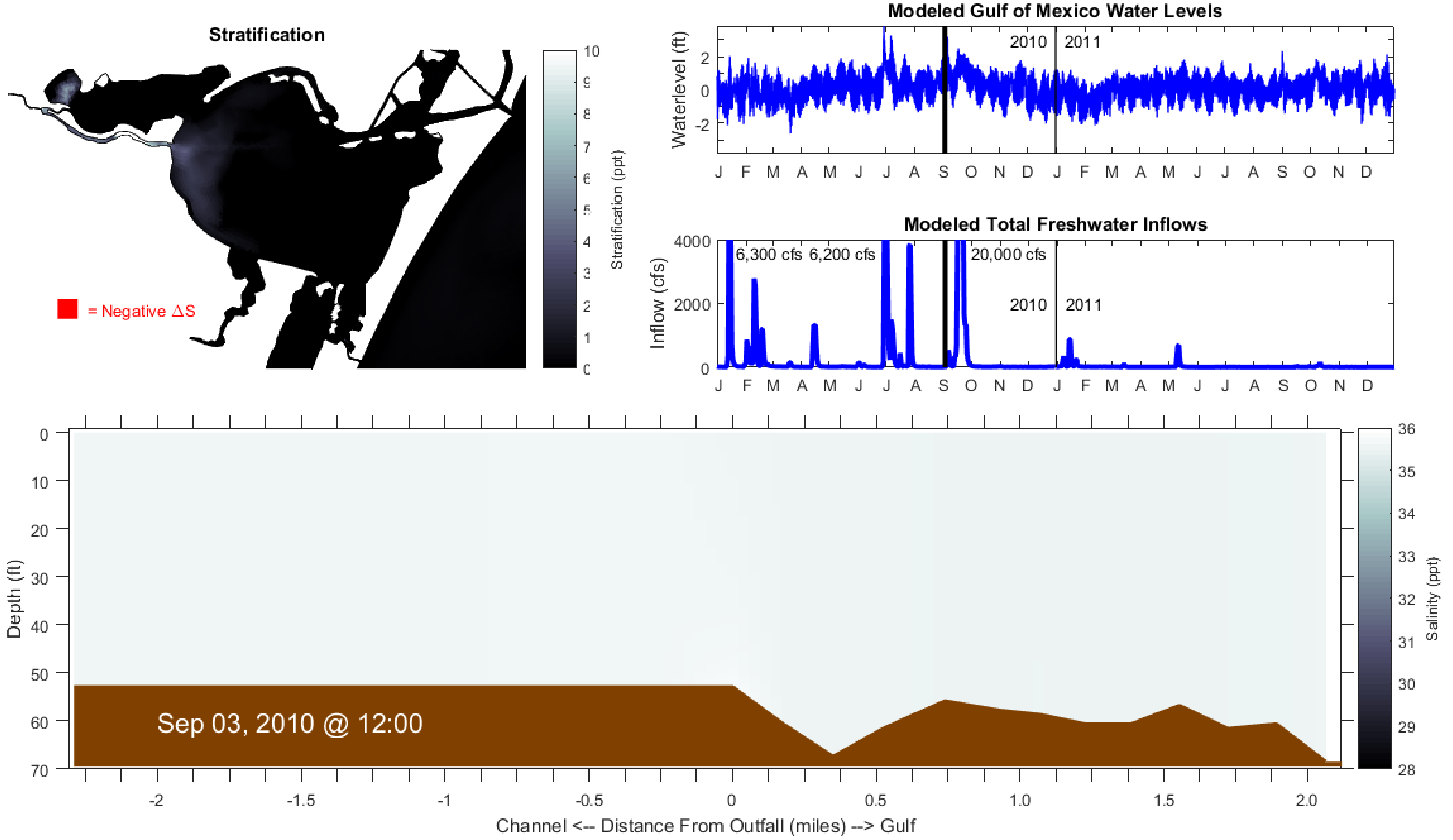


Figure 25 – Model results including the Harbor Island discharge for September 3, 2010, prior to the large freshwater inflow event.

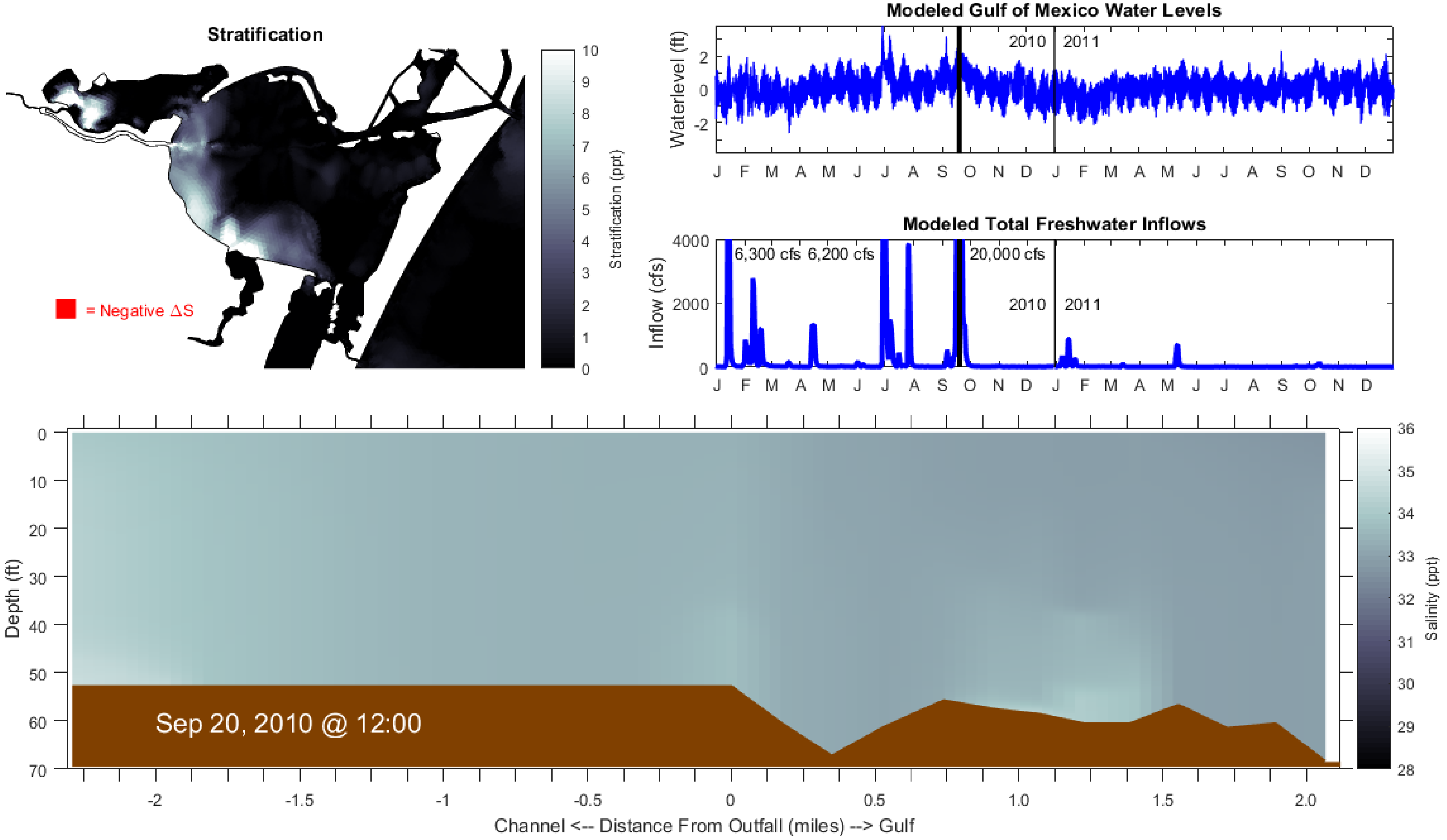


Figure 26 – Model results including the Harbor Island discharge for September 20, 2010, during the large freshwater inflow event.

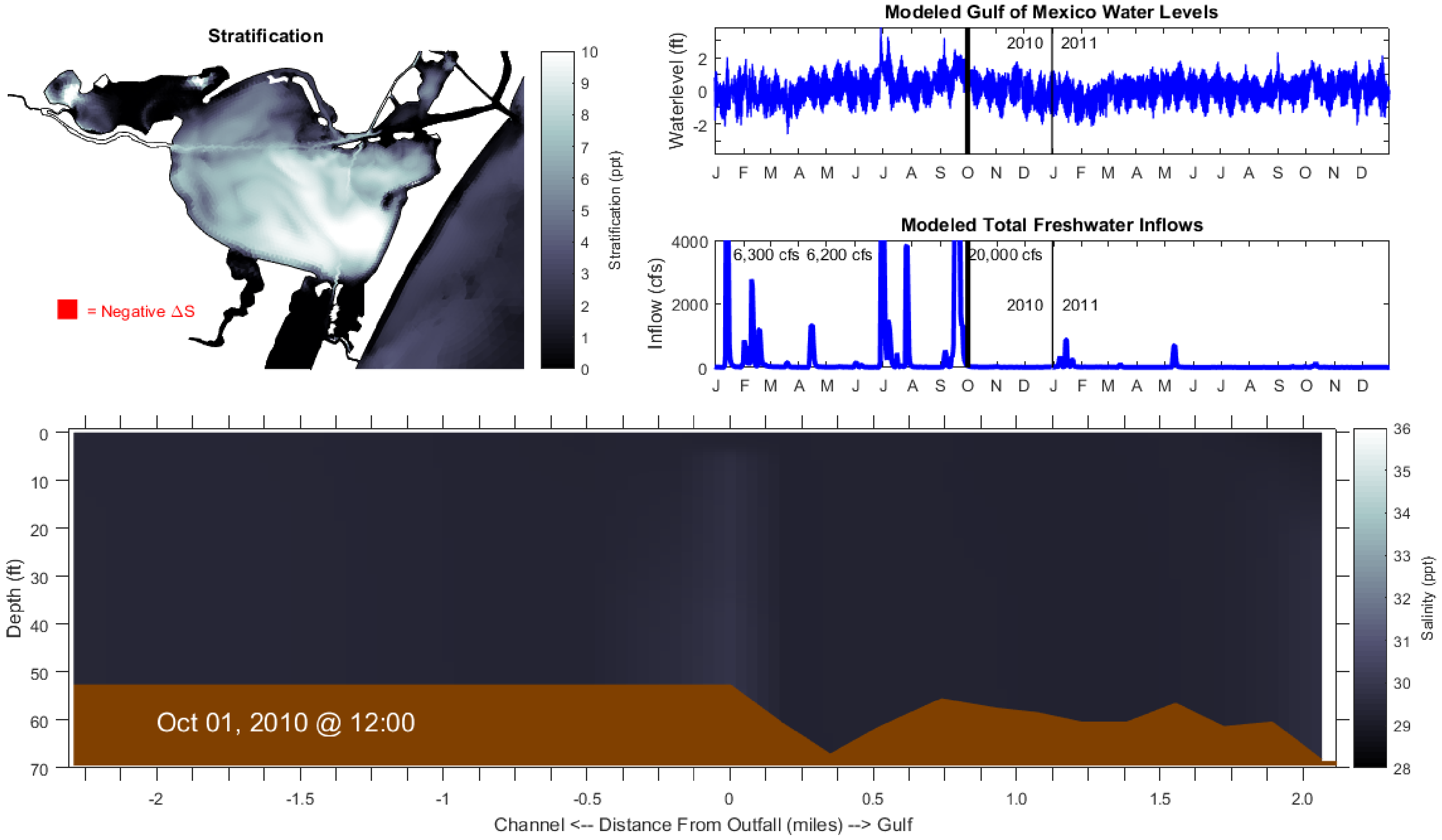


Figure 27 – Model results including the Harbor Island discharge for October 1, 2010, just after the large freshwater inflow event.

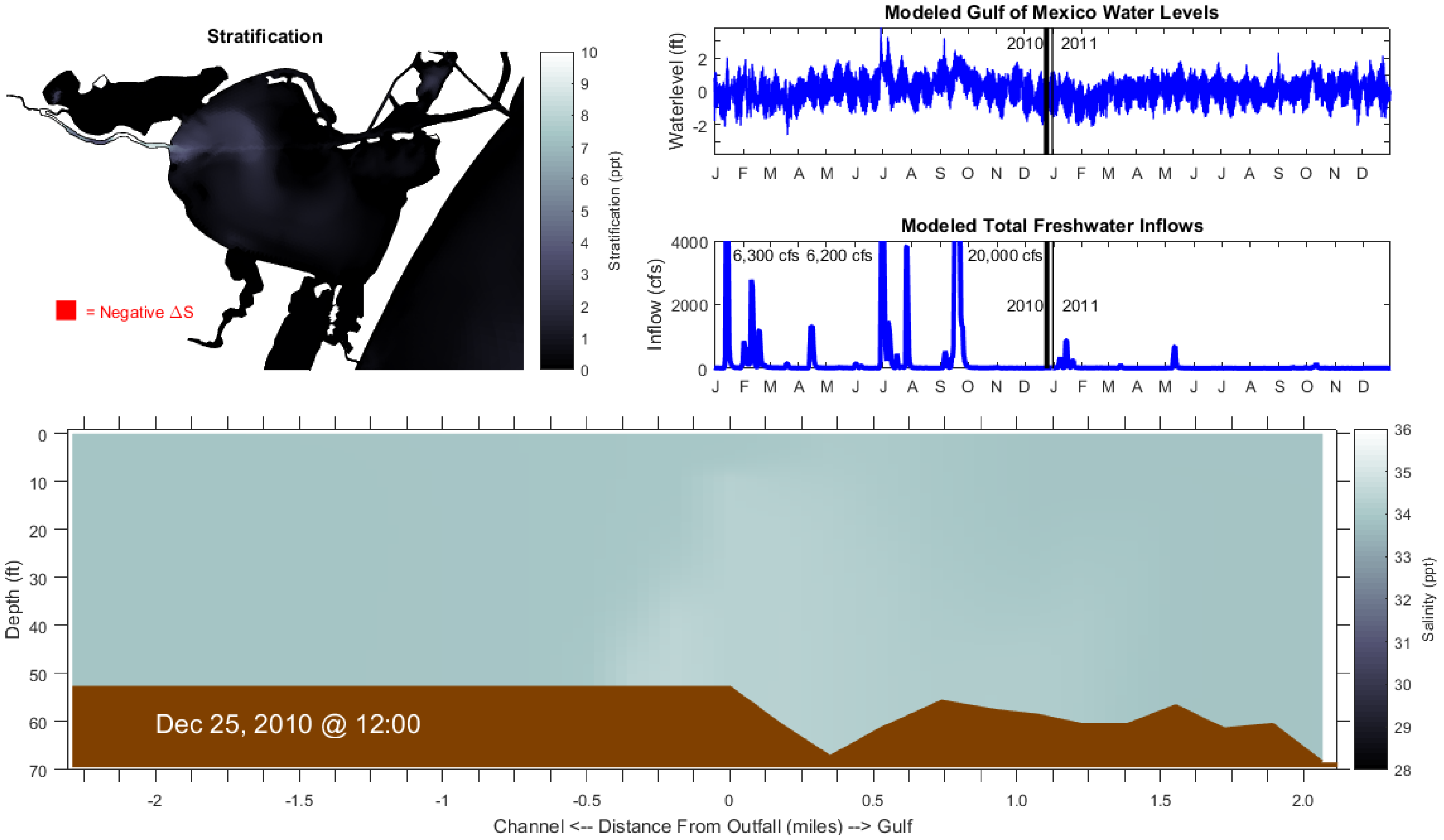


Figure 28 – Model results including the Harbor Island discharge for December 25, 2010, after nearly 3-months of low inflows following the large inflow event in September

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Figure 27 shows computed salinities on October 1, 2010 just after the end of the large inflow event. Within the Corpus Christi ship channel, salinities are now uniformly well mixed to 28-29 ppt, yet higher discharges around the Harbor Island discharge are evident and higher salinity water along the channel bottom is evident 1.5 miles up-channel from the discharge. Stratification is evident throughout much of Corpus Christi Bay, as the freshwater continues to mix with the saltier bay water. Stratification is minimal at the Harbor Island discharge location, indicating that the location is minimally influenced by even larger freshwater inflow events. Its proximity to the Gulf and the resulting strong tidal forcing causes rapid water column mixing and destruction of salinity stratification that would result from large inflow events.

Figure 28 shows model results from December 25, 2010, nearly three dry months after the large inflow event in September. Salinity values within the Corpus Christi Ship Channel have increased to 34 ppt, with some higher salinities located around the modeled discharge. During the three-month period since the large inflow event, circulation processes have returned nearly the entire bay to a vertically well-mixed state, with stratification only evident in the up-channel portion of the Corpus Christi ship channel.

In combination, Figure 25-Figure 28 demonstrate the impact of large inflows and tidal fluxes on mixing and circulation within the Corpus Christi Bay system. These results indicate that large inflow events will reduce system-wide salinity and mask salinity increases resulting from the desalination brine discharge. It is also evident, however, that prolonged periods with low inflows result in increases in salinities within the Corpus Christi ship channel. These increases, however, do not result solely from the desalination brine discharge, as similar increases are observed when the models include or exclude the simulation of the discharge.

Based on the modeling results presented herein, the proposed brine discharge from the Harbor Island desalination facility will result in an increase in ambient salinity of 0-1 ppt. The SUNTANS model indicates that the increase in ambient salinity (resulting from the Harbor Island desalination brine discharge) will not continuously increase over time in the vicinity of the discharge. The tidal forcing near the discharge location is sufficiently strong to result in near-constant water column mixing, which minimizes any increases in salinity resulting from the brine discharge. Similar bottom salinity increases of 0-1 ppt were determined to occur throughout the Corpus Christi Bay system as a result of both the Harbor Island and La Quinta Channel desalination brine discharges. LRE Water suspects, but did not calculate, that lower bottom salinity increases would occur if only the Harbor Island discharge were modeled.

Further Modeling Recommendations

The SUNTANS model presented herein is a well-developed model capable of determining the likely impact of the proposed desalination brine discharge at Harbor Island. LRE Water does not expect the SUNTANS model to produce significantly different results with regard to the proposed Harbor Island discharge if the numerical model grid were sufficiently refined enough to resolve the complex bathymetry in the vicinity of the discharge location.

Further model improvements would be necessary, however, to model brine discharges at other locations within the Corpus Christi Bay system, including the La Quinta Channel. Specifically, the model's triangular grid should be refined to better represent the true width of smaller channels within the system. The model grid would also need to be refined to better represent the island located immediately to the south of the proposed discharge within the La Quinta Channel.

In addition, LRE recommends review of the SUNTANS algorithms determining salinity and temperature within the water column. It appears that these algorithms may inappropriately retain heat energy during cooler months, and may produce artificially high-salinity values in shallow portions of the Corpus Christi Bay system.

References

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