A Hydrodynamic Model of the Nearshore and Offshore Waters Adjacent to the Proposed Tampa Bay Water Gulf Coast Desalination Facility

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FOREWORD

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ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

To meet required reductions in groundwater pumping, Tampa Bay Water has identified several alternative sources, including seawater desalination. A seawater desalination plant is currently being considered near the Anclote River on Florida's Gulf Coast. The major advantage of seawater desalination is that it provides a drought-proof water source. However, the desalination process produces a concentrate with a salinity that is approximately twice that of the source water. The discharge of this concentrate, therefore, will increase the salinity of the receiving waters. Depending upon the duration and magnitude, salinity changes can effect the distribution of organisms in the receiving waters. The task is to identify the least environmentally intrusive method of discharge (including how and where) of the concentrate.

Two locations were considered for discharge of the desalination concentrate, nearshore (into the Progress Energy discharge canal) and offshore (where depths are approximately 30 feet or more). A hydrodynamic model was developed to examine the relative effects of the discharge locations on salinity in the receiving waters. The objectives of this report are to

- describe the hydrodynamic model of the potential offshore and nearshore discharge areas, and
- to predict and compare the changes in salinity in these areas that would result from a series of potential concentrate volumes.

The predicted changes in salinity in the offshore area were consistently less than 2 ppt for both the 10 MGD and 25 MGD product water scenarios examined. For the nearshore area, the following desalination product water scenarios were examined: 10 MGD, 15 MGD, 18 MGD, 21 MGD, 25 MGD, and 35 MGD. The nearshore discharge into the power plant discharge also resulted in increases in salinity. The increase in salinity occurs in a nearshore area of relatively shallow water, primarily in the area immediately outside the discharge canal. The increase in salinity in this area ranges from less than 0.5 ppt to approximately 2 ppt, depending upon the volume of concentrate discharged. As expected, the magnitude of the change increases with the amount of product water produced, and therefore the amount of concentrate produced.

For the nearshore location, model predictions for both short-term (hour to hour) and long-term (over a 5-year period) time scales were examined. The increases in salinity varied within a year from month to month, depending upon river flow and, more importantly, the amount of cooling water used by the power plant. The greatest increases in salinity were found in March, in the area immediately outside the discharge canal. For March, the mean salinity change for each nearshore scenario is as follows:

- 10 MGD: 0.6 ppt
- 15 MGD: 0.8 ppt
- 18 MGD: 1.0 ppt
- 21 MGD: 1.1 ppt
- 25 MGD: 1.3 ppt
- 35 MGD: 1.7 ppt

During the months of May, June, July, August, September, and October, the predicted change in salinity in the near-discharge area averaged less than 1 ppt for all scenarios. Model predictions suggest that no increasing trends in salinity (over a 5-year period) are to be expected.

An ecological characterization of aquatic (inshore and offshore) habitats of the Anclote River estuary and the Anclote Anchorage has been completed. This document presents details of the project area including climate and meteorology, wind patterns, hydrology and hydrodynamics, water quality, major habitat types, and biota. Historical data show that salinity in the offshore area, as expected, is relatively constant at 35-36 ppt. In the Anclote Anchorage area, the salinity is typically lower and more variable, ranging from 23 to 38 ppt during 2000-2001. Critical habitats in the offshore area include hard and soft bottoms. Hard bottom habitats contain sponges, clams, and corals. Seagrass beds represent critical habitat in the nearshore area.

A review of the spatial and temporal variation of salinity within estuarine and offshore environments has been completed, providing information regarding the tolerance of the vegetation, invertebrates, fish, and marine mammals commonly found in the Anclote Anchorage and offshore areas to withstand changes in salinity. Organisms most likely found in the offshore areas require relatively higher, more constant salinity waters. Organisms found in the nearshore area typically tolerate a wider range of salinity. In particular, turtle grass, the predominant seagrass found in the Anclote Anchorage, is typically found in waters that range in salinity from 20-40 ppt, and is typically limited by lower salinities. Other important biota and their associated salinity tolerances include spotted seatrout (5-35 ppt), snook (0-35 ppt), oysters (2-40 ppt), corals (26-44 ppt), and manatees (0-35 ppt).

The predicted changes in salinity in both the offshore and nearshore waters resulting from the discharge of the desalination concentrate have been compared to the salinity tolerances for the biota exposed to the expected salinity changes. This comparison shows that the expected changes in salinity will not be of sufficient magnitude nor duration as to cause impacts to the biota of the receiving waters.

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1.0 Introduction

The West Coast Regional Water Supply Authority, the predecessor to Tampa Bay Water, adopted a Master Water Plan in 1995. The Plan was developed in response to rapid growth in the Tampa Bay area, and the concomitant increase in demand for potable water. The Plan includes replacing a portion of the water currently obtained from active groundwater well fields with water from other sources, and provides for additional water needs that may occur through 2014.

The Northern Tampa Bay New Water Supply and Groundwater Withdrawal Reduction Agreement between Tampa Bay Waters member governments and the Southwest Florida Water Management District (SWFWMD) was approved in 1998. The Agreement provides for SWFWMD funding (up to $183 million) for development of new alternative water supplies for the region and pumpage reduction in eleven well fields in Northern Tampa Bay (Pasco and northern Hillsborough counties). The Agreement specified a reduction in pumpage from well fields in Northern Tampa Bay from a permitted 158 million gallons per day (MGD) to 121 MGD by 2003 and to 90 MGD by 2008.

The Agreement required that Tampa Bay Water submit a New Water Plan to the Southwest Florida Water Management District by mid-1998. The New Water Plan contained water supply projects that must be permitted, constructed, and operational by the end of 2008 for supply of 85 MGD. Seawater desalination was proposed as part of the 85 MGD of new production required.

A desalination facility was recently completed on the site of the Tampa Electric Company's Big Bend Power Station, in southern Hillsborough County. This facility will initially provide 25 MGD of potable water, with possible expansion to 35 MGD. Tampa Bay Water has completed a feasibility study for a second seawater desalination facility. This included identification of potential sites in Pasco and Pinellas counties. The feasibility study examined each potential site for possible environmental impact, site limitations, economic viability, and permitting potential. The study also compared the option of co-locating a desalination plant with a facility that already has a permit for surface water discharge with the option of creating a stand-alone desalination plant. The site selected was the Anclote Power Station, near the mouth of the Anclote River along the county line between Pinellas and Pasco counties.

Tampa Bay Water is currently considering alternatives for design of a Gulf Coast Desalination facility in the Anclote Anchorage area of Southwest Florida. These alternatives include consideration of concentrate discharge at a nearshore location (the Anclote Anchorage) and an offshore location in the Gulf of Mexico. The discharge of concentrate from the proposed facility may influence future hydrodynamic conditions in the vicinity of the discharge. Therefore, Tampa Bay Water funded the development and execution of a hydrodynamic model to evaluate simulated discharge results in support of the planning and permitting process for the proposed Gulf Coast Desalination Facility. This document describes the hydrodynamic model and the results of predictive model scenarios for various discharge locations and product water quantities requested by PB Water and Tampa Bay Water engineers.

1.1 Objectives

The purpose of this project was to provide a tool to predict the hydrodynamic conditions that are expected to occur as the result of various design and siting options for the Gulf Coast Desalination Facility. The results of this study will be applied to the informed decision-making process regarding concentrate discharge siting alternatives at various flow rates. The specific objectives of this study were:

- to develop a calibrated hydrodynamic model suitable for use in support of the discharge siting selection process and the permitting process, and

- to utilize the hydrodynamic model to predict the relative changes in the hydrodynamic conditions that could result from the siting and discharge alternatives.

1.2 Approach

The method employed for completion of the above objectives is described in the following, and summarized in Figure 1.1. After selection of the most appropriate model, a list of data types necessary for model development was compiled. A survey of available data sources was then performed. A monitoring plan for the Anclote Anchorage was developed and implemented to provide additional data needed for the model. A large-grid (10 km x 10 km grid cells), coarse spatial resolution model was then developed for the west coast of Florida, from the mouth of Tampa Bay to Homosassa Bay, to provide input to the smaller-grid (100 m x 100 m grid cells), higher spatial resolution models of the Anclote Anchorage and an offshore discharge area. The large-grid model was run using observed conditions as forcing functions, with output saved for use as input data to the small-grid model. The small-grid model in the Anchorage was then calibrated to observed conditions using iterative runs until all calibration criteria were satisfied. Having satisfied the calibration criteria, the small-grid models for the Anchorage and offshore discharge site were set up and run for baseline and various product water quantity scenarios. Finally, output from the model runs were evaluated with respect to the potential effects on salinity and circulation due to various discharge location and product water quantity scenarios.

1.3 Study Area Setting

The study area is located on the west central Gulf coast of Florida (Figure 1.2) and includes the lower Anclote River, the Anclote Anchorage, and adjacent waters of the Gulf of Mexico. The lower Anclote River flows past the City of Tarpon Springs and enters the Anclote Anchorage from a southeasterly direction. The desalination facility may be co-located with the Anclote Power Station (Figure 1.3).

The tidally affected portion of the Anclote River extends about 21 kilometers upstream from the river mouth (Fernandez, 1990). The width of the tidal Anclote River is highly variable - about 550 meters at the mouth, narrowing to about 75 meters at Alternate U.S.

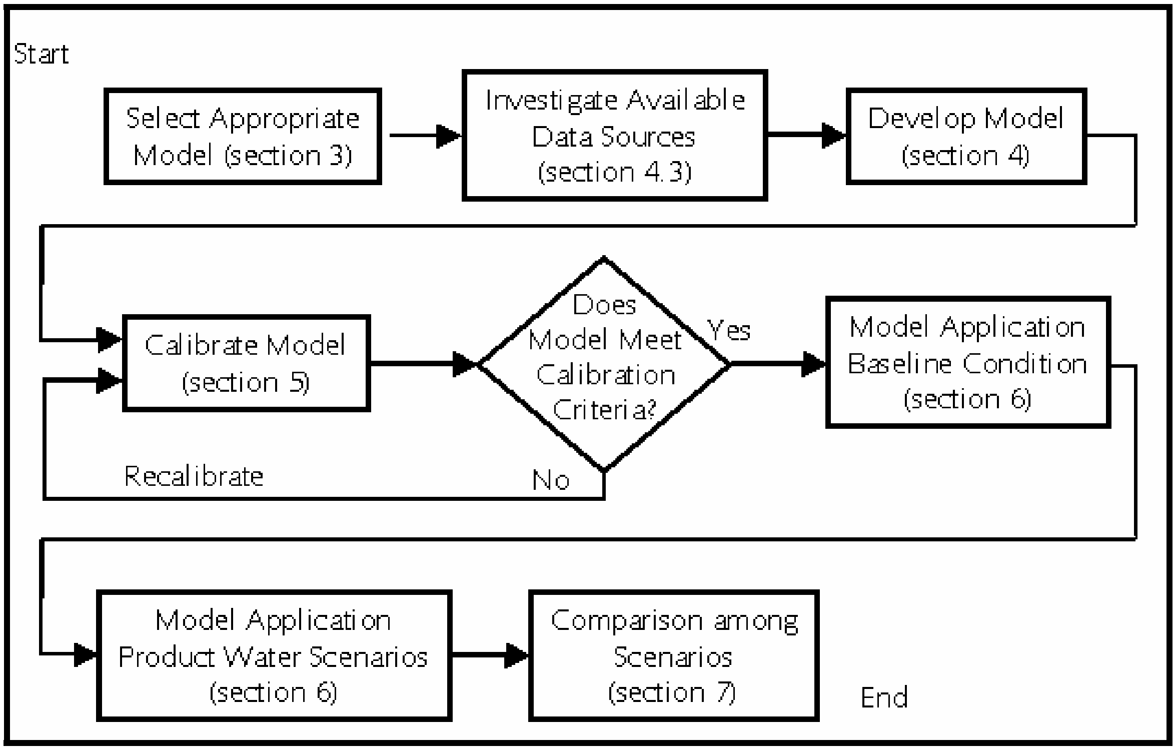

Figure 1.1. Conceptual figure presenting the overall approach (including sections of this report).

19 in Tarpon Springs, increasing to about 520 meters between Alternate 19 and U.S. 19, narrowing to about 120 meters at U.S. 19, and widening again to about 915 meters (an area that includes Salt Lake) upstream from U.S. 19. The wider sections contain extensive salt marshes and may act to delay and attenuate the effects of both incoming tides and outgoing freshwater runoff (Fernandez, 1990).

The Anclote Anchorage is an area of protected estuarine and marine water that lies west of the river mouth, between Anclote Key and the mainland (Figure 1.3). The Anchorage is relatively shallow, particularly along its eastern side where water depths typically range from 0 to 1 meter at mean lower low water (MLLW). Depths are greater in the central portion of the Anchorage, ranging between 1 and 4 meters at MLLW. Depths greater than 4 meters occur in a small area, within the narrow channel immediately north of Anclote Key that connects the Anchorage to the Gulf of Mexico. St. Joseph's Sound lies to the south of the project area and is a portion of the Pinellas County Aquatic Preserve. Open shelf waters of the Gulf of Mexico lie to the west and north.

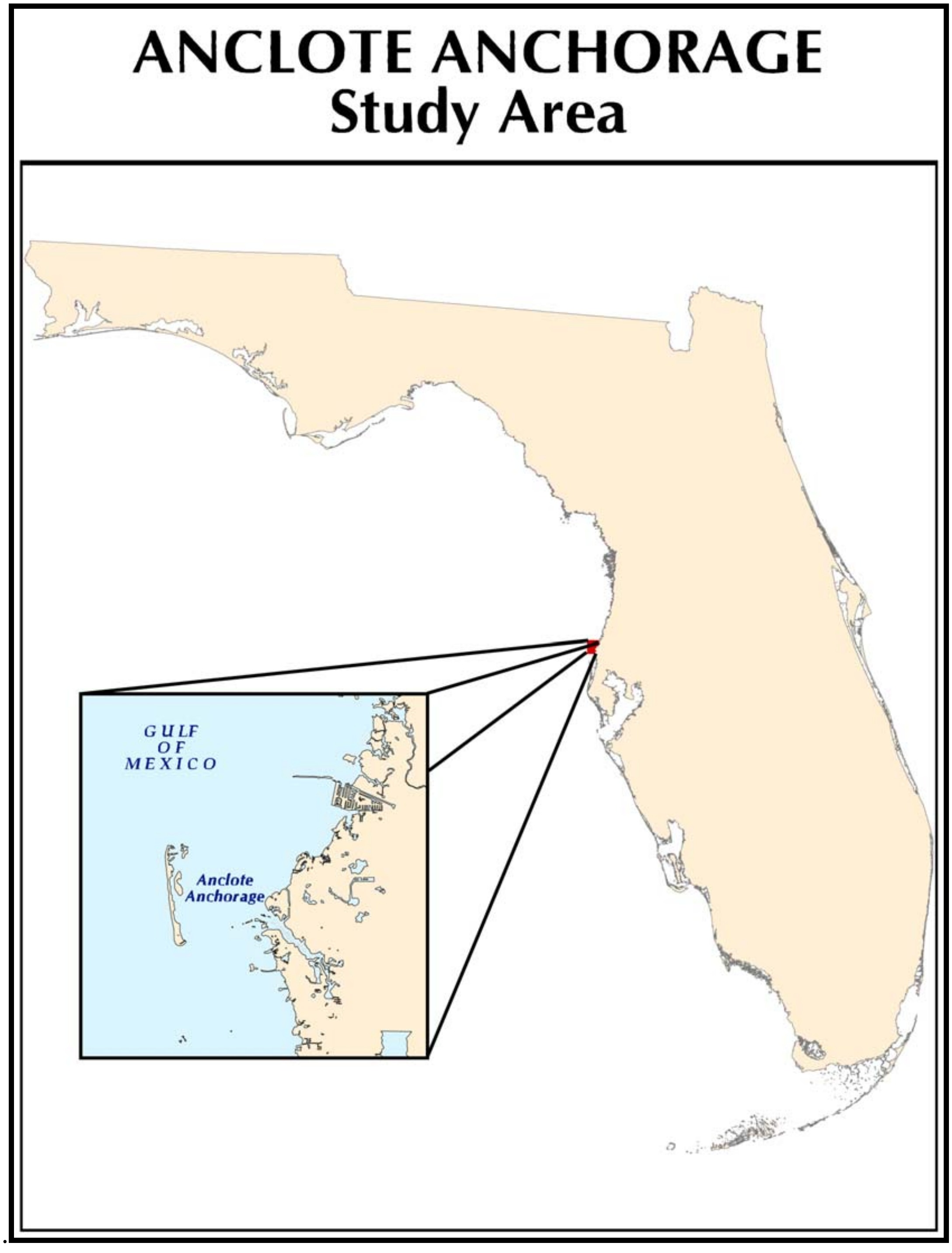

Figure 1.2. Map showing the location of the Anclote Anchorage area on the west coast of Florida.

Figure 1.3. Map of the Anclote Anchorage.

The coastal area to the north of Anclote Key is known as the "Springs Coast" (Wolfe, 1990), a marsh-dominated complex of spring-fed rivers and coastal estuaries that extends northward to the Waccassassa River in Florida's Big Bend region (Wolfe, 1990). The seafloor west of the Springs Coast has a very gentle slope, inhibiting the propagation of large waves and producing an extremely low-energy shoreline (Hine and Belknap, 1986). This low-energy estuarine and marine environment is conducive to the development of extensive shoreline marshes and nearshore seagrass meadows.

The Anclote River originates in south-central Pasco County and flows to the southwest, crossing a portion of Pinellas County before discharging into the Anclote Anchorage. As currently defined by the U.S. Geological Survey (USGS), the Anclote River watershed includes approximately 290 square kilometers (Fernandez, 1990). Under pre-development conditions the watershed included a subterranean connection to Lake Tarpon that linked to Salt Lake via a sinkhole located on the western side of Lake Tarpon. The sinkhole has been sealed off, however, to prevent brackish water in the lower Anclote River from entering Lake Tarpon.

The Anclote River watershed lies on the Tampa Plain, a physiographic unit within Florida's Ocala Uplift District. The Tampa Plain, characterized by lowland karst features underlain by the Tampa Limestone formation, covers a large portion of western Hillsborough, northern Pinellas and western Pasco counties. Pine flatwoods dominate the inland portions of the plain, with relict dune systems and ancient shoreline features present near the coast (Wolfe and Drew, 1990).

The karst topography of the area is marked by sinkholes that have formed over thousands of years as the underlying limestone has been dissolved by rainfall and stormwater runoff. Sinkhole development is still occurring in the region, as fractures and underground solution caverns continue to form in the limestone bedrock. Many of these sinkholes penetrate the water table and fill with water, forming a direct connection between the land surface and the underlying aquifer system. Many of the isolated wetlands and cypress domes in the region are also karst features, which act to retard and store stormwater runoff prior to its infiltration to the underlying groundwater system.

The ancient shorelines and dune systems in the region take the form of sandy terraces and scarps that run roughly parallel to the existing coastline. Crossing these features, the Anclote River basin rises from sea level at the river's mouth to eight meters above mean sea level (MSL) at the Pamlico Terrace, 13 meters above MSL at the Talbot Terrace, and 21 meters above MSL at the Penholoway Terrace (PBS&J, 1999). Land surface elevation is about 24 meters above MSL in the headwaters region of the basin (PBS&J, 1999).

The Anclote River mouth and Anclote Anchorage lie in a transition zone. A sand-rich coastline dominated by beaches and barrier islands extends southward, and a sand-starved, low-energy coastline of the Springs Coast, which is dominated by marshes and coastal hammocks, extends to the north. Until recently Anclote Key was the northernmost of the west-central Florida barrier islands, marking the transition point between the beach-dominated and marsh-dominated coastal zones (Hine and Belknap, 1986). Sand on the Gulf bottom is continuing to move northward in response to prevailing longshore currents, however, and a new barrier island has recently formed immediately north of the key (FDEP, 1998).

1.3.1 Hydrodynamic Setting

Large-scale circulation features in the deeper Gulf of Mexico are linked to the overall circulation pattern of the North Atlantic, and evolve over monthly time scales. The circulation along the eastern Gulf of Mexico continental slope and west Florida shelf is affected in turn by that in the main Gulf of Mexico, with changes in circulation occurring at monthly time scales or less. Also affecting flows along the west Florida shelf are tides, winds, and density differences. Near the coast, the affects of the circulation of the deeper Gulf of Mexico are not felt as strongly as along the outer and mid-shelf. Wind- and tidal-driven circulations serve as the primary forcing mechanisms for transport near the coast, along with density differences arising from freshwater inflows.

1.3.1.1 Gulf of Mexico

Gulf of Mexico circulation patterns are dominated by the Loop Current and its related eddy fields. The Loop Current is part of the western boundary current of the North Atlantic Ocean. The Loop Current transports relatively warm water from the South Atlantic Ocean and the Caribbean Sea into the Gulf of Mexico through the Yucatan Straits. The Loop Current flows into the eastern Gulf of Mexico, and exits the Gulf of Mexico through the Florida Straits. Over a typical period of six to thirteen months, the Loop Current extends northward into the central Gulf of Mexico, sometimes as far as the continental slope and outer shelf south of the Mississippi River delta (Schmitz, 2002), then flows eastward and southward to the Florida Straits. The "loop" of warm water carried into the Gulf of Mexico eventually "pinches off" from the main Loop Current, creating a large clockwise circulating (anti-cyclonic) eddy. When this happens, the main Loop Current moves directly from the Yucatan Straits to the Florida Straits, and out along the eastern continental slope of the U.S., where it becomes the Gulf Stream. Figure 1.4 shows a typical evolution cycle of a Loop Current incursion into the Gulf of Mexico, with associated sea surface height and current velocities as derived from satellite altimetry.

Interactions of the Loop Current with the eastern Gulf of Mexico occur primarily when the current is extended northward into the Gulf of Mexico. During these times, the Loop Current flows southward along the continental slope and outer shelf. The slope and outer shelf are about 200 km west of the west coast of central Florida. The interaction of the Loop Current with the slope and outer shelf may result in the creation of counter-clockwise circulating eddies. The effects of the Loop Current farther inshore are diminished, and the most inshore areas are typically not affected at all. Modeling studies have suggested that inshore of the 50-m isobath (the mid-shelf region) winds play the dominant role in circulation forcing (Yang and Weisberg, 1999). Drift studies at the mid-shelf region suggest a seasonal signal in surface circulation (Tolbert and Salsman, 1964; Williams et al., 1977) distinct from Loop Current cycles as well.

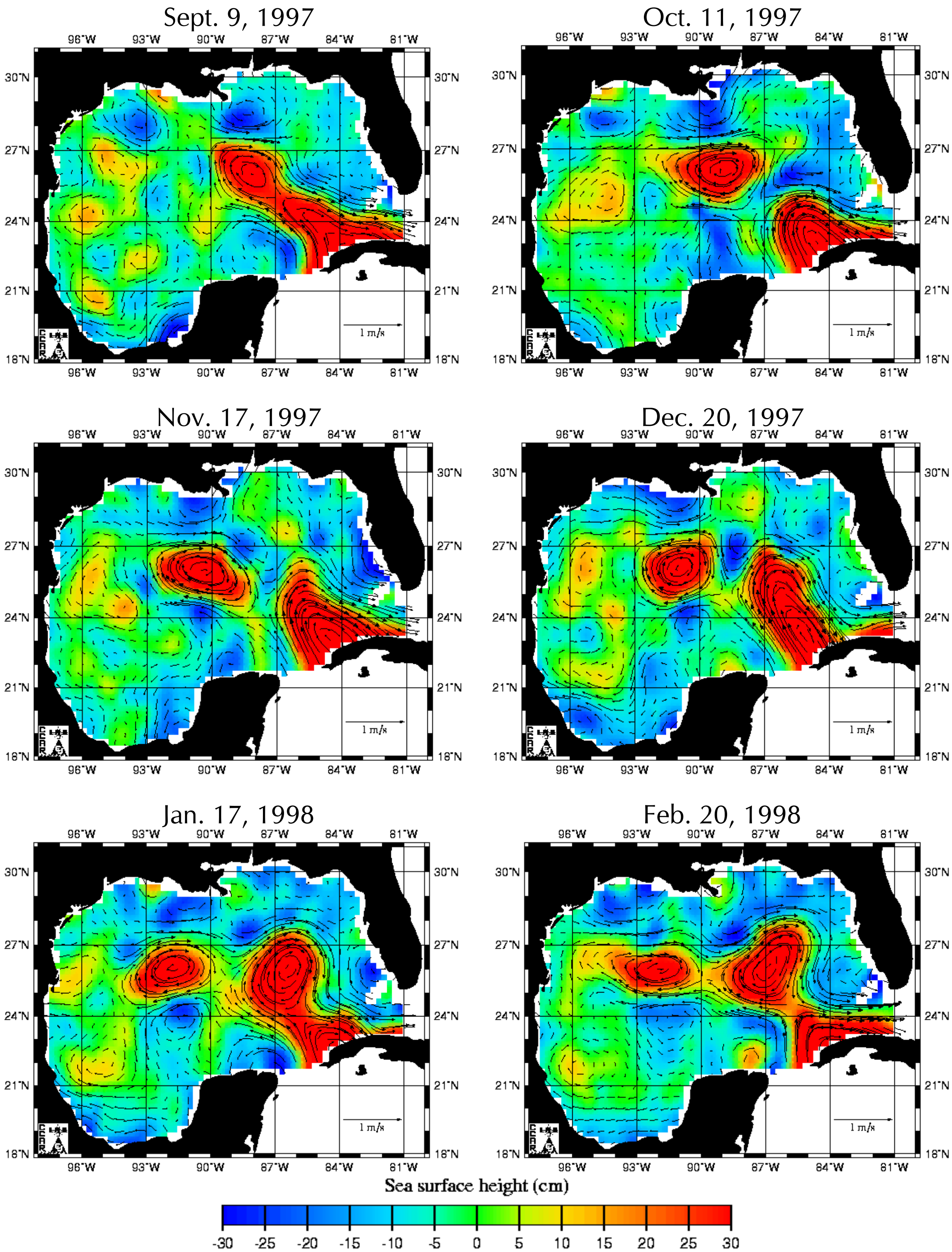

Figure 1.4. Sea surface height and current velocity showing the evolution of the Loop Current including separation of two anti-cyclonic Loop Current eddies in the Gulf of Mexico. Developed by Colorado Center for Astrodynamics Research (CCAR) from TOPEX and ERS-2 altimeter data.

1.3.1.2 West Florida Shelf

Circulation on the west Florida shelf is driven by winds, density gradients, tides, and interactions with the Loop Current. The Loop Current is not typically a primary forcing function inshore of the outer shelf, although intrusion may occur in the northern portion of the west Florida shelf (Gilbes et al., 1996). From the mid-shelf (50-m isobath) to the coast, a comparison of model results to measured data suggests that wind is the dominant forcing mechanism for circulation (Yang and Weisberg, 1999). Winds from the northeast in winter (October-March) typically result in southeastward flow along the coast from the Big Bend region to south of Tampa Bay, while winds from the southeast in summer (April-September) result in northwestward flow along the coast.

Offshore of the 50-m isobath, model studies suggest that horizontal density differences may also be important determinants of circulation (He and Weisberg, 2002a). These density differences may result from differential solar heating effects, with quicker heating of shallow water than of deeper water. Horizontal density differences may also result from transport of fresher water, as from the Mississippi River, along the outer shelf (He and Weisberg, 2002a).

Tidal circulation on the west Florida shelf results in cross-shelf movement of water parcels in an elliptical pattern, with no net displacement over a tidal cycle (Weisberg et al., 1996). Simulations of tidal circulation (He and Weisberg, 2002b) suggest that residual tidal circulation is small in the region of the Anclote Anchorage, with residual circulation directed to the southwest, north and south of the Anchorage. During summer, when winds are typically from the southeast, tidal levels are higher than during winter, when winds are typically from the northeast.

1.3.1.3 Anclote Anchorage

Wind and tidal action, in concert with density effects related to freshwater inflow, are the primary forcing mechanisms for circulation in the Anclote Anchorage. Predicted tidal ranges for 2002 vary according to location. For example, the difference between predicted highest and lowest tides at the north end of Anclote Key is 1.5 m, at the south end of the Key is 1.4 m, and at Tarpon Springs in the Anclote River is 1.4 m (Pentcheff, 2002). The mean diurnal tidal range, 0.8 m as measured at two nearby sites (Clearwater and Indian Rocks beaches), is approximately half the annual range. Observations of particle movement suggest that near the coast in the Anclote area, flooding tides transport water to the northeast, while ebbing tides transport water to the southwest (He and Weisberg, 2002b). Early studies of the Anclote area (Baird et al., 1972) support these observations.

Wind-induced circulation in the nearshore environment has been examined as part of a larger circulation study of the west Florida shelf (Yang and Weisberg, 1999). Model results suggest that winter (October-March) winds from the northeast result in southward flowing nearshore currents from Tampa Bay to the Big Bend area, while summer (April-September) winds from the southeast result in northward flowing nearshore currents along the entire west Florida coast. These results agree with observed transport off the coast of Clearwater.

Fresh water enters the Anchorage from the Anclote River, via discharge from the river mouth and through the Anclote Power Station discharge canal. Fresh water inflow to the coastal areas north of the Anchorage, from sources including the Pithlachascotee, Weeki Wachee, and Chassahowitzka rivers, may also be transported into the Anchorage. Transport of fresh water southward along the coast is dependent on wind-induced circulation, and is most likely when winds are from the north, as is typical during the winter. The main channel for the Anclote River extends into the Anchorage westward and then west-southwest in the direction of the southern end of Anclote Key. The Anclote Power Station canal discharges to the Anchorage north of the river mouth, in the direction of the northern end of the Key. Salinity near the mouth of the river is typically 1-3 ppt less than in the middle of the Anchorage, based on data collected by the SWFWMD in 2000 and 2001.

1.4 Desalination Facility Operation

The proposed Gulf Coast Desalination Facility will likely be operated in a manner similar to that of the Tampa Bay Desalination Facility. The Tampa Bay facility was recently completed on the site of the Tampa Electric Company's Big Bend Power Station, in southern Hillsborough County. The Big Bend facility currently utilizes approximately 1400 MGD of cooling water from the bay, of which 44 MGD is re-routed to the desalination facility after it leaves the Big Bend cooling area. After removing 25 MGD of fresh water, the remaining 19 MGD is returned to the discharge line closer to the discharge point (Figure 1.5). Mixing of the 19 MGD from the desalination operation with the almost 1400 MGD of cooling water results in salinity values approximately 1%-1.5% higher in the discharge than in the intake (Coastal Environmental/PBS&J, Inc., 1998; Ocean Modeling and Prediction Lab and PBS&J, Inc., 1998). Typical salinities in the Big Bend region of Tampa Bay range from 21-28 ppt, so that the increase in salinity in the discharge stream is likely to be about 0.2-0.3 ppt. The discharged water then mixes with the salt water in the bay, further reducing the salinity signal from the desalination facility.

After entering the Tampa Bay desalination plant, the source water goes through a series of filters to separate algae, other organic material and particles from the water. The treated source water then goes through reverse osmosis, a process that uses high pressure to force water through semi-permeable membranes, leaving the salt and other minerals behind in a seawater concentrate (Figure 1.6). Reverse osmosis has been successfully used in nearly 200 water and wastewater treatment plants throughout Florida (Tampa Bay Water website).

Twenty-five MGD of desalinated drinking water will be delivered to the Tampa Bay Water Regional Facilities Site from the Tampa Bay desalination facility. The water will be blended with drinking water from other sources before being delivered to Tampa Bay Water's member governments.

Tampa Bay Water has completed a feasibility study for a second seawater desalination facility. The study included identification of potential sites in Pasco and Pinellas counties, and examined each potential site for possible environmental impact, site limitations, economic viability, and permitting potential. The study also compared the

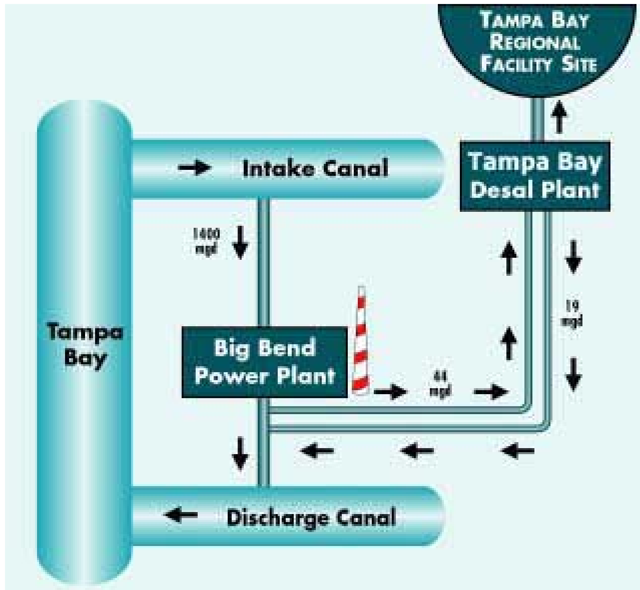

Figure 1.5. Overview of water flow at the Tampa Bay Desalination Plant. (Source: Tampa Bay Water).

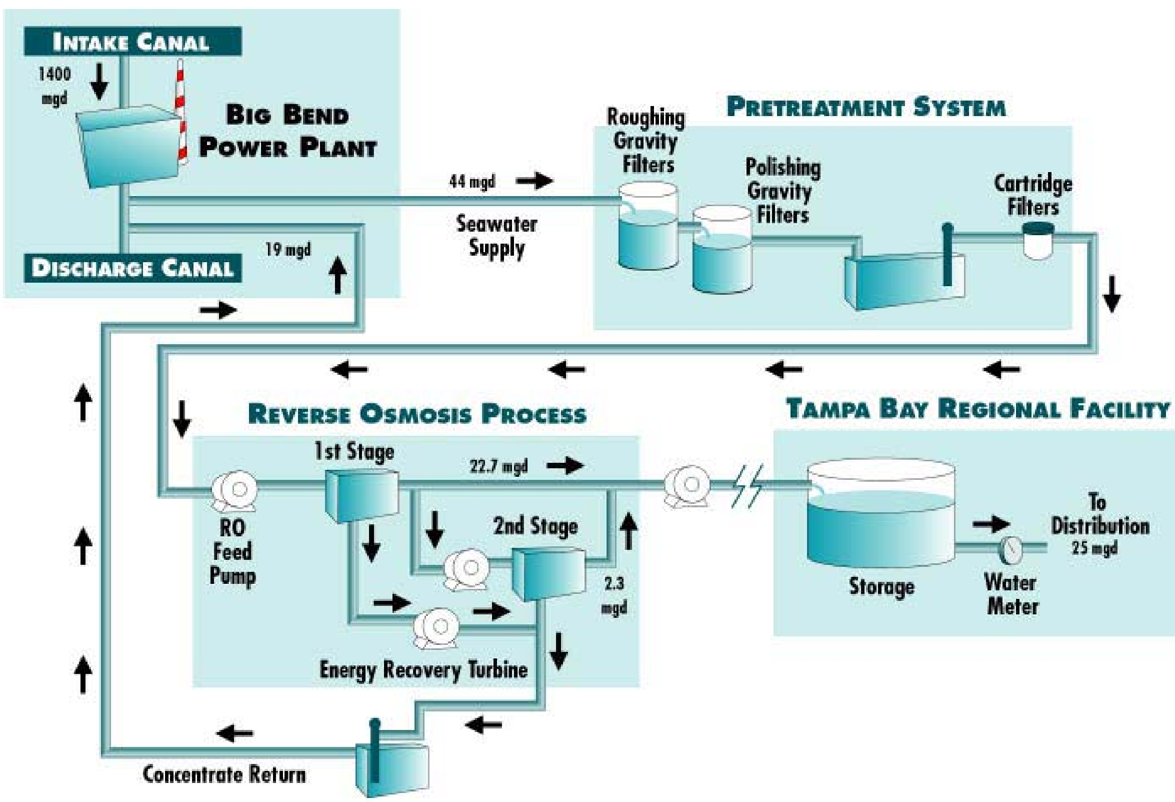

Figure 1.6. Schematic showing the steps involved in the desalination process at the Tampa Bay Desalination facility. (Source: Tampa Bay Water).

option of co-locating a desalination plant with a facility that already has a permit for surface water discharge with the option of creating a stand-alone desalination plant. The site selected was the Anclote Power Station, near the mouth of the Anclote River along the county line between Pinellas and Pasco counties.

The Anclote Power Station utilizes water from just upstream of the mouth of the Anclote River for cooling purposes. Based on operating data for 1997-2001, the facility intake volume ranges between 243 MGD (376 cfs) and 3556 MGD (5502 cfs), depending on the operating mode, with discharges of cooling water into the Anclote Anchorage. As with the Big Bend desalination facility, some portion of this cooling water flow, on the order of 50 MGD, will be re-routed to the desalination plant. After 25 MGD of freshwater is removed, the remaining water will exit the desalination facility with an elevated salinity. This desalination concentrate will re-enter the aquatic environment, although the final method and location of this discharge is not yet determined.

To aid in deciding on the most prudent means of concentrate discharge, some method must be used which can provide scientifically sound estimates of the expected salinity changes resulting from the concentrate discharge to the environment. The location and timing of any potential changes in salinity and/or circulation resulting from the concentrate discharge must be examined for possible effects on the living resources and circulation characteristics of the area.

These same concerns regarding salinity changes were considered when permitting the Big Bend desalination facility. A three-dimensional time-dependent hydrodynamic model of Tampa Bay was used to evaluate the potential effects of the discharged concentrate from the facility on salinity in the bay. The hydrodynamic model predicted salinity responses throughout the water column and across the bay over a two-year time period. The model results suggested only slight increases in salinity in a very localized area near the discharge (Vincent et al., 2000).

For the Gulf Coast Desalination study, a model of the Anclote Anchorage and offshore areas has been developed. This three-dimensional time-dependent model utilizes the same hydrodynamic principles used to predict salinity and circulation resulting from the desalination facility at Big Bend.

2.0 Hydrodynamic Conditions

As described above, hydrodynamic conditions in the Anclote Anchorage are the result of the interaction of the bathymetry, tides, meteorological conditions (winds, rainfall, temperature), and freshwater inflows, including those from the Anclote River via its mouth and via the Anclote Power Station discharge canal, and from the rivers north of the Anchorage. The following sections provide a description of the effects of each of the forcing functions on hydrodynamic conditions in the Anchorage, and the resulting hydrodynamics within the Anchorage.

2.1 Forcing Functions

Circulation in the Anclote Anchorage is driven by the bathymetry of the Anchorage, tides, meteorological conditions, and freshwater inflow to the Anchorage. The bathymetry of the Anchorage serves as a steering mechanism for tidal flows and other large-scale circulation mechanisms. Tidal movements result in diurnal changes in current directions, moving water into and out of the Anchorage on a regular basis. Meteorological conditions affect circulation via winds, temperature fluctuations, and precipitation events. Winds result in the movement of water through drag effects on the surface, which is translated via frictional effects deeper into the water column. Winds also contribute to changes in water surface elevation along the coast, as the wind may push water onshore or offshore depending on wind conditions. Contributing to density differences are temperature and salinity differences resulting from meteorological conditions and freshwater inflow to the Anchorage. Freshwater inflows to the Anchorage occur from the east through the mouth of the Anclote River and the mouth of the discharge canal, as well as from the north from the multiple river inflows along the coast. Each of these forcing functions and the effects on the hydrodynamics of the Anchorage is described in further detail below.

2.1.1 Bathymetry

The Anclote Anchorage is an area of protected estuarine and marine water that lies west of the river mouth, between Anclote Key and the mainland. The bathymetry of the Anchorage is relatively shallow, particularly along the eastern side of the Anchorage where water depths typically range from zero to 1 meter at mean lower low water (MLLW). Depths are greater in the central portion of the Anchorage, ranging between 1 and 4 meters at MLLW. Depths greater than 4 meters occur in a small area, within the narrow channel immediately north of Anclote Key that connects the Anchorage with the Gulf of Mexico (Figure 2.1). The Anclote River channel enters the Anchorage from the southeast, with the dredged channel turning to the southwest. The remnant of the old channel runs to the north and west, ending near the middle of the Anchorage. The Anclote Power Station discharge canal empties into the Anchorage near the middle of the Anchorage as well.

As expected given the bathymetry of the Anchorage, the primary exchange of water with the Gulf of Mexico shelf region is along the north-south axis of the Anchorage. The shallow areas along the eastern side of the Anchorage and along Anclote Key restrict water movement in the east-west direction, with the exception of the small channel between the northern end of Anclote Key and the sand bar to the north.

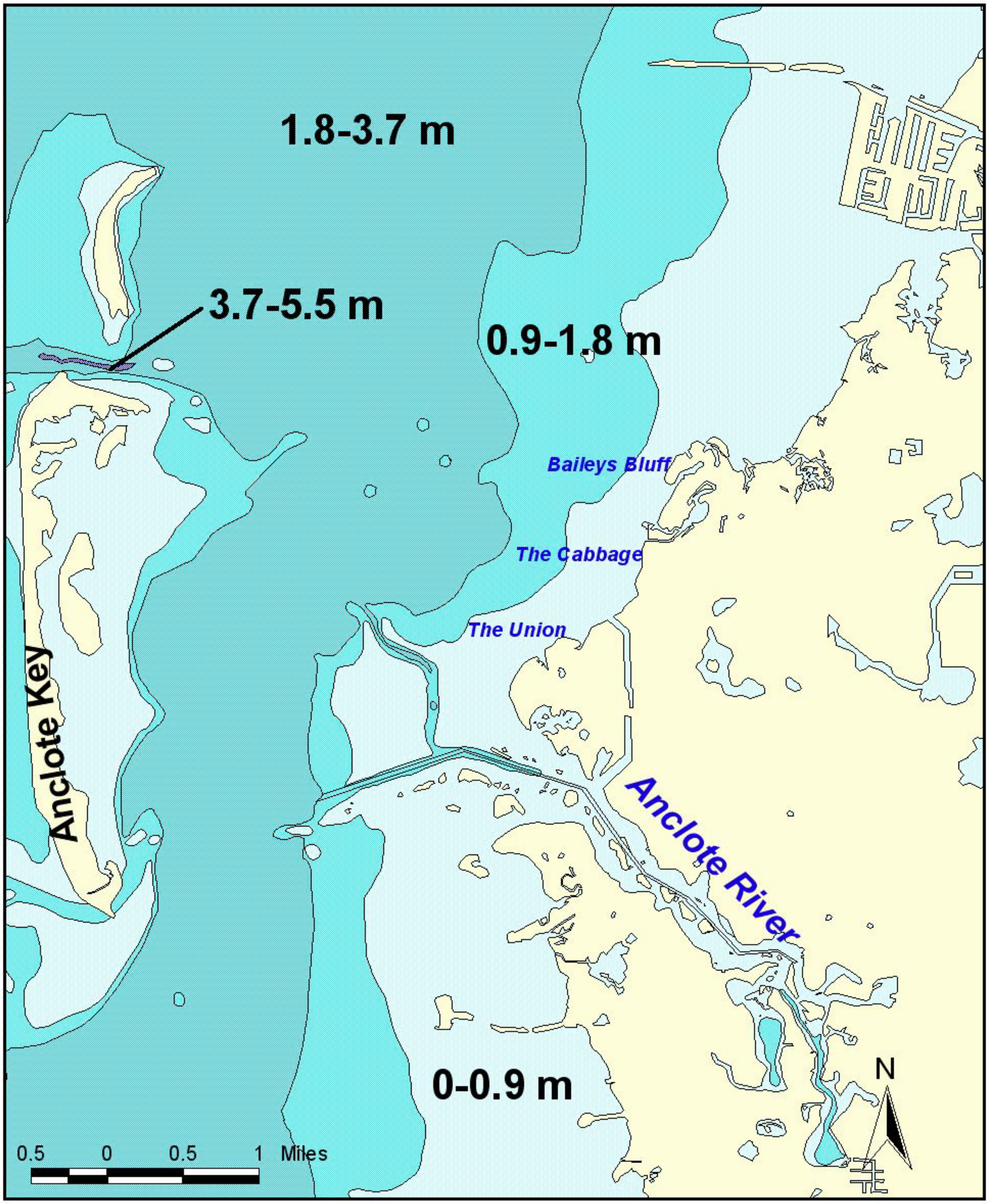

Figure 2.1. Bathymetry of the Anclote Anchorage, with reference to MLLW.

2.1.2 Tides

Tides in the Anclote Anchorage area are "mixed", with approximately equal "diurnal" (one low water and one high water per day) and "semidiurnal" (two low waters and two high waters per day) influences. As a result, two unequal low and two unequal high tides usually occur each day (Fernandez, 1990). An example of this type of tidal regime is shown in Figure 2.2. The tidal range in the area (i.e., the vertical difference between the lowest and highest tides on a given day) is low, usually less than one meter.

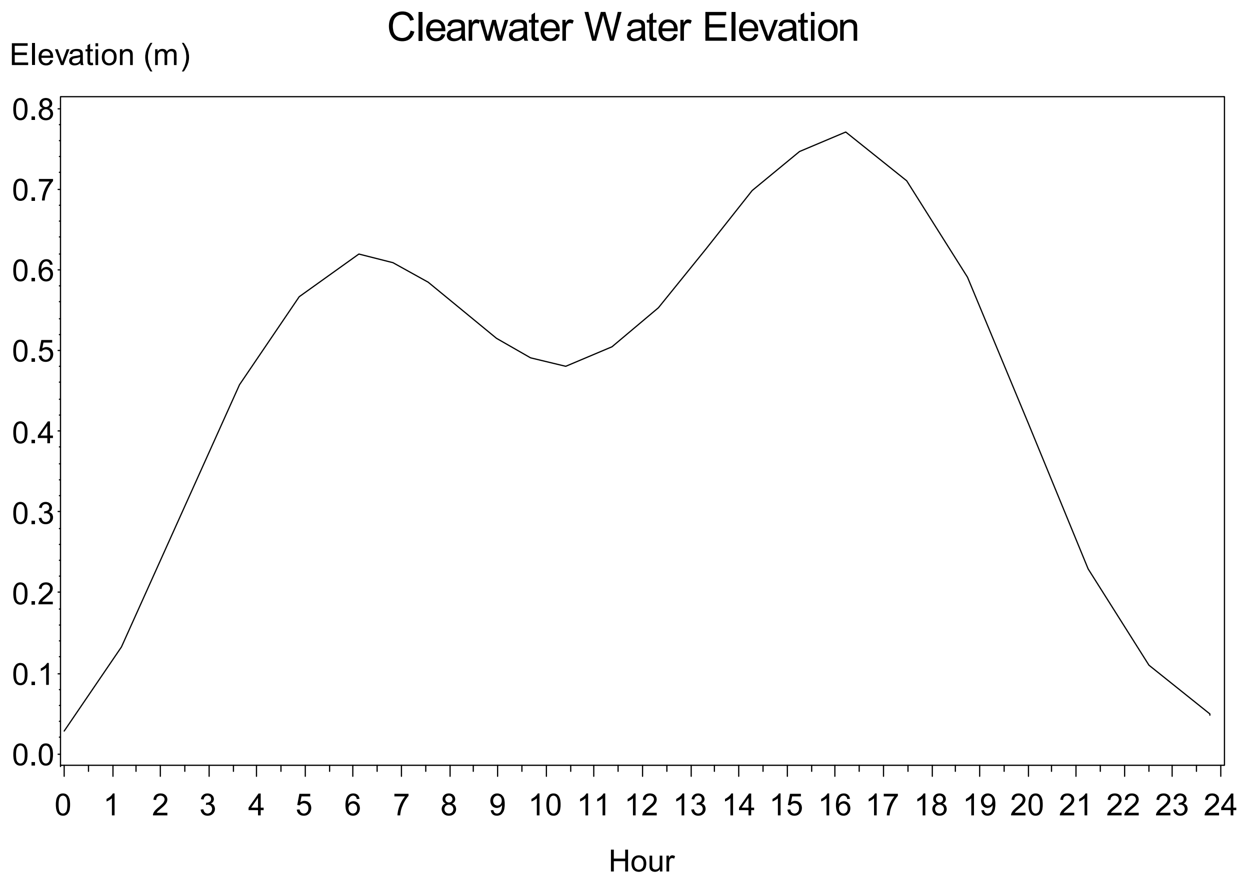

Figure 2.2. Illustration of a typical mixed semi-diurnal tidal signal.

2.1.3 Meteorological Conditions

The climate of the area is maritime temperate to sub-tropical, with relatively mild winters and humid summers. Rainfall in the area averages around 55 inches/year, with approximately 60% of this falling during the June-September period. Tropical storms and hurricanes affect the region, primarily during September and October, with associated high winds, storm surge, and heavy rainfall. Air temperatures rarely fall below 0°C during winter, and summer time temperatures may be 35-37°C.

2.1.3.1 Temperature

Summer air temperatures typically range between 21°C and 32°C, with an average temperature of approximately 27°C. Winter air temperatures generally range between 0°C and 24°C, with monthly averages between 13°C and 16°C. Occasional strong cold fronts, occurring approximately once per year, can cause air temperatures to fall below freezing for several hours, a factor that restricts the distribution and abundance of tropical plants and animals within the region. Water temperatures show a clear pattern of seasonal fluctuation (Frazer et al., 2001), with lowest surface values observed in the winter months (November through January) and highest surface values in late spring through fall (May through September).

Water temperature data were collected at ten sites in the Anclote Anchorage (Figure 2.3) during 2000-2001 as part of a SWFWMD study performed by the University of Florida (Frazer et al., 2001). The highest annual median temperatures in the Anclote Anchorage, 24.8°C and 24.7°C, were observed at stations ACLT2 and ACLT3, respectively, reflecting the discharge of cooling water from the Anclote Power Plant, which is located just inshore from station 2. The lowest annual median temperatures, 24.2°C and 24.0°C, were observed at stations ACLT5 and ACLT6, respectively, which are located on the western side of the Anchorage immediately east of Anclote Key.

The surface temperatures for the January 2000 through December 2001 period, as measured during Project COAST 2000, .are shown for the sampling area for each month in Figures 2.4 through 2.27. As can be seen from examining the surface temperatures in the Anchorage, the horizontal temperature distribution typically shows little variation in the Anchorage. Exceptions occur near the river mouth and near the mouth of the discharge canal, likely indicative of the influence of the freshwater inflow from the river and the elevated temperatures from the cooling water exiting the discharge canal.

Effects of Anclote Power Plant operations on temperature distributions in the Anclote Anchorage have been investigated by the Florida Power Corporation. Thermal effects observed in a continuous monitoring program conducted between May 18, 1990 and January 3, 1991 were summarized as follows (FPC, 1991):

> "The heat content contributed by the Anclote Power Plant evidenced substantial seasonal variations as the result of planned operational practices... During the warmest summer period, heat content was increased on average by only 2.6%. The largest temperature increases across the plant took place during the fall and winter months (October to January) when the heat content of the intake waters was increased by up to 25%. On a daily basis, two periods of maximum discharge were typically observed and were presumably associated with periods of peak demand (0600-0800 hours and 1500-1800 hours). Diurnal cycles of temperature at the point of discharge produced maxima in later afternoon-early evening. These cyclical processes, coupled with tidal controls on the area and orientation of the plume, produce extremely variable thermal regimes within the study area."

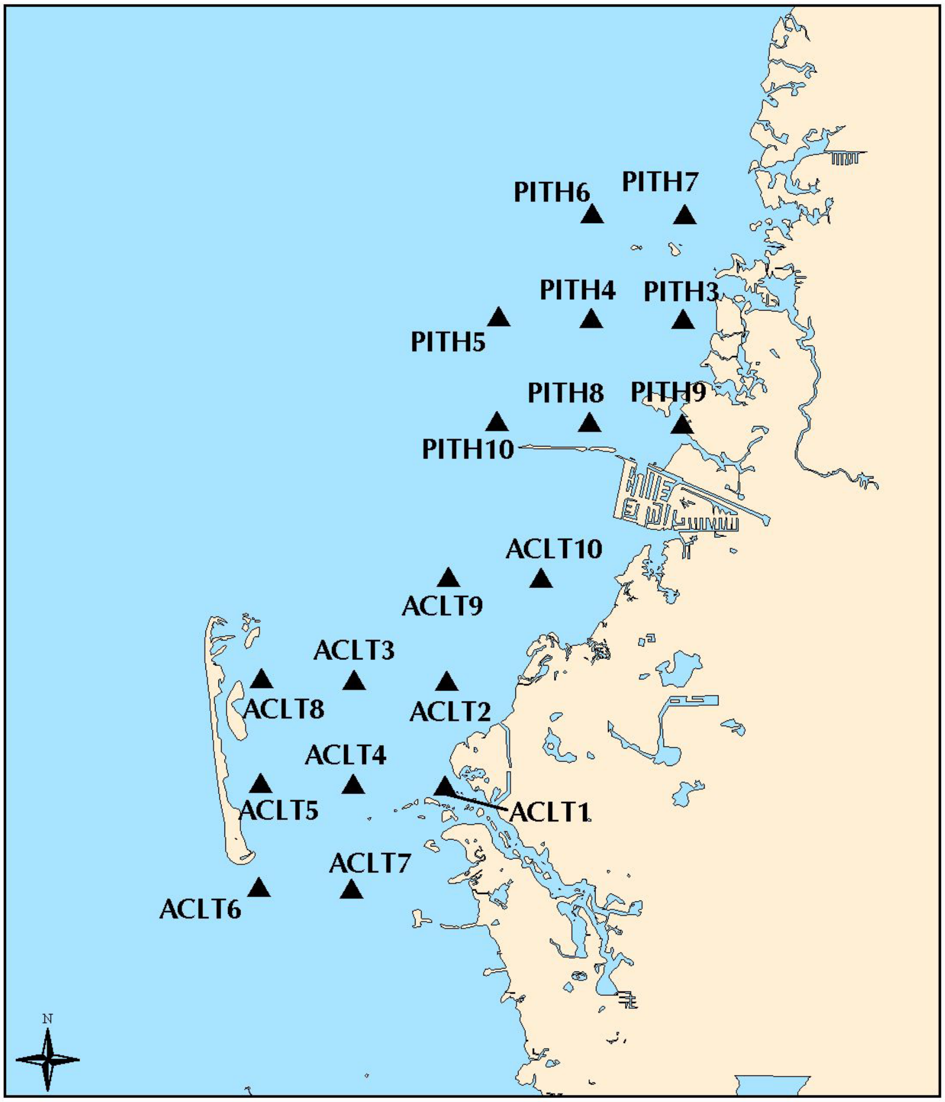

Figure 2.3. Project COAST 2000 water quality sampling sites (after Frazer et al., 2001).

2.1.3.2 Wind

Wind patterns are one of the primary forcing functions for circulation in the Anclote Anchorage. Wind patterns show variation over various spatial and temporal scales. Near the coast, the wind and tides serve as the primary forcing mechanisms for transport, along with density differences arising from freshwater inflow. Data from the Tarpon Springs meteorological site, monitored by the Coastal Ocean Monitoring and Prediction System (COMPS) and obtained from the University of South Florida Marine Science Department, were analyzed to provide an understanding of the local wind patterns affecting the Anchorage. The data analyzed cover the period May 2001-April 2002.

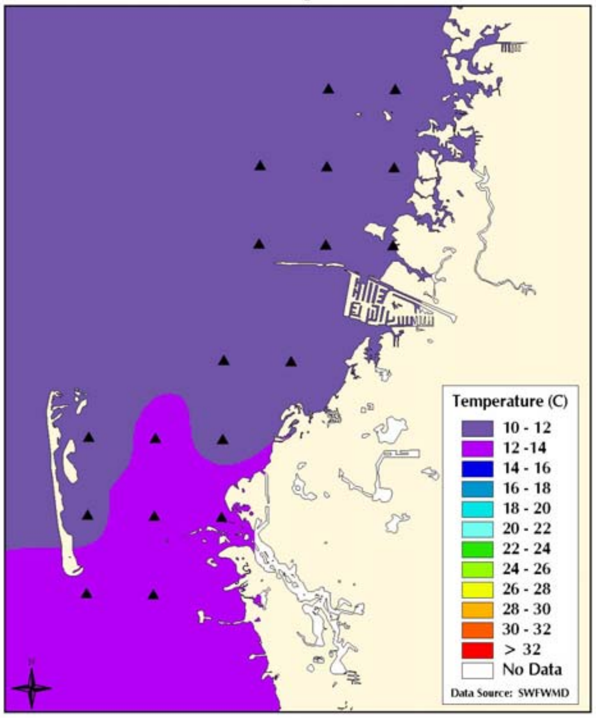

Figure 2.4. Project COAST 2000 surface temperature, January 2000.

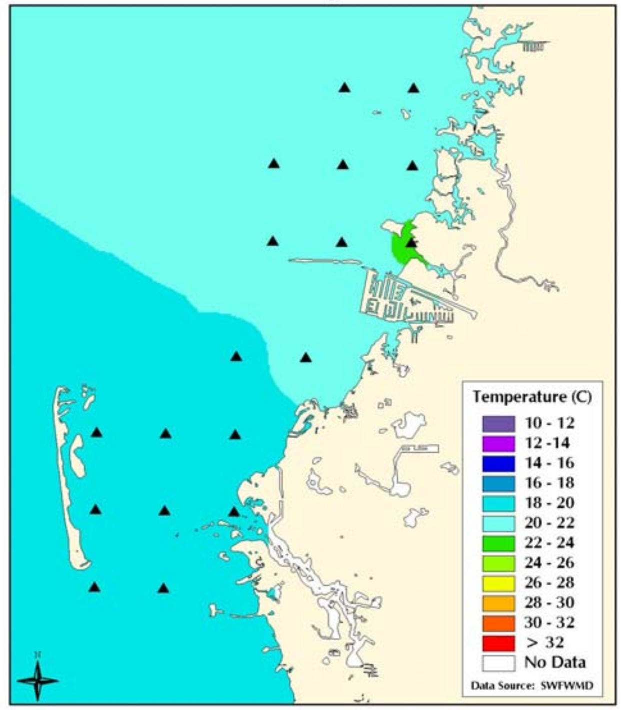

Figure 2.5. Project COAST 2000 surface temperature, February 2000.

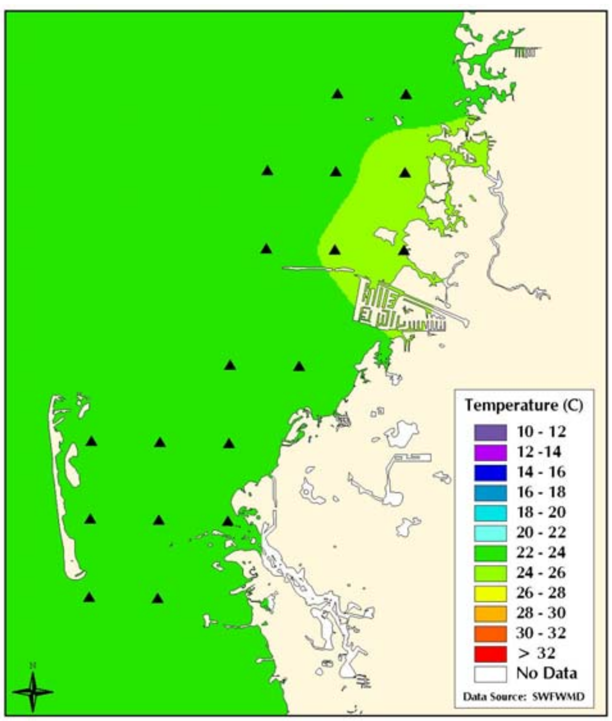

Figure 2.6. Project COAST 2000 surface temperature, March 2000.

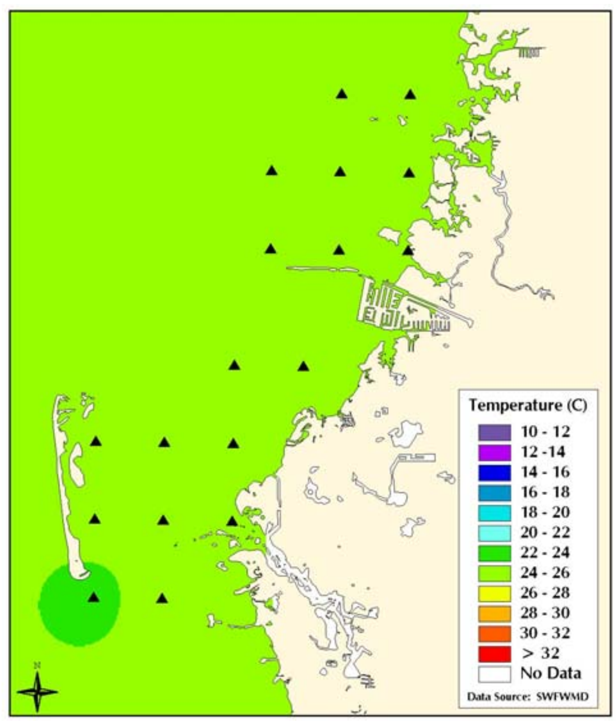

Figure 2.7. Project COAST 2000 surface temperature, April 2000.

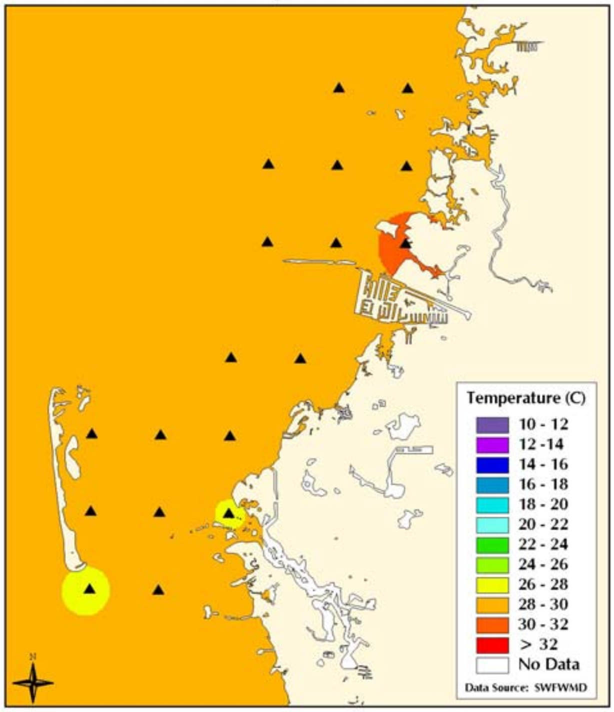

Figure 2.8. Project COAST 2000 surface temperature, May 2000.

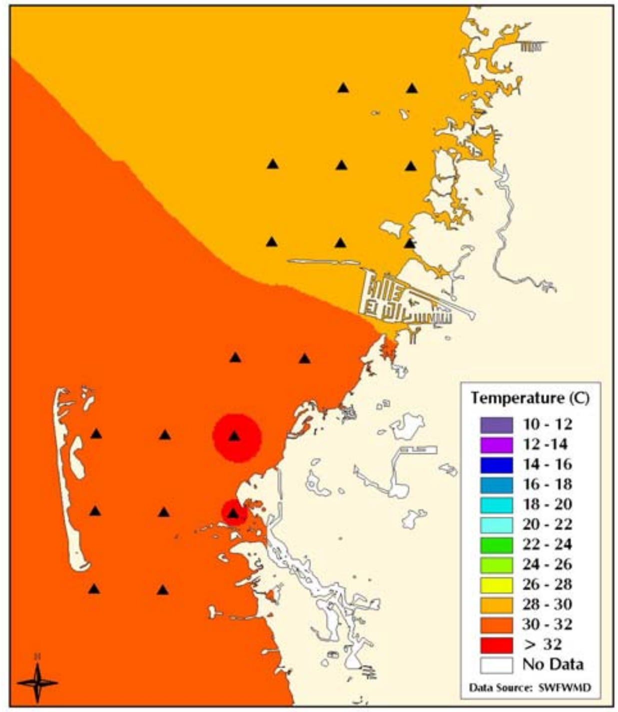

Figure 2.9. Project COAST 2000 surface temperature, June 2000.

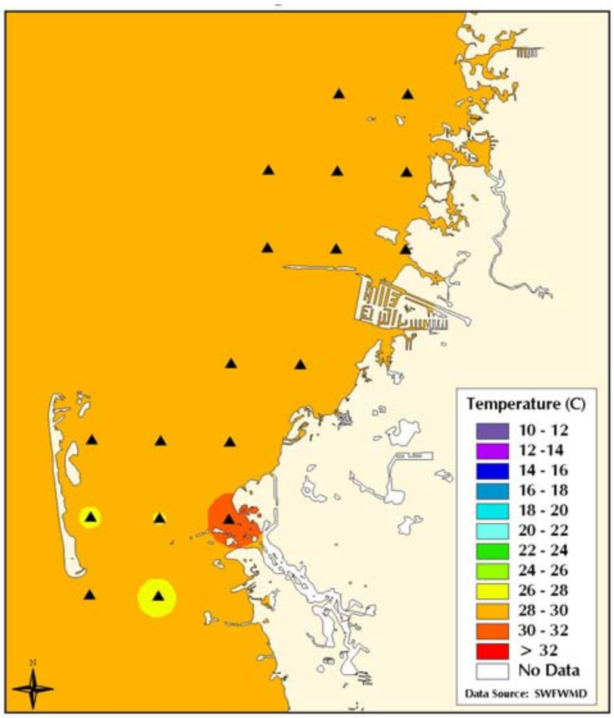

Figure 2.10. Project COAST 2000 surface temperature, July 2000.

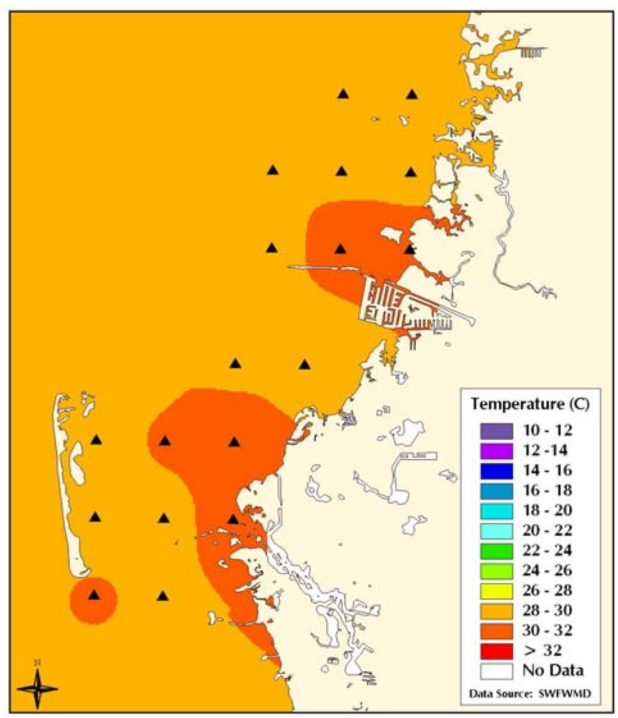

Figure 2.11. Project COAST 2000 surface temperature, August 2000.

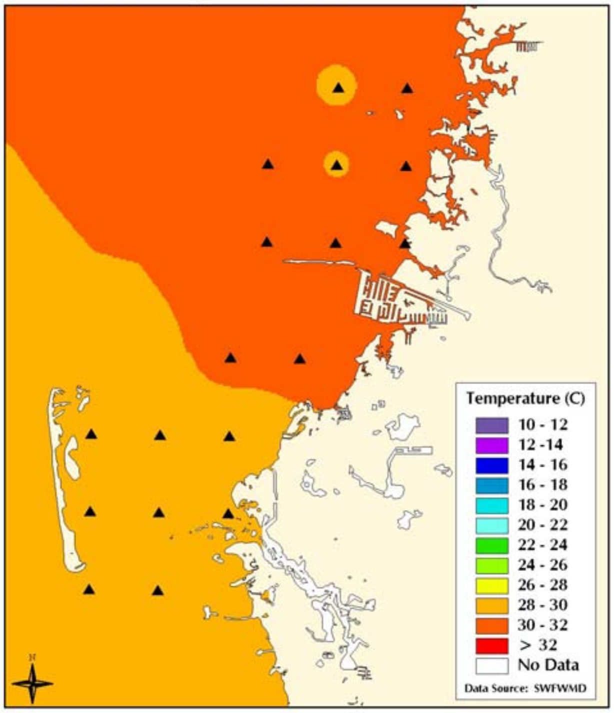

Figure 2.12. Project COAST 2000 surface temperature, September 2000.

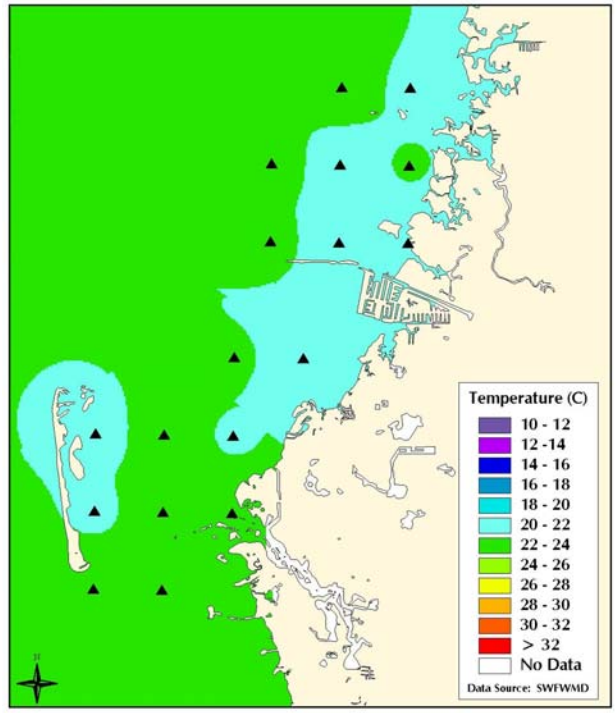

Figure 2.13. Project COAST 2000 surface temperature, October 2000.

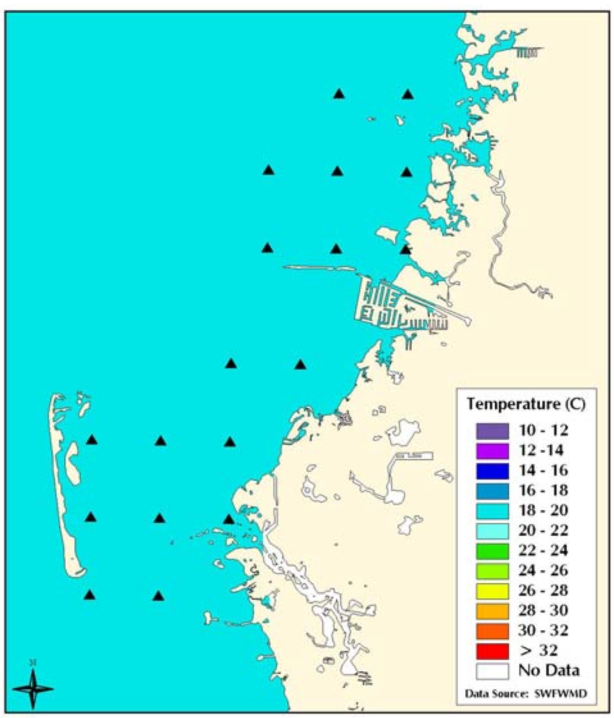

Figure 2.14. Project COAST 2000 surface temperature, November 2000.

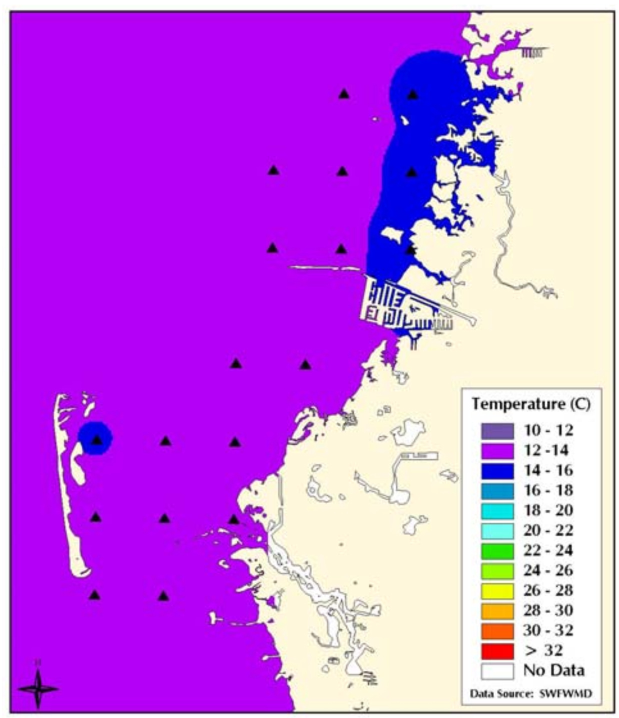

Figure 2.15. Project COAST 2000 surface temperature, December 2000.

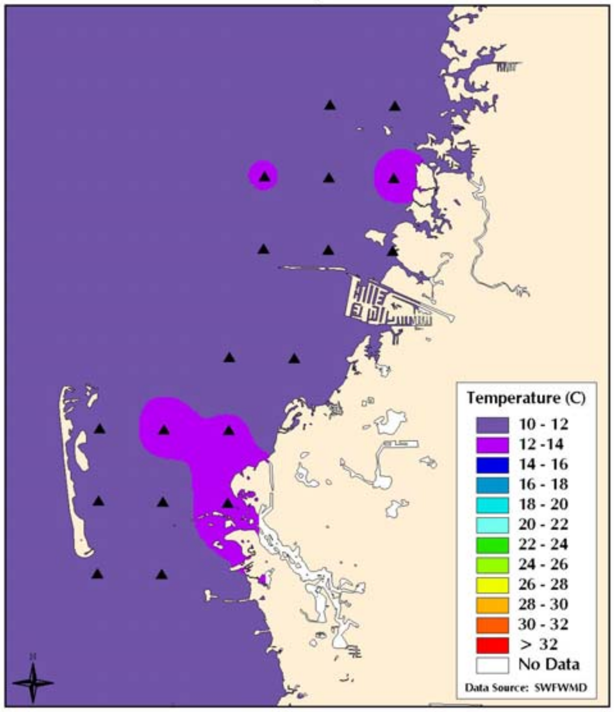

Figure 2.16. Project COAST 2000 surface temperature, January 2001.

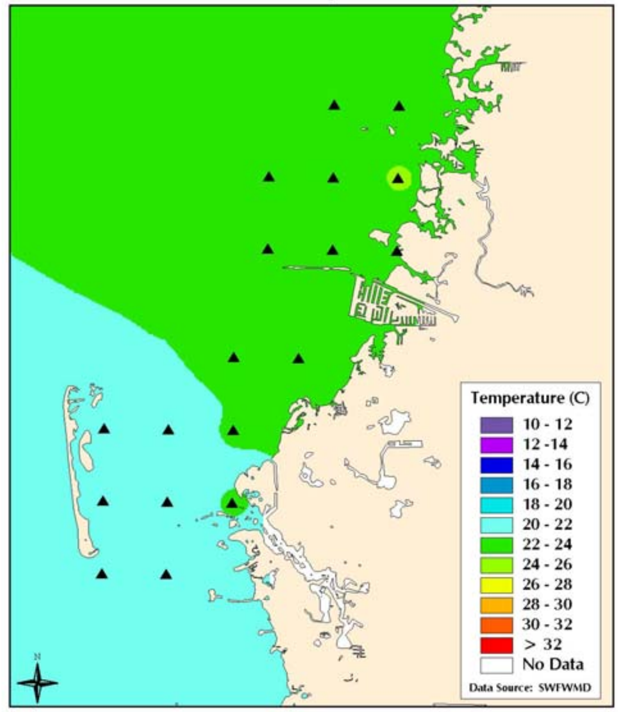

Figure 2.17. Project COAST 2000 surface temperature, February 2001.

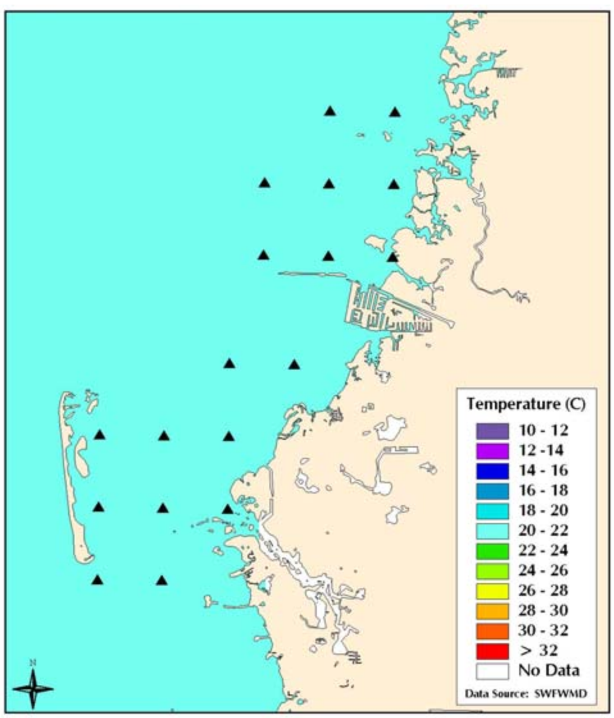

Figure 2.18. Project COAST 2000 surface temperature, March 2001.

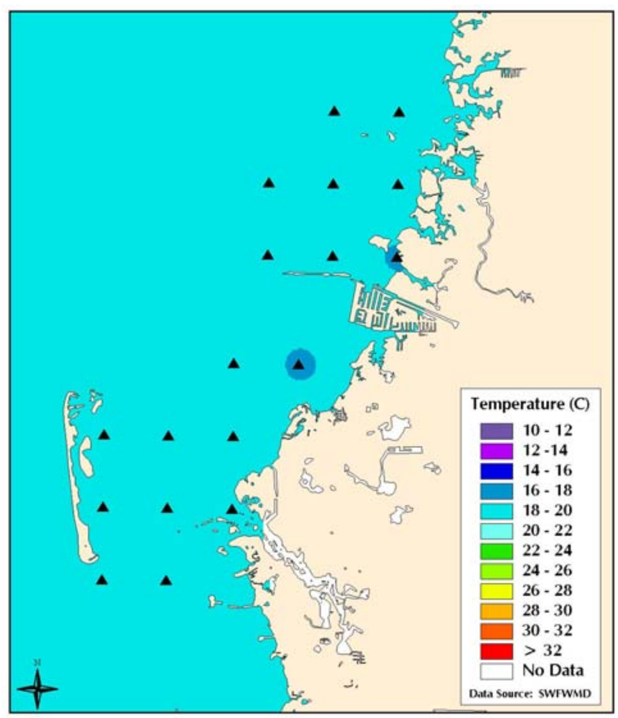

Figure 2.19. Project COAST 2000 surface temperature, April 2001.

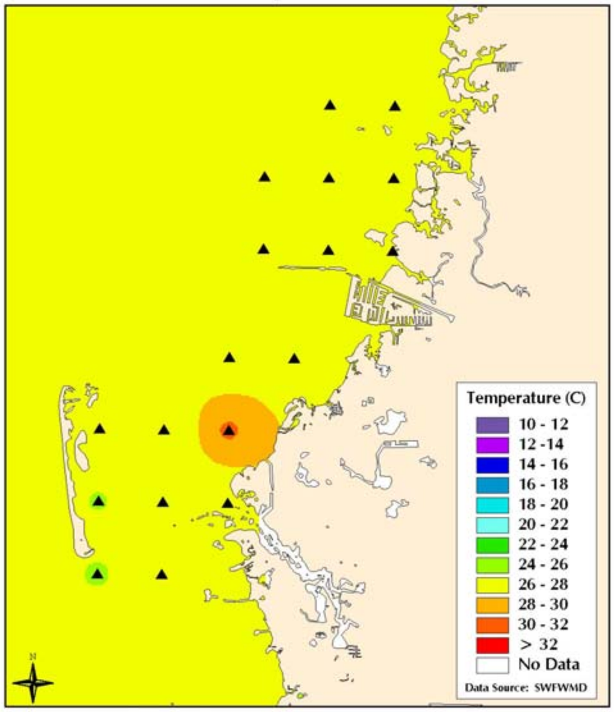

Figure 2.20. Project COAST 2000 surface temperature, May 2001.

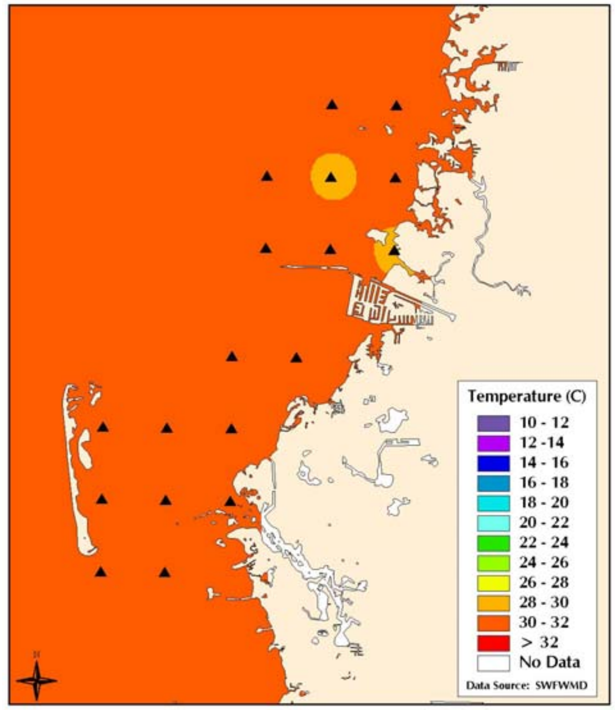

Figure 2.21. Project COAST 2000 surface temperature, June 2001.

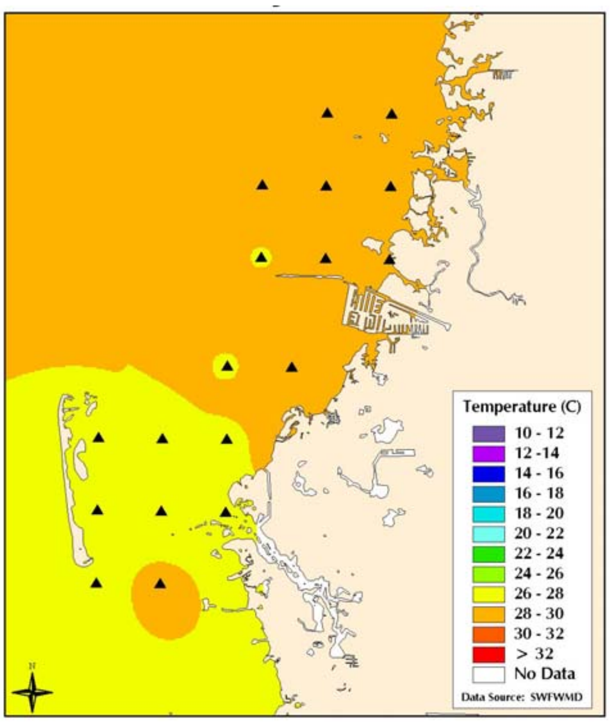

Figure 2.22. Project COAST 2000 surface temperature, July 2001.

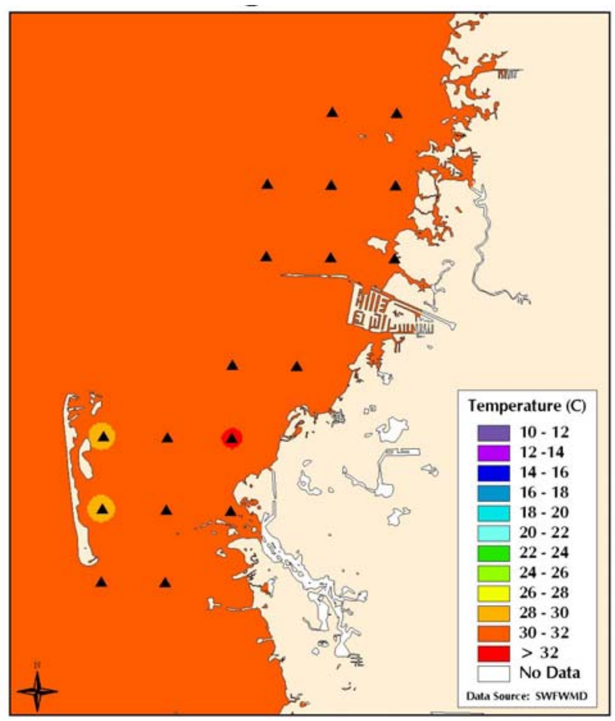

Figure 2.23. Project COAST 2000 surface temperature, August 2001.

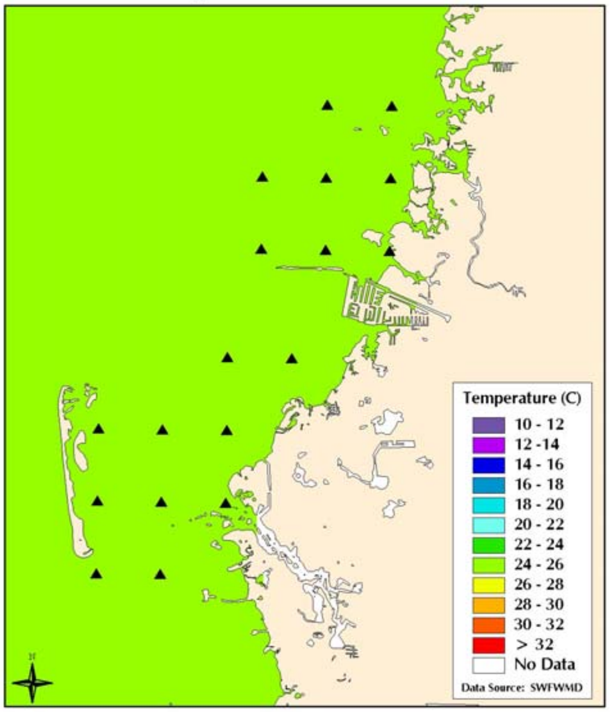

Figure 2.24. Project COAST 2000 surface temperature, September 2001.

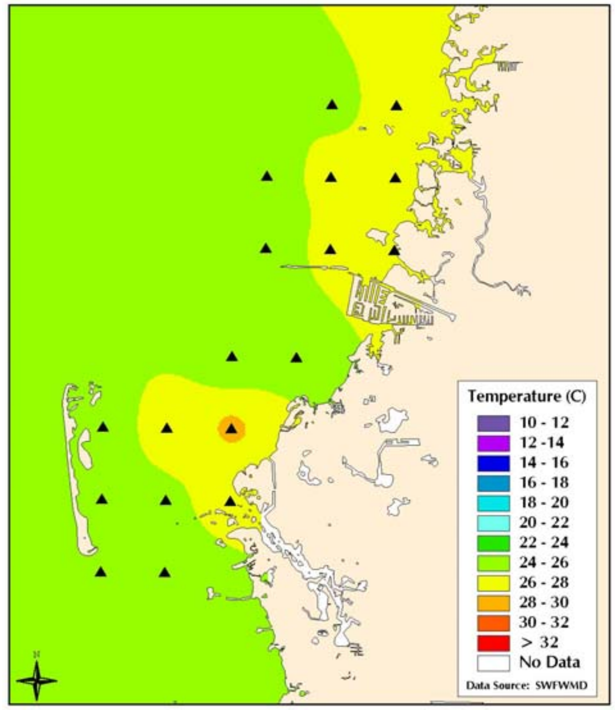

Figure 2.25. Project COAST 2000 surface temperature, October 2001.

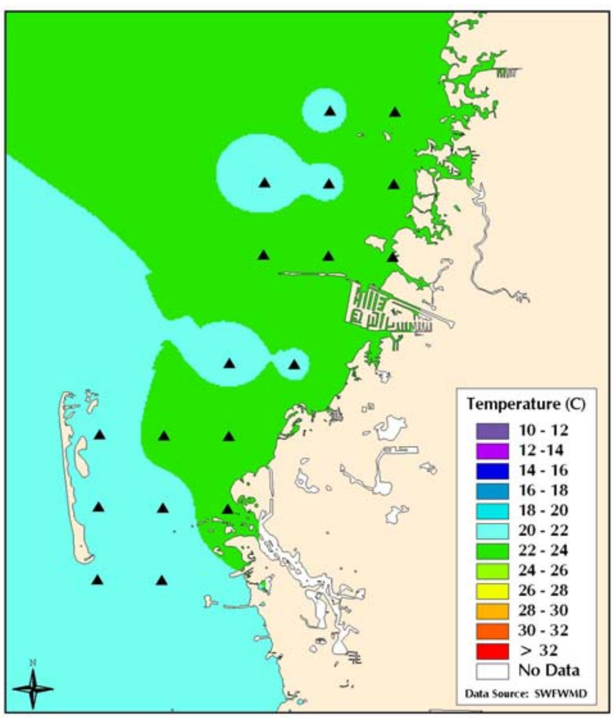

Figure 2.26. Project COAST 2000 surface temperature, November 2001.

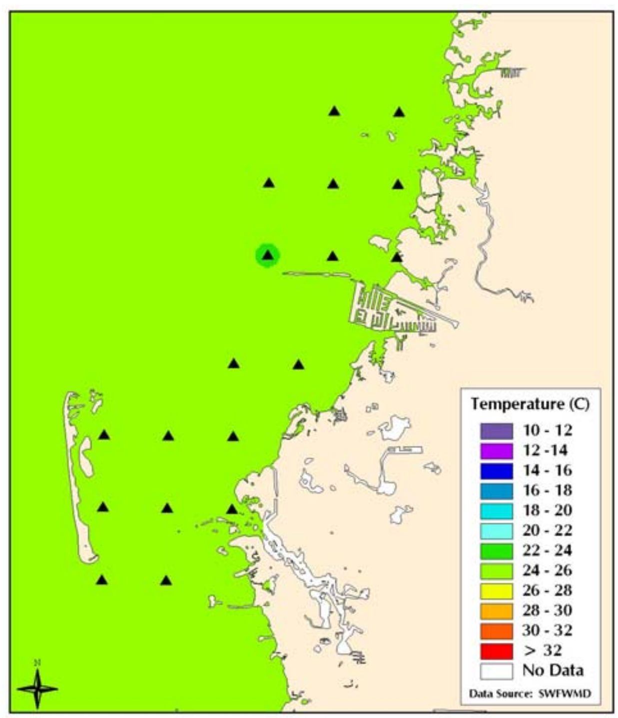

Figure 2.27. Project COAST 2000 surface temperature, December 2001.

For this site, the following wind metrics were examined:

- Hourly mean wind speed and direction for each month, May 2001-April 2002;
- Monthly mean wind speed and direction, May 2001-April 2002;
- Univariate analysis of wind speed for the year; and
- Univariate analysis of wind speed for each month.

The meteorological data at the Tarpon Springs site are reported at six-minute intervals. During the year of May 2001-April 2002, the median wind speed was 1.5 m/s, the 25^{th} percentile wind speed was 0.4 m/s, and the 75^{th} percentile wind speed was 2.6 m/s.

Following are synopses of the hourly mean wind speed and direction for each month.

January, February –
Winds are primarily from the northeast during the morning and early afternoon, then shifting to northwest in the evening. The strongest winds occur during early morning and late evening.

March, April –
Winds are from the northeast in the morning, and switch to the southwest in the late afternoon and evening. The strongest winds occur in the evening.

May -
Winds are from the northeast in the morning, and from the northwest in late afternoon and evening.

June -
Morning and early afternoon winds are from the southeast, with late afternoon and evening winds from the southwest.

July, August –
Winds are primarily from the south and southwest.

September –
Winds are from the northeast in the morning and early afternoon, shifting to the northwest in the evening.

October-December –
Winds are predominantly from the northeast, with some winds from the northwest during evening hours.

Table 2.1 below summarizes the monthly mean wind speed and direction for the period. Mean monthly wind speeds are greatest during the fall and winter. Mean monthly wind direction is from the northern quadrant for much of the year. Table 2.2 below provides a synopsis of the monthly wind speed distribution, with the fall and winter months typically having the highest wind speeds.

Table 2.1. Mean monthly wind speed and direction.		
Period	**Wind Direction**	**Wind Speed (m/s)**
January	North-Northeast	1.0
February	North	1.0
March	North-Northeast	0.2
April	Southeast	0.4
May	North-Northwest	0.9
June	Southwest	0.6
August	West	0.1
September	North-Northeast	0.7
October	North-Northeast	1.5
November	North-Northeast	1.2
December	North-Northeast	0.8

Table 2.2. Monthly wind speed distribution (m/s).			
Month	**25^{th} Percentile**	**50^{th} Percentile**	**75^{th} Percentile**
January	0.2	1.5	4.1
February	0.8	1.9	3.2
March	0.8	2.0	3.2
April	0.1	1.1	2.2
May	1.0	1.9	2.7
June	0.3	1.4	2.4
July	0.4	1.4	2.3
August	0.1	1.0	2.0
September	0.2	1.1	2.2
October	1.2	2.3	3.3
November	0.3	1.6	2.8
December	0.1	1.0	2.1

2.1.3.3 Precipitation

Average annual rainfall in the area, based on records from a National Weather Service monitoring station in Tarpon Springs for the years 1901 through 2000, is 1.33 meters (52 inches) per year. Rainfall amounts are highly variable from year to year, however, and both droughts and floods are relatively common events. During the period 1901 – 2000 annual rainfall amounts ranged between a minimum of 0.84 meters (33 inches) in 1956 and a maximum of 2.11 meters (83 inches) in 1959.

Precipitation in the area is produced by three types of weather systems: convective, tropical cyclonic, and frontal systems. In most years more than 50% of the annual rainfall occurs between the months of June and September. During these “rainy season” months convective thunderstorms can occur on an almost daily basis, producing intense rainfall for short periods over localized areas. Tropical cyclonic systems, which can occur during the same months, produce larger rainfall volumes and strong winds, which are spread over a larger geographic area. Rainfall during the remainder of the year is typically due to large-scale frontal systems and is more evenly distributed throughout the region.

2.1.4 Freshwater Inflow

Freshwater input to the Anclote Anchorage occurs from the Anclote River, through rainfall, and from the coastal area north of the Anchorage, from rivers discharging to the Gulf. Discharge from the Anclote River is via the mouth of the river and from the Anclote Power Station discharge canal. Each of these inputs is described below.

2.1.4.1 Anclote River

Streamflow in the Anclote River basin is monitored by the U.S. Geological Survey (USGS), whose most downstream monitoring station is located near the community of Elfers in Pasco County (Coffin and Fletcher, 1999). The USGS has monitored river stage and estimated streamflow at the Elfers station continuously since May 1946. The USGS streamflow records from the gage near Elfers were used to estimate the total discharge from the Anclote River watershed for this modeling effort. The area of the watershed drained through this gage is listed by the USGS as approximately 188 square kilometers. The total area of the Anclote River watershed as estimated from the SWFWMD drainage basin coverage is approximately 293 square kilometers. The estimated streamflow at Elfers was multiplied by the ratio of the total watershed area to that of the Elfers gaged watershed area (ratio = 1.55) in order to obtain estimated discharge values for the Anclote River.

Estimates of monthly mean discharge from the river are shown in Figure 2.28, based on period of record data for 1947-1999. Monthly mean discharge exhibits an obvious relationship with seasonal rainfall patterns, with low flows occurring in the latter part of dry season (May-June) and high flows occurring during the rainy season months of July through October. A secondary high-flow period also occurs in March, associated with frontal systems that often pass through the region in that month. Table 2-3 presents the monthly mean flows from the Anclote River in tabular format.

Table 2.3. Monthly mean flows from Anclote River, 1947-1999.

Month	Million Gallons per Day (MGD)	Cubic Feet per Second (CFS)
January	41	64
February	47	73
March	72	111
April	34	53
May	14	22
June	23	36
July	63	98
August	139	215
September	157	243
October	61	94
November	21	33
December	30	46

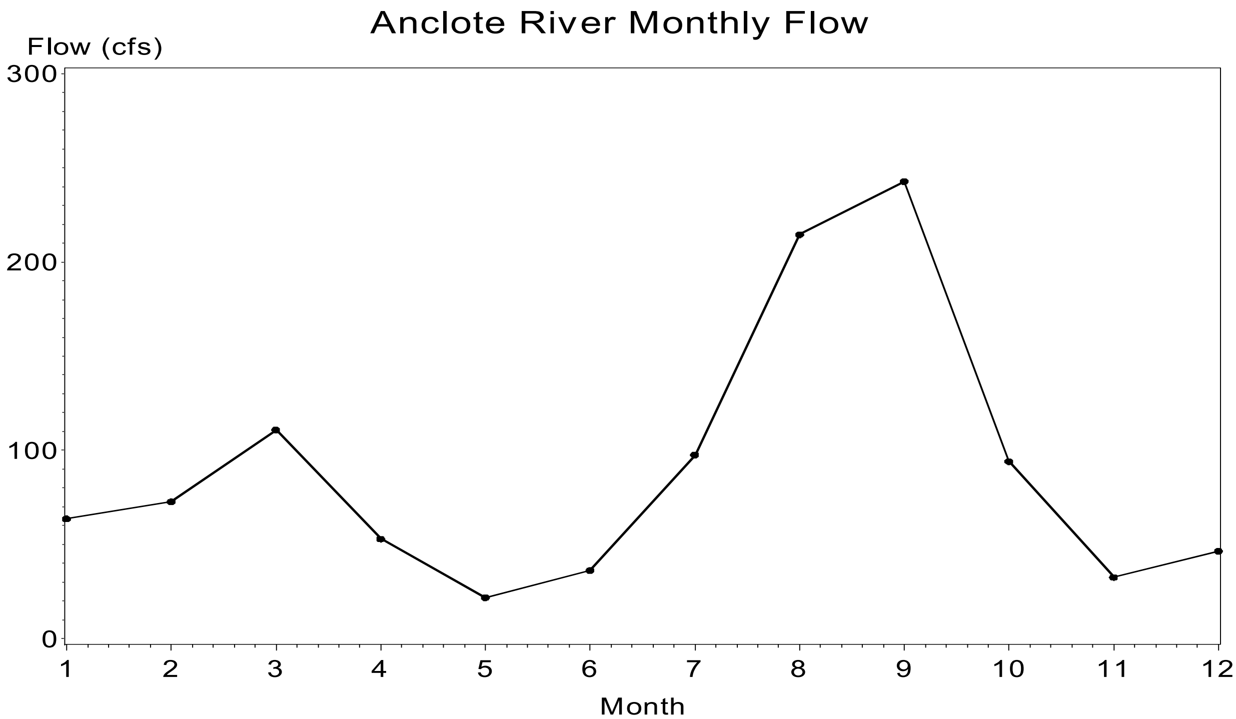

Figure 2.28. Anclote River estimated monthly mean discharge (cfs).

Streamflow shows pronounced year-to-year fluctuations, responding to annual variations in total rainfall, as shown in Figure 2.29. Between 1947 and 1999, the estimated annual mean discharge at the river mouth was 91 cfs (59 MGD), but mean flows for individual years ranged between 9.6 cfs (6 MGD) in 1999 and 321 cfs (207 MGD) in 1959.

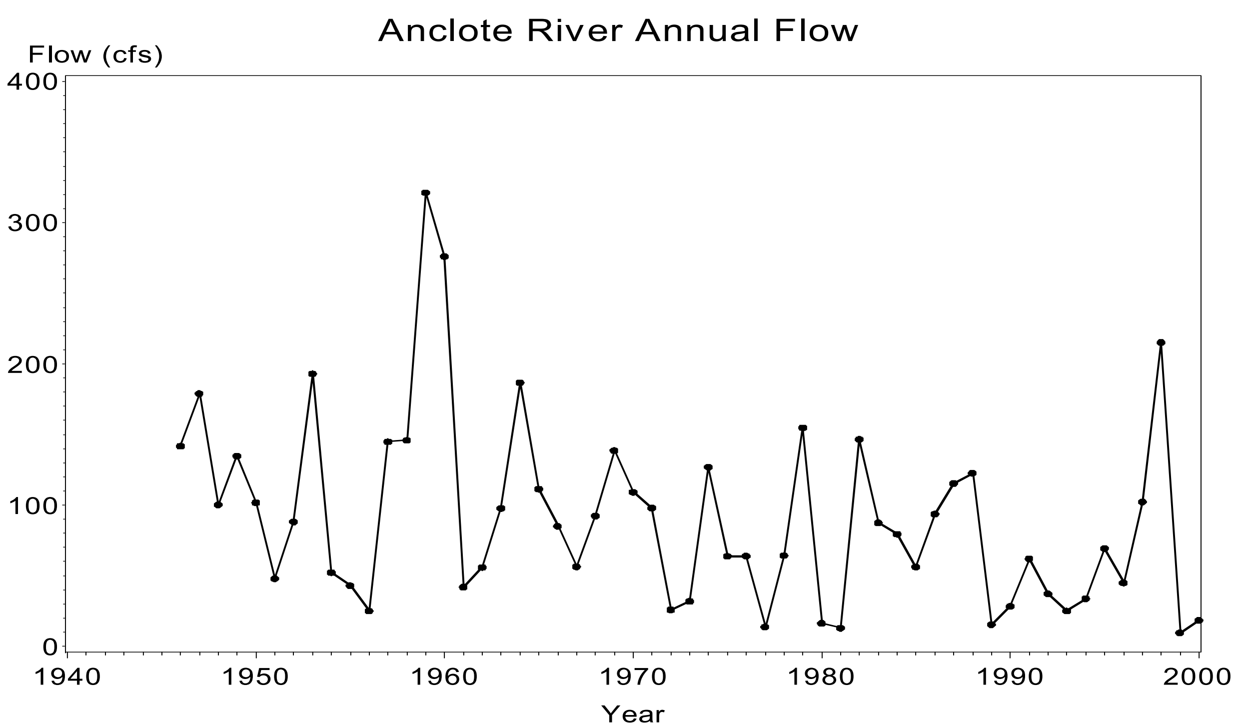

Figure 2.29. Anclote River estimated mean annual discharge (cfs).

The Anclote Power Station is located on the river's northern shoreline, immediately upstream from the mouth of the river (Figure 1.3). The station includes a combination of oil-fired and natural gas-fired generators that are capable of producing up to 1,054 megawatts of electricity (PBS&J, 1999). Cooling water for the station is taken from just upstream of the mouth of the Anclote River, through an intake canal that is 134 meters long, 69 meters wide, and 3 meters deep (PBS&J, 1999). After passing through the station's cooling system, the heated water is discharged through a 1.4 km long outlet canal to the central Anclote Anchorage (Figure 1.3). The station uses a combination of on-site cooling towers and dilution pumps to reduce its thermal impact on the receiving waters of the Anchorage. The dilution pumps are capable of pumping up to 1,530 MGD (2,367 cfs) from the intake canal directly to the outlet canal, bypassing the station's cooling system and reducing the temperature of water present in the discharge canal (PBSJ, 1999). The cooling towers and dilution pumps are used most heavily in the summer months, as the temperature of the intake water reaches the highest levels of its annual cycle. Based on operating data for 1997-2001, the facility intake volume ranged between 243 MGD (376 cfs) and 3,556 MGD (5,502 cfs), depending on the operating mode.

Figure 2.30 displays the daily total flow through the Anclote Power Station for the period January 1997 through December 2001. Peak flows occur in the summer, as expected, with monthly mean flows of 2,298 MGD (3,709 cfs) during August. Table 2.4 provides the monthly mean flows over the 1997-2001 period.

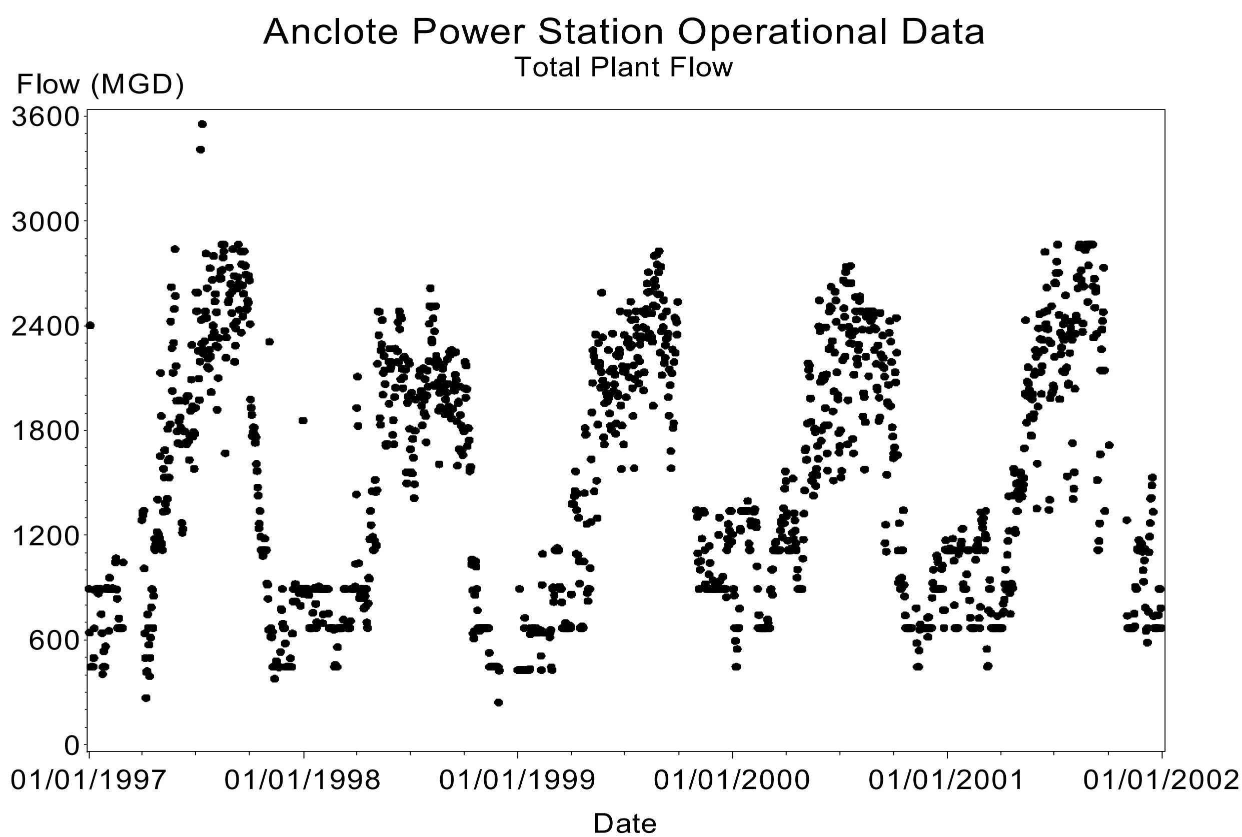

Figure 2.30. Daily flows through the Anclote Power Station, 1997-2001.

Table 2.4. Monthly mean flows through Anclote Power Station, 1997-2001.		
Month	**Million Gallons per Day (MGD)**	**Cubic Feet per Second (CFS)**
January	830	1284
February	808	1250
March	884	1368
April	1048	1622
May	1846	2856
June	2047	3167
July	2235	3458
August	2398	3709
September	2205	3412
October	1296	2006
November	757	1171
December	894	1383

The quantity of water used by the Anclote Power Station is large in comparison to the freshwater discharge from the Anclote River. This can be seen by comparison of the monthly mean flows from the river (Table 2.3) with the monthly mean flows through the station (Table 2.4). Monthly mean flows from the river range from less than one percent to eight percent of the total intake by the power station. Assuming the 1997-2001 power station data may be taken as typical, and the 1947-1999 Anclote flow data are typical, the Anclote Power Station intake is approximately 25 times the river discharge on an annual basis. Therefore, most of the water being utilized for cooling purposes is being pulled in from the Anchorage through the mouth of the river.

2.1.4.2 Rainfall

Rain falling directly on the surface of the Anchorage is probably an insignificant component of the annual water budget. Evaporation rates in the central portion of the Florida peninsula are about 1.17 to 1.27 meters per year (46-50 inches/yr) (Fernald and Purdum, 1998), while annual mean rainfall at Tarpon Springs is about 1.33 meters (52 inches) per year. This suggests that the volume of fresh water contributed to the surface of the Anchorage by rainfall each year is only slightly larger than the volume lost through evaporation.

2.1.4.3 Northern Coastal Region

Freshwater inflow to the coastal region north of the Anchorage may also be transported into the Anchorage. Transport of fresh water southward along the coast is dependent on wind-induced circulation, and is most likely when winds are from the north, as is typical during the winter. Livingston (1990) provided the following description of the coastal area that extends northward from the Anclote Anchorage:

"The region from the Anclote Keys north to the Ochlockonee River drainage can be viewed as one massive estuary. This open estuarine system is supplied by freshwater from the Anclote, Pithlachascotee, Weeki Wachee, Homosassa, Chassahowitzka, Crystal, Withlacoochee, Waccasassa, Suwanee, Steinhatchee, Spring Warrior, Fenholloway, Econfina, Aucilla, St. Marks, and Ochlockonee rivers. This combined drainage system of springs and streams contributes approximately 1 billion gallons of fresh water per day to...the northeastern Gulf of Mexico. This massive drainage is associated with relatively intact wetlands. The associated estuarine area, still undisturbed by human activities, is one of the least polluted coastal regions in the continental United States."

2.2 Resulting Hydrodynamics

The hydrodynamic conditions of the Anclote Anchorage reflect the interactions of the forcing functions described in the previous section. Variability in hydrodynamic conditions occurs over temporal scales of different lengths. Changes in water surface elevation due to tidal forcing and wind forcing occur on time periods of hours, changes in circulation due to freshwater input may occur over time periods of days to weeks, seasonal changes in circulation occur because of seasonal changes in wind and freshwater input, and inter-annual changes in circulation may occur due to changes in long-term atmospheric conditions and because of changes in bathymetry. Observations of circulation patterns over tidal cycle time scales, seasonal time scales, and inter-annual time scales are described below.

Observations of particle movement suggest that near the coast in the Anclote area, flooding tides transport water to the northeast, while ebbing tides transport water to the southwest (He and Weisberg, 2002b). Early modeling studies of the Anclote area (Baird et al., 1972) support these observations. Observed currents during ebb and flood tides are presented in Figures 2.31 and 2.32.

As seen in Figure 2.31, observed current directions during ebb flow are to the south out of the southern portion of the Anchorage, and to the west out of the northern portion of the Anchorage. Conversely, during flood flow, shown in Figure 2.32, current directions are to the north into the southern Anchorage and to the east into the northern Anchorage. In these figures, transport velocities are shown as arrows, with the length of the arrow signifying transport speed and the direction of the arrow signifying transport direction.

Wind-induced circulation in the nearshore environment has been examined as part of a larger circulation study of the west Florida shelf (Yang and Weisberg, 1999). The model suggests that winter (October-March) winds from the northeast result in southward flowing nearshore currents from Tampa Bay to the Big Bend area, while summer (April-September) winds from the southeast result in northward flowing nearshore currents along the entire west Florida coast. The model results agree with observed transport off the coast of Clearwater.

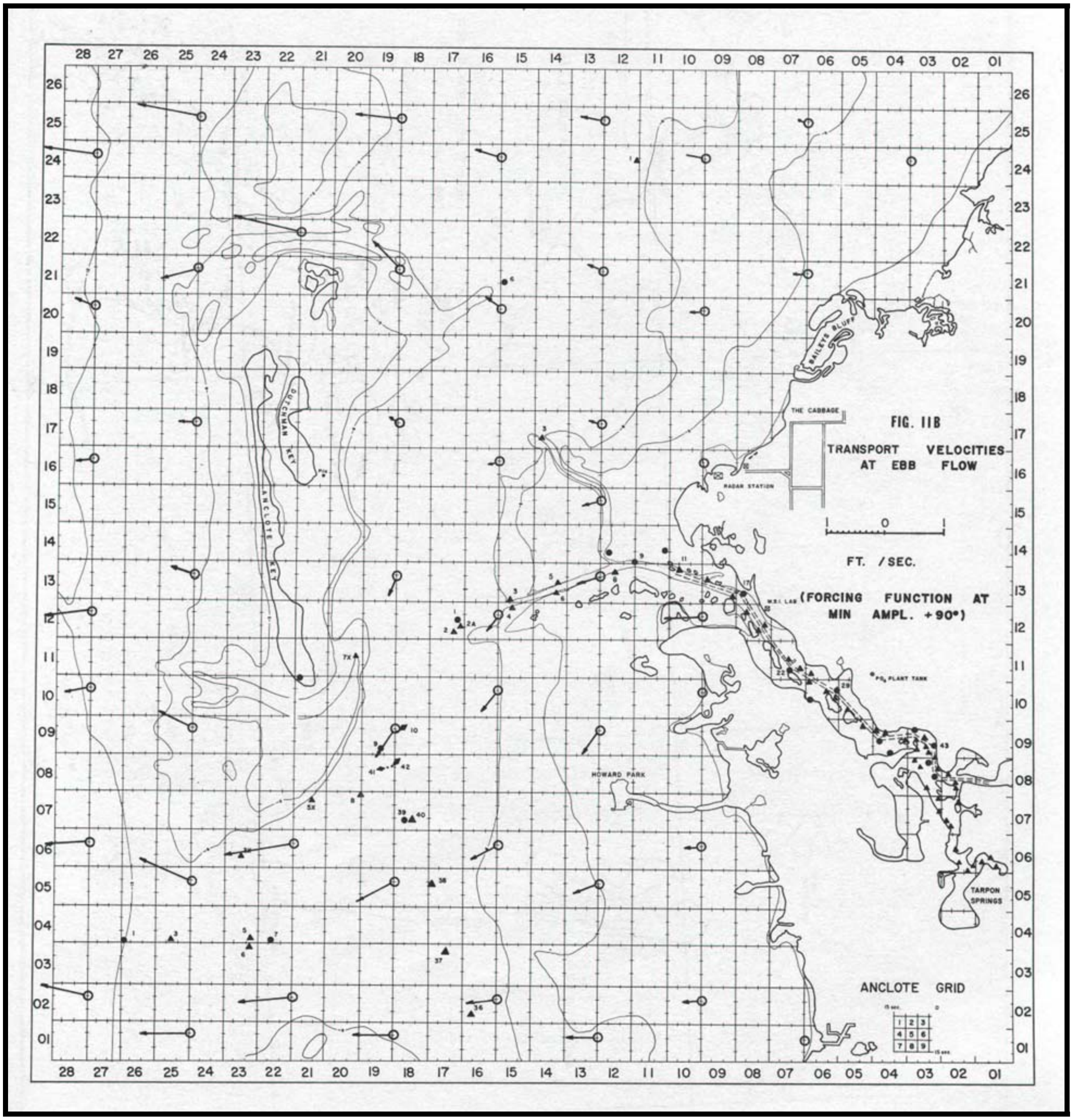

Figure 2.31. Observed transport velocities at ebb flow under light wind conditions, Anclote Anchorage, November 22, 1970 (from Baird et al., 1972).

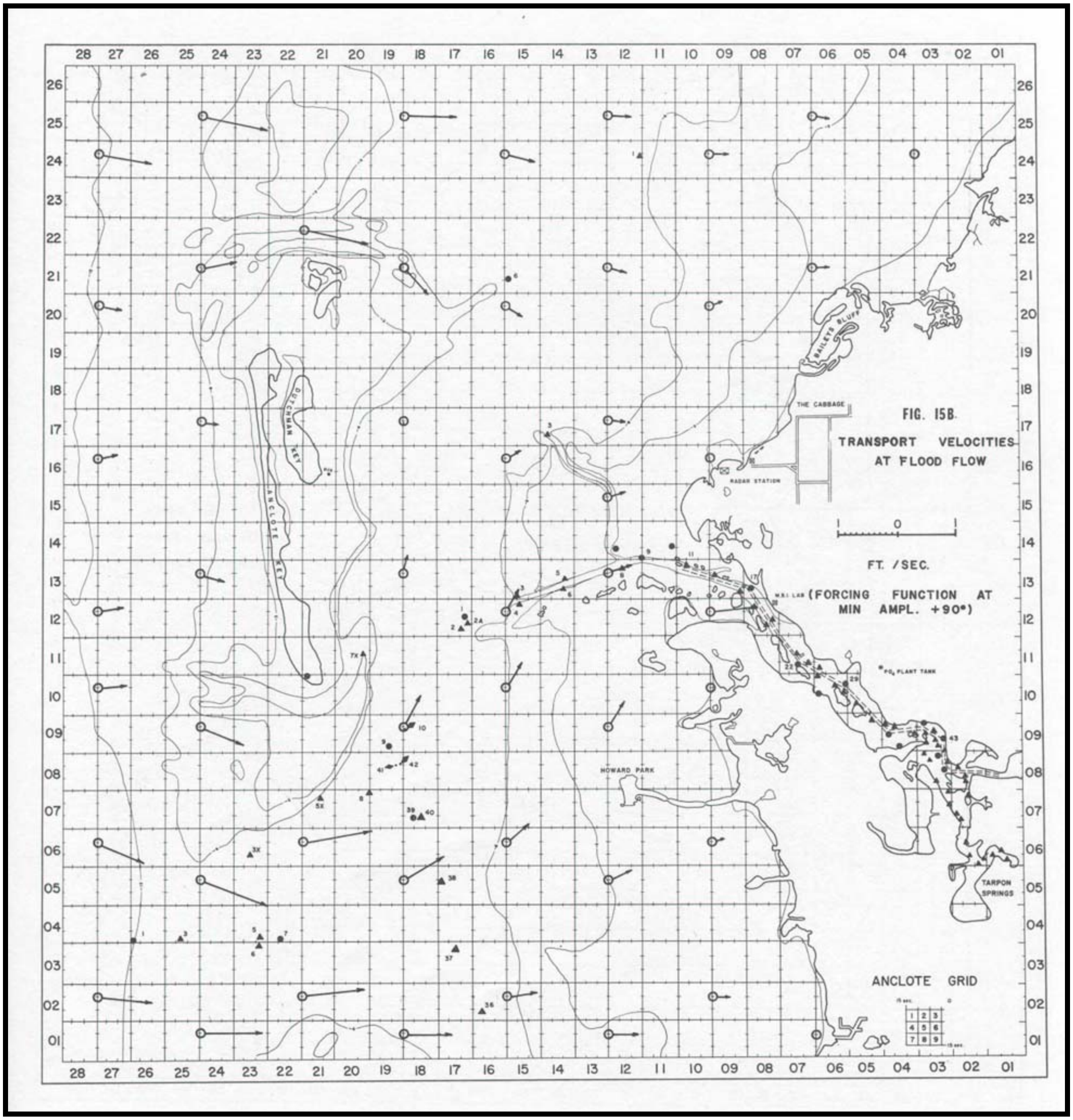

Figure 2.32. Observed transport velocities at flood flow under light wind conditions, Anclote Anchorage, November 22, 1970 (from Baird et al., 1972).

The effects of freshwater inflow on circulation on seasonal and inter-annual time scales may be evaluated through examination of observed salinity patterns in the Anchorage. In addition to the temperature measurements taken as part of Project COAST 2000, described above, salinity measurements were also taken in the Anchorage during monthly sampling from January 2000 through December 2001 (Frazer et al., 2001). The surface salinity values are shown for the sampling area for the wet and dry seasons of each year in Figures 2.33 through 2.36. The horizontal salinity distribution typically shows lower salinity values near the coast, with the lowest values north of the Anchorage.

This is the result of freshwater inflows from river systems north of the Anclote. Seasonal changes in salinity distribution are evident, with the dry season salinity values higher than those during the wet season, as expected.

Inter-annual differences due to freshwater input are also evident. The 2000 dry season salinity in the Anchorage (Figure 2.33) was approximately 32-36 ppt, while that in 2001 (Figure 2.34) was 28-32 ppt. The 2000 wet season salinity in the Anchorage (Figure 2.35) was approximately 28-34 ppt, with a similar range for the 2001 wet season salinity (Figure 2.36), although the 2001 data showed somewhat fresher water over much of the Anchorage than was found in 2000.

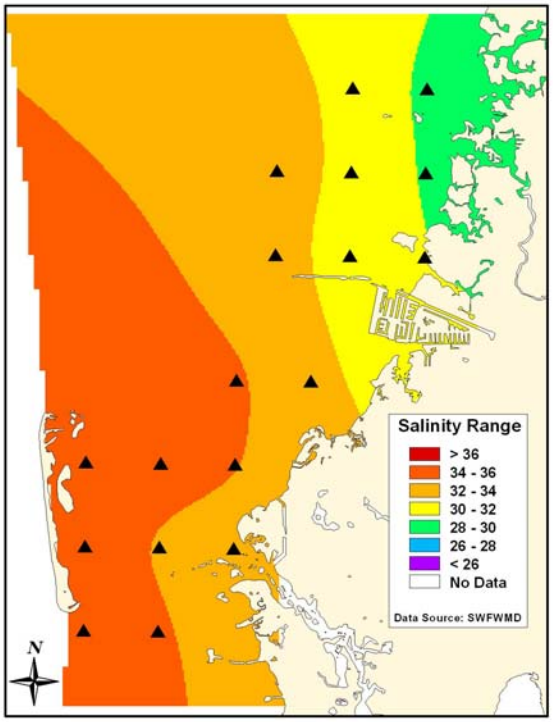

Figure 2.33. Project COAST 2000 surface salinity, dry season (Jan-Jun, Nov-Dec).

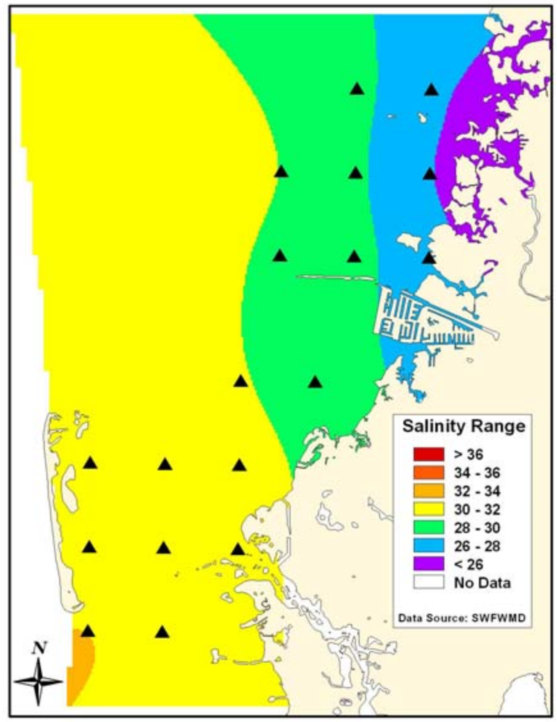

Figure 2.34. Project COAST 2001 surface salinity, dry season (Jan-Jun, Nov-Dec).

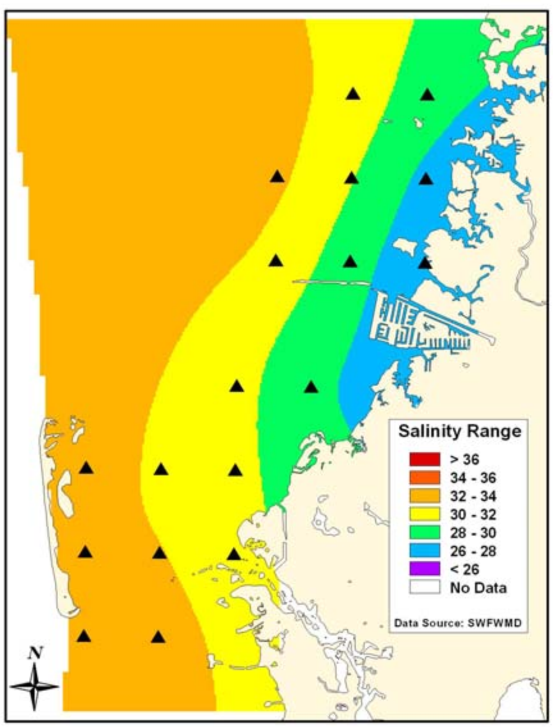

Figure 2.35. Project COAST 2000 surface salinity, wet season (Jul-Oct).

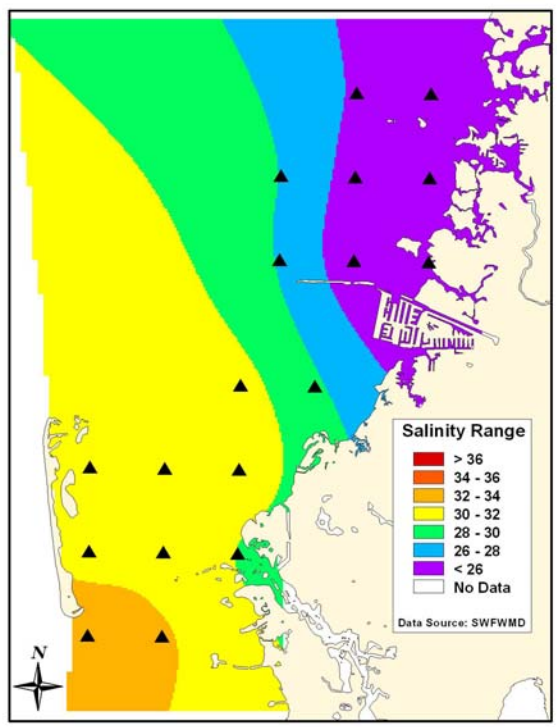

Figure 2.36. Project COAST 2001 surface salinity, wet season (Jul-Oct).

3.0 Model Selection and Description

The hydrodynamic model selected for this project serves as a predictive tool to examine the conditions that are expected to occur as the result of various design and siting options for the Gulf Coast Desalination Facility. This model should be capable of predicting temperature, salinity, and water surface elevation responses to tidal forcing, wind forcing, freshwater inflow, and bathymetric influences. This model should provide predictions over various temporal scales so that the full spectrum of temporal effects may be evaluated, from short-term (hourly) to long-term (inter-annual) effects. Additionally, the model must provide sufficient spatial resolution to allow examination of potential effects over relatively small horizontal extents and throughout the water column. Descriptions of the types of model constructs available, and a description of the model selected, follow.

Three different vertical coordinate systems are typically considered, with the system selected dependent upon the type of system being modeled. One choice for vertical coordinates is the z-system. In this system, each vertical layer has a fixed depth, with grid cells added or subtracted from columns dependent on depth. This coordinate system is the simplest, and has been utilized since early ocean models were developed. This system allows for simple numerical methods to be used, which can be of importance for large model domains over long time spans, such as climate-ocean interaction studies. The non-linear equation of state for seawater can be accurately represented using this system. However, this system has drawbacks. The representation of tracer (salinity) advection and diffusion along inclined density surfaces in the interior of the model domain is cumbersome. Representation and parameterization of the bottom boundary layer and surface mixed layer is not as simple as in other systems. Representation of bottom topography is difficult, with the z-system resulting in the bottom being represented as a step-like contour. Variable surface heights in the real-world ocean require cells in the z-system that are sometimes "dry", that is, above the sea surface.

Another vertical coordinate system is the potential density system. Models utilizing this system are well suited to representing the dynamics of systems in which constant density surfaces are parallel to local potential density surfaces, as typically found in the ocean interior. Tracer (i.e. salinity) transport in the ocean typically occurs along potential density surfaces. However, this system, like the z-system, also has difficulties representing the surface mixed layer and bottom boundary layer sufficiently, as these layers are mostly unstratified (no potential density difference). Additionally, it is difficult to represent the effects of the non-linear equation of state in this system.

The third coordinate system is the sigma coordinate system. In deeper waters, the sigma coordinate system can result in the surface and bottom boundary layers being less highly resolved than desired. One of the advantages of the sigma coordinate system, however, is that in relatively shallow systems (coastal areas), this coordinate system typically generates sufficient resolution for realistic surface and bottom boundary layer depths. It is particularly well suited for modeling flows over the continental shelf and slope. Difficulties with this coordinate system may arise when topographic variations are sudden; however, Western Florida coastal areas typically have gently sloping bottoms.

The Princeton Ocean Model (POM) was selected for use in modeling the Anclote Anchorage and surrounding area to examine the effects of a desalination facility on salinity in the area. The POM was originally developed by Alan Blumberg and George Mellor in the late 1970s. Further modifications to the model have been added in the intervening years. The model has been utilized by the Atmospheric and Oceanic Sciences Program of Princeton University, the Geophysical Fluid Dynamics Laboratory of the National Oceanic and Atmospheric Administration, and Dynalysis of Princeton, among others. Researchers at the University of South Florida Marine Science Program have applied the POM to nearshore and offshore systems around the world, including the Tampa Bay Estuary. The POM has been used extensively for coastal engineering applications, prediction, and regional and basin-wide studies.

POM is a three-dimensional, time dependent, nonlinear, free surface primitive equation model. The model predicts conditions in all three spatial dimensions over time. Relationships between responses and forcing functions are often nonlinear. The model predicts changing depths in response to wave and tidal action. The model utilizes continuity and Newton's Second Law of Motion to predict mass movement. The continuity equation states that the mass entering a grid cell over a period of time is balanced by the change in mass in the cell and the mass exiting the cell during the same time. Newton's Second Law of Motion states that the acceleration on a body is equal to the force applied to the body divided by the mass of the body. POM solves the three-dimensional time dependent equations for conservation of mass, momentum, heat, and salinity. The model contains a turbulence closure sub-model that simulates mixed layer dynamics, including vertical mixing. The model produces realistic bottom boundary layers, typically important in coastal waters.

The model may utilize either a curvilinear orthogonal coordinate grid system or a rectangular grid system in the horizontal. In the vertical, the model utilizes sigma coordinates. Sigma coordinates range from 0 at the surface to –1 at the bottom, so that the depth intervals spanned by vertical grid cells are dependent on the depth of the system. The sigma coordinate system provides better estimation of conditions given significant topographical variability, as often found in estuaries and near-shore areas.

Other classes of primitive equations models are also used for ocean simulation. One of the primary differences between these model classes and the POM lies in the choice of vertical coordinate systems. Ocean modeling studies have shown that the vertical coordinate system selected is often the most important aspect of model design. It is important that the vertical coordinate system selected be capable of sufficiently resolving the surface mixed layer. This layer is generally turbulent and well mixed, and is dominated by transfers of momentum (wind forcing) and heat between the atmosphere and the sea. Similarly, the bottom topography acts as a strong forcing mechanism on overlying currents, so that it is also important that this layer be sufficiently resolved. These considerations must be noted when selecting a vertical coordinate system for a given model domain.

4.0 Model Development

Prior to developing the model for use in the Anclote Anchorage, it was necessary to identify the level of resolution needed in the spatial and temporal domains, the data available for model setup, and the type of model output required. This section provides a discussion of the domain selection, as well as a description of the data sources used to provide boundary and initial conditions for the model, and a summary of the types of data provided as output from the model for analysis.

4.1 Spatial Scale

In discussion with Tampa Bay Water prior to model development, it was decided that two potential discharge locations would be examined, a nearshore siting alternative and an offshore siting alternative. The nearshore alternative includes mixing of the concentrate from the desalination operation with the cooling water from the Anclote Power Station prior to release into the discharge canal, which empties into the Anchorage. The offshore alternative involves piping the concentrate offshore to a location where the water depth is at least nine meters, or approximately 15-20 km offshore, with discharge near the bottom of the water column.

In the two discharge site alternatives, the Anchorage and the offshore area, relatively high spatial resolution is required for evaluation of potential effects of the desalination operation on the surrounding system. Circulation in the Anchorage is affected by the hydrodynamics of the adjacent coastal areas to the north and south, as well as by the offshore area to the west. Circulation in the area of the offshore discharge site is also affected by the hydrodynamics of the surrounding region in all directions, likely including freshwater inflow effects from the nearshore environment. However, providing a high resolution model grid construct for the entire area of the west coast of Florida would be computationally expensive, so that an alternative model grid construct was developed.

It was necessary when developing the model grid construct to meet three important requirements:

- Provide relatively high spatial resolution in the areas surrounding the Anchorage and offshore discharge regions.

- Provide reasonable boundary conditions for the two high resolution areas with respect to horizontal and vertical structure of salinity, temperature, and currents. These boundary conditions should be from a more spatially extensive model encompassing the eastern Gulf of Mexico nearshore region expected to drive circulation at the two discharge sites.

- Provide a linkage between the boundary conditions from the spatially extensive model and the high resolution areas.

To meet the first two requirements listed above, a relatively coarse horizontal grid system, with horizontal cells of 5 km x 5 km, was developed for the spatially extensive model. This system will be referred to as the large-grid system. The spatial domain of the large grid system ranges from 28.8°N-27.6°N (from Homosassa in the north to the mouth of Tampa Bay in the south) and from the western coast of Florida to 83.6°W (to depths in excess of 100 ft), or approximately 80 km offshore. The large grid system is shown in Figure 4.1. Two high resolution grid systems were inset into the appropriate cells of the large grid system to allow greater resolution in the Anchorage (Figure 4.2) and in the offshore discharge area (Figure 4.3). The horizontal extent of the cells in these systems was 100 m x 100m. These grid systems will be referred to as the nearshore small grid and the offshore small grid systems, respectively. The nearshore small grid system covers three of the large grid cells in the Anchorage, and the offshore small grid system covers two of the large grid cells.

The water column in all three grid systems is divided into five equal depth vertical layers. The depth of each horizontal grid cell is typically different, so that the layer depths in the adjacent cells are not the same. In the nearshore small grid domain, depths range to approximately 4 m, so that maximum layer depths are on the order of 0.8 m. In the offshore small grid domain, the depth is approximately 9 m, so that layer depths are on the order of 1.8 m.

The current model construct does not allow drying and wetting of shallow surfaces. In the shallowest regions, the model construct retains the five vertical layers. When predicted water surface elevations fall below 0.5 m MLLW, the model sets minimum elevations to 0.5 m MLLW.

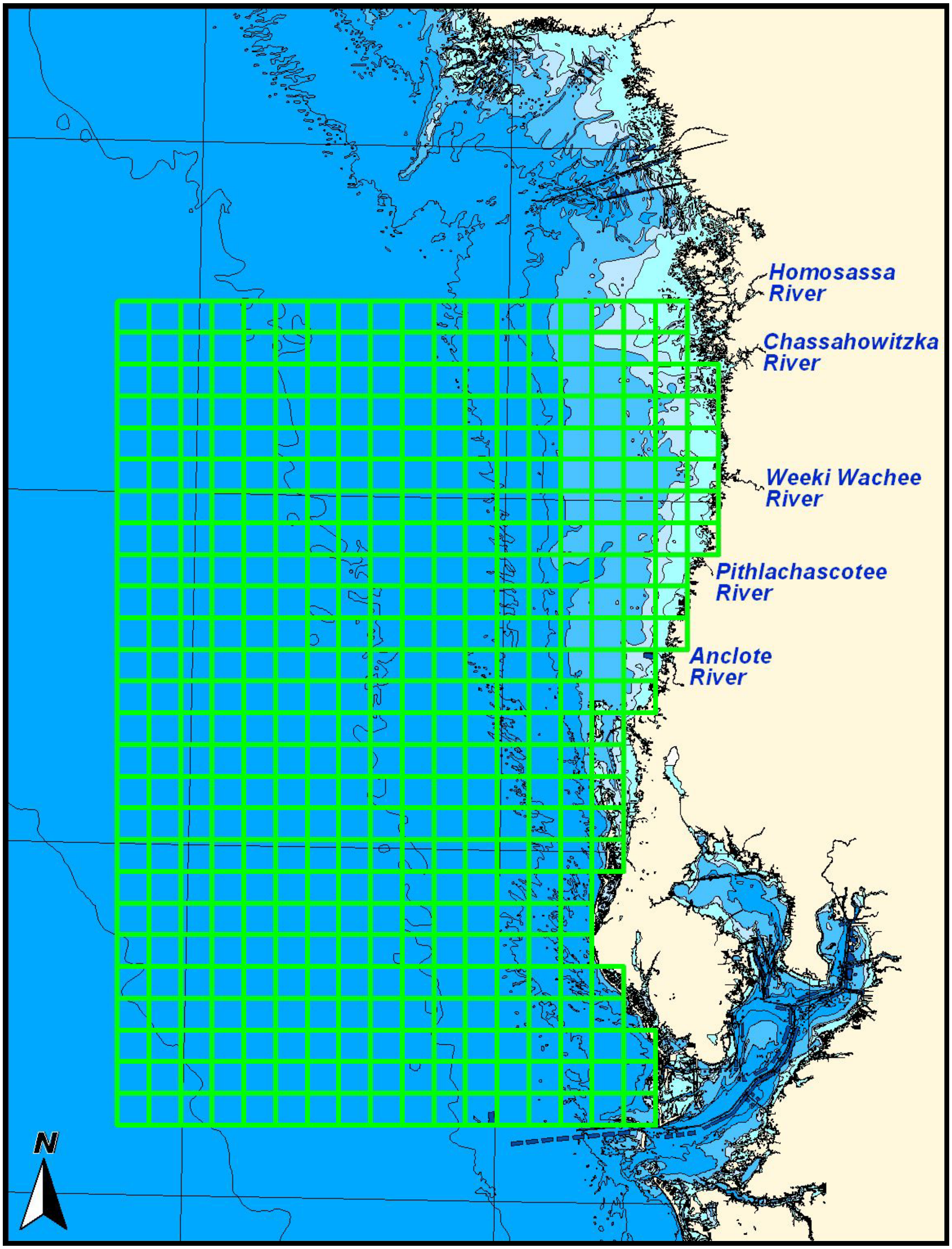

Figure 4.1. Large grid (5 km x 5 km cells) used for Gulf Coast Desalination model, west coast of Florida.

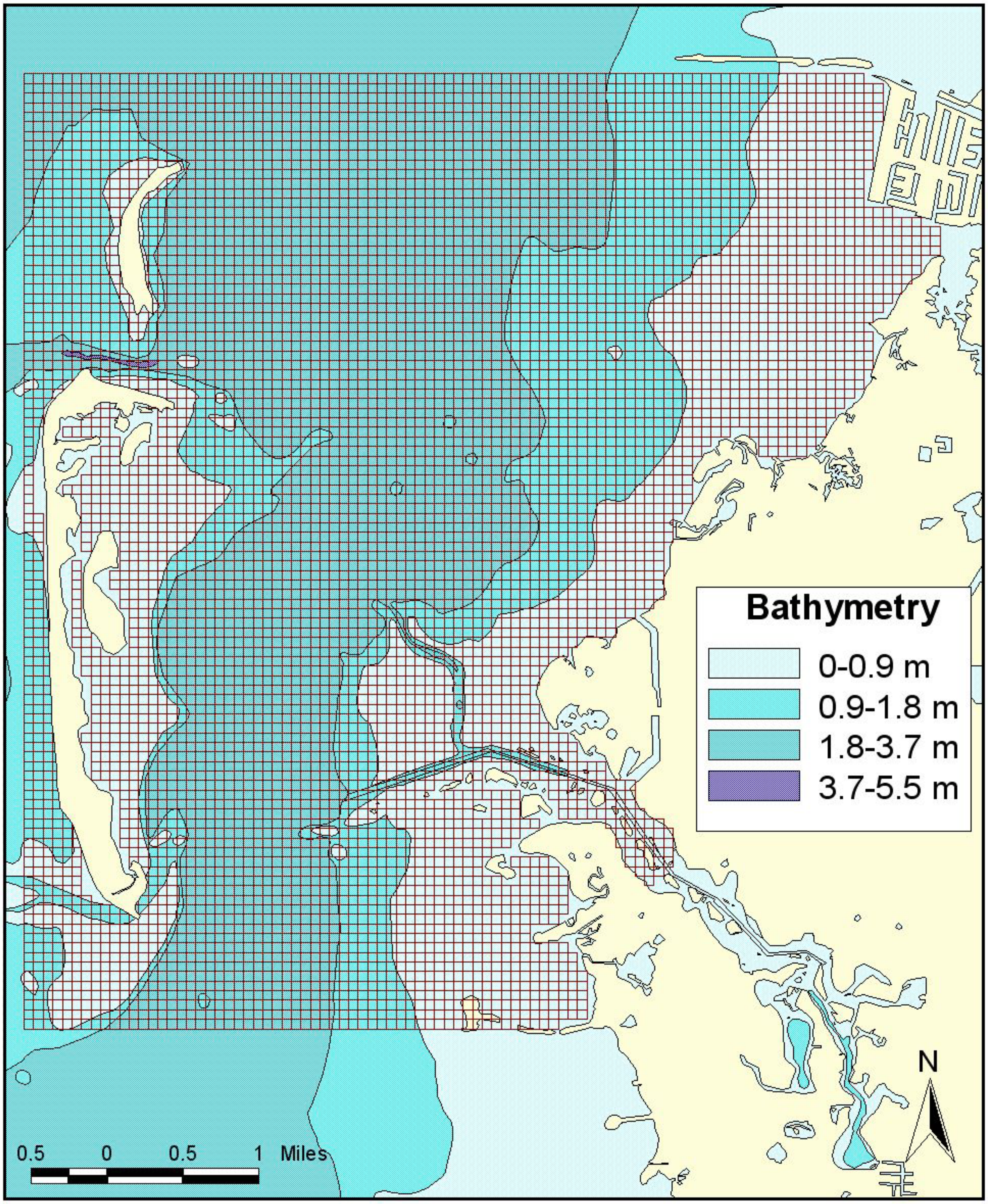

Figure 4.2. Nearshore small grid (100 m x 100 m cells) used for Gulf Coast Desalination model, Anclote Anchorage.

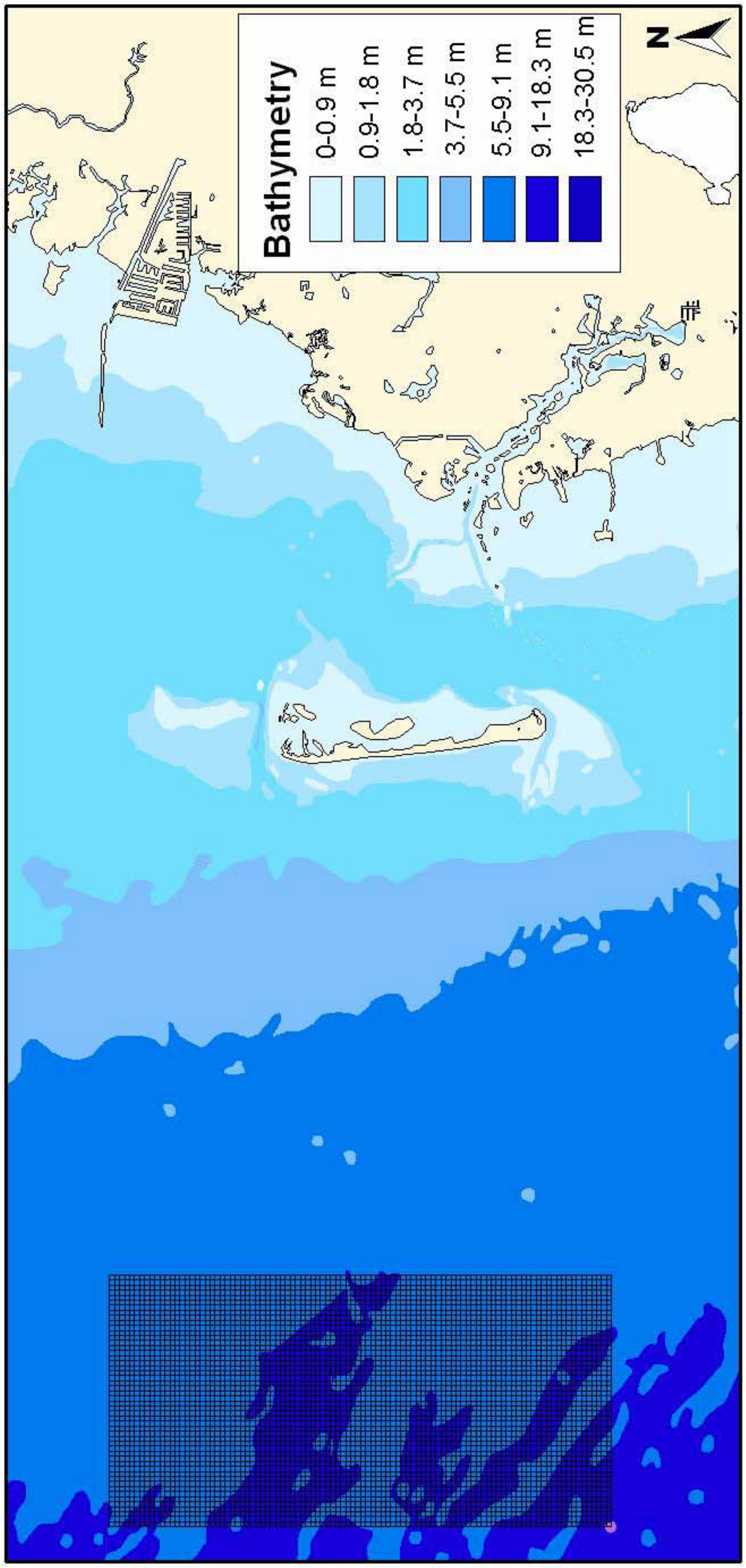

Figure 4.3. Offshore small grid (100 m x 100 m cells) used for Gulf Coast Desalination model.

4.2 Temporal Scale

The model allows predictive output at time intervals as frequently as desired, with a minimum output frequency determined by the time step requirements of the model. For the purposes of tracking changes in temperature, salinity, and water surface elevation for predictive scenario evaluation, the output frequency was set to hourly. This allows identification of differences in scenarios at a frequency less than the tidal cycle, so that short-term changes can be identified. For longer-term evaluations, mean values of model output parameters were compared.

For the scenarios examined, the model provided a year or more of output. Constraints on the model temporal domain were imposed by the availability of data used for initial and boundary conditions for the model. Longer model runs were employed to examine the effects of multi-year discharges from the desalination facility. The time period used for model scenario comparison was June 2001-May 2002.

4.3 Data Sources

Observed data were necessary for use as initial and boundary conditions for the model, and to provide calibration data for comparison to model output. The data used for these purposes are described below.

4.3.1 Initial Conditions and Boundary Conditions Data

Initial and boundary conditions are necessary for temperature and salinity distributions, velocity fields, water surface elevations, and winds. Boundary conditions of freshwater inflow are also necessary from the rivers discharging to the model domain. The cooling water intake by the Anclote Power Station and flow from the discharge canal are also needed. The bathymetry of the spatial domain is necessary as a bottom boundary, as is the shoreline as a lateral boundary.

The bathymetry and shoreline data used in the model construct were obtained from the Florida Marine Research Institute of the Florida Fish and Wildlife Conservation Commission, based on data collected by the National Oceanic and Atmospheric Administration (NOAA). Modifications were made to the shoreline of Anclote Key and the sandbar north of the Key to reflect changes since the NOAA data were collected. These changes were based on aerial photography from 2002.

Water surface elevation data were obtained for use as boundary conditions for the large grid model. Estimated water surface elevation data for Egmont Key, Clearwater Beach, and Homosassa Bay were obtained from a University of South Carolina website, tbone.biol.sc.edu/tide, which utilizes the tide estimation software used by the National Ocean Service. Prior to use, the estimated water surface elevations were compared to observed elevations, and showed only small differences in elevation or timing.

Initial conditions for water temperatures in the large grid mode were set to a constant over the model domain at a value typical for the eastern gulf during the month of January, when the model started. The value used for this initial condition was 20°C, typical for the early winter in the eastern Gulf of Mexico. Large grid model boundary conditions for water temperature were derived from sea surface temperature estimates obtained from the Naval Research Laboratory (NRL) 1/8° Global Coastal Ocean Model. These boundary conditions were at a daily frequency.

Initial conditions for salinity in the large grid model were set to a constant 36 ppt over the model domain. The west coast of Florida shows little variation in salinity, except for small changes in the very near shore area due to freshwater inflow (Orlando et al., 1993). Boundary conditions for salinity for the large grid model were derived from sea surface salinity estimates obtained from the Naval Research Laboratory (NRL) 1/8° Global Coastal Ocean Model. These boundary conditions were at a daily frequency.

Boundary conditions of freshwater inflow to the large grid model domain were estimated using USGS data for the Anclote River, the Pithlachascotee River, the Weeki Wachee River, the Chassahowitzka River, and the Homosassa River. These data were obtained at a daily frequency for the period of the model runs.

Intake and discharge volumes and temperatures for the Anclote Power Station were obtained from Progress Energy Florida. Data were provided at an hourly frequency. These data were used only for the nearshore small grid model.

Wind data were obtained from meteorological monitoring sites at Tarpon Springs, Egmont Key, Clearwater, and in the Gulf of Mexico northwest of Tampa Bay. The shore-based sites are part of the Coastal Ocean Monitoring and Prediction System (COMPS) of the University of South Florida. The Gulf of Mexico monitoring site is operated by the National Data Buoy Center, NOAA, and is located west of the northern portion of the large grid. The data were utilized at an hourly frequency.

4.3.2 Calibration Data

Data were required for comparison to model output so that the model could be tested and revised to the point where it accurately predicted observed conditions given appropriate boundary conditions. The process of model testing and revision is known as model calibration. For the Anclote Anchorage, few data were available for comparison to model results. Therefore, a monitoring program was designed and implemented to provide support for the development of the hydrodynamic model for the Anclote Anchorage.

The monitoring plan included three continuous recorders and 60 hydrolab and current meter sampling sites each month within the Anchorage. Three datasondes were used to collect continuous records of salinity, temperature, and water level (pressure). The datasondes were placed at the entrance of the Anclote Power Station intake canal, at the mouth of the discharge canal, and out in the river channel, as shown in Figure 4.1. Of the 60 hydrolab and current meter sampling sites each month, nine were at the sites of the datasondes, 15 were at the five fixed sites (Sites 4-8) shown in Figure 4.1, and the remainder were from randomly selected points within the nearshore small grid model domain. Monitoring was initiated in November 2001, and continues through the present.

Additional water surface elevation data were obtained for use as calibration data for the model. Estimated water surface elevation data for the north end of Anclote Key and for the south end of the Key were obtained from a University of South Carolina website, tbone.biol.sc.edu/tide, which utilizes the tide estimation software used by the National Ocean Service.

4.4 Model Output Specifications

The purpose of the model is to provide a tool for evaluating potential changes in the hydrodynamics (salinity and circulation) of the two potential discharge areas resulting from various discharge volume and location scenarios. Analyses of changes should be performed on various temporal scales (i.e., daily, monthly) and spatial scales (i.e., large areas around the discharge, very localized areas near the discharge).

To provide for these multiple scale analyses, the model was designed to provide output every hour for every cell in the model domain. Output data were provided for temperature, salinity, and water velocity at five vertical layers, with water surface elevation and vertically integrated water velocity provided at every cell. Output at this frequency and spatial scale allows combining output data in space and/or time.

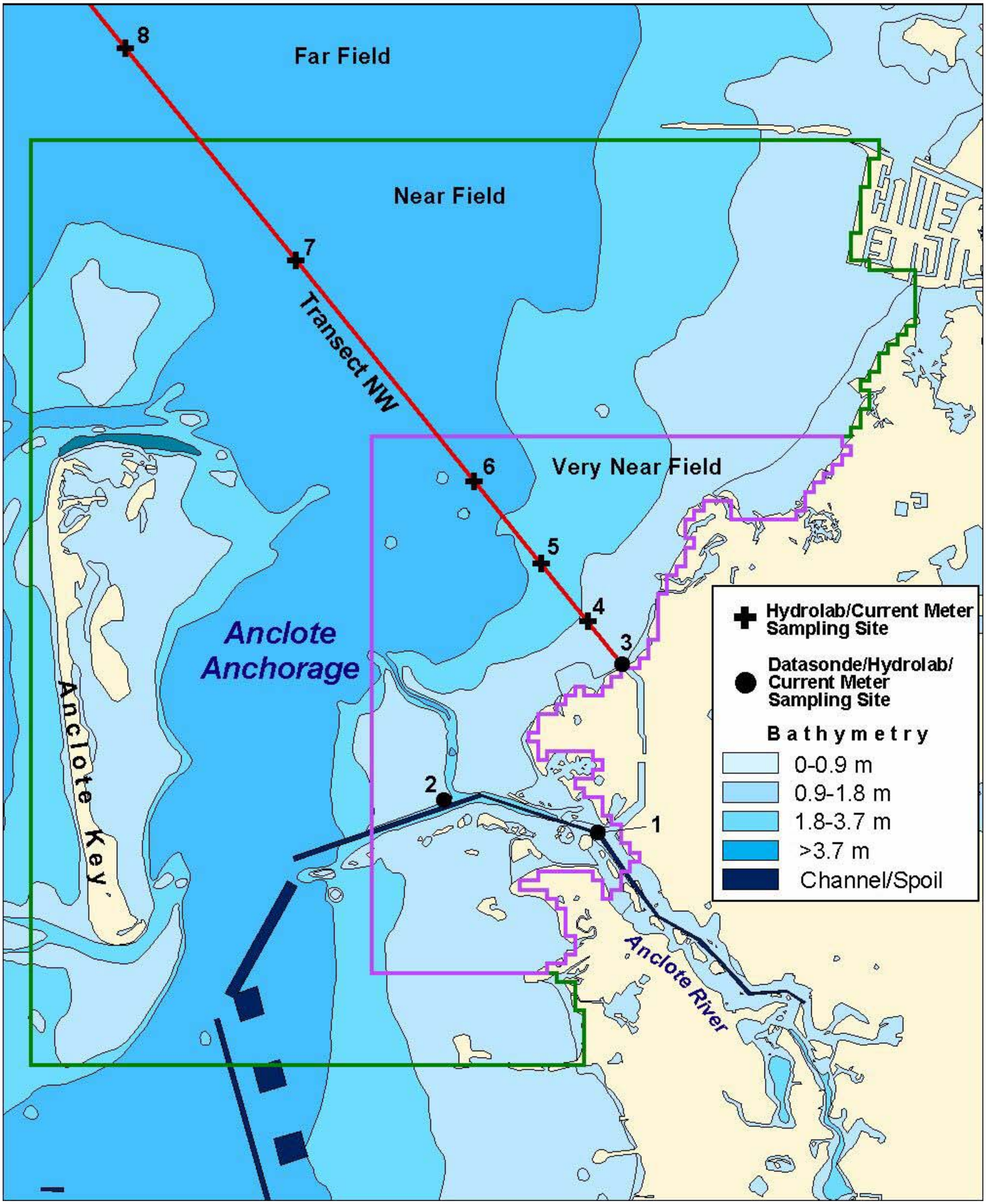

Figure 4.4 Anclote Anchorage monitoring locations, datasondes and fixed stations for hydrolab and current meter.

5.0 Calibration

Calibration of the model is necessary to provide assurance that predicted conditions accurately recreate observed conditions under a given set of forcing functions (freshwater inflow, winds, and tidal conditions). Prior to calibration, criteria must be set to quantify the success of the calibration. The calibration criteria for this model are provided below, followed by the results of the calibration.

5.1 Calibration Criteria

The calibration criteria selected for model development provide indicators of successful attainment of a calibrated model. Other modeling efforts performed to examine the Tampa Bay Desalination project (Blake and Blumberg, 2001; Vincent et al., 2000) compared model results to data to provide quantification of the goodness of fit of the models results. For the Gulf Coast Desalination Model, calibration criteria were chosen using the goodness of fit of the Tampa Bay models as guidelines.

Tampa Bay is a relatively data-dense system for calibration purposes, with long time series of salinity and temperature data (25 years) available over the entire bay, including the mouth of the bay. Also available are multiple water surface elevation sites, including at the mouth of the bay as well, which serves as the downstream boundary condition for the Tampa Bay model.

The Anclote Anchorage, however, has not been included in long-term data monitoring programs. To assist in this modeling effort, a monitoring program was designed and implemented to provide data for use in calibration. Water surface elevation data are collected as part of this monitoring effort within the Anchorage. Additional water surface elevation estimates based on tide algorithms utilized by the National Ocean Service were obtained for select locations for comparison to model predictions.

The Tampa Bay model results reported in Blake and Blumberg (2001) showed errors in water surface elevation of <2% for four stations where data were collected. Because of the much more open boundary conditions of the Anclote Anchorage in comparison to Tampa Bay, and because of the scarcity of observed water surface elevation data in the Anchorage, the water surface elevation calibration criterion was set to <5% for this modeling effort. This criterion may be set to a more restrictive level in the future as model refinement becomes necessary.

The salinity comparison for the Tampa Bay model developed by Blake and Blumberg (2001) showed that salinity errors with respect to observed data were <10% for almost all surface and bottom predictions. This same percentage error, <10%, was used for the calibration criteria for the Gulf Coast Desalination model. The temperature calibration criterion was set to <10% error as well.

In summary, the calibration criteria established for water surface elevation, salinity, and temperature for this model development effort were as follows:

	Mean % Error
Water surface elevation	<5%
Salinity	<10%, surface and bottom
Temperature	<10%, surface and bottom

The mean percentage error is defined as the mean of the residuals divided by the mean of the comparison data. The residual is the difference between the model prediction and the comparison data value.

5.2 Calibration Results

The water surface elevation and salinity and temperature calibration criteria were met by the predictive model. Predicted water surface elevations had a mean error <1% relative to estimated tides at the northern end of Anclote Key, and 3.5% relative to estimated tides at the southern end of Anclote Key. The predicted salinity values had a mean error relative to observed data of 5.6% at the surface and 5.5% at the bottom. However, errors in predicted salinity values increased with increasing proximity to shore, and thus shallower depths, indicating a bias in this area of the model domain. The predicted temperature values had a mean error relative to observed data of 10.0% at the surface and 9.4% at the bottom. The water level calibration and the salinity and temperature calibrations are described more fully below.

5.2.1 Water Level

Comparison of model predictions and estimated water surface elevations at the northern and southern ends of Anclote Key were performed for the time period June 2001 – April 2002. The estimated water surface elevations were derived from the algorithm used by the National Ocean Service for tide predictions, and will be denoted as "observed" elevations for the remainder of this discussion.

Time series plots of predicted and observed water surface elevations are shown in Figures 5.1 and 5.2 for the northern and southern ends of Anclote Key, respectively, during June 2001. These figures show only three days of the eleven-month period examined. The model predictions for the period shown in these figures slightly underestimate the tidal amplitude, but do very accurately simulate the tidal phase. This pattern holds throughout the temporal domain of the model.

A direct comparison of predicted and observed water surface elevations at the northern and southern ends of the Key is provided in Figures 5.3 and 5.4, respectively. As shown in the figures, the predicted water surface elevations are relatively evenly distributed about the observed values. The observed values fall along the 1:1 diagonal line. The accuracy of the tidal phase and amplitude predictions results in a coefficient of determination (r^2) of 0.99 for both comparison sites. For the northern end of the Key, the percent error over the entire year was <1%, while for the southern end of the Key, the percent error was 3.5%. Both these error rates satisfy the calibration criterion of <5% error.

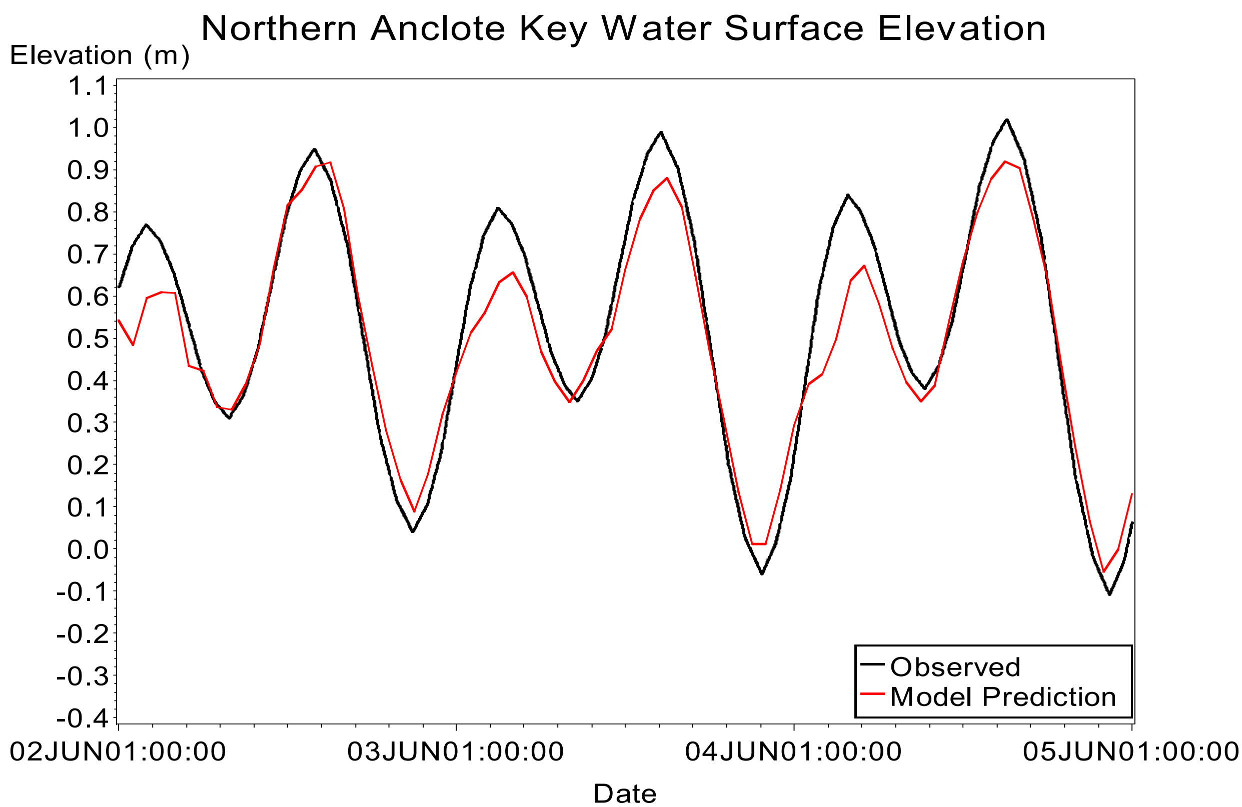

Figure 5.1. Predicted and observed water surface elevation, northern end of Anclote Key.

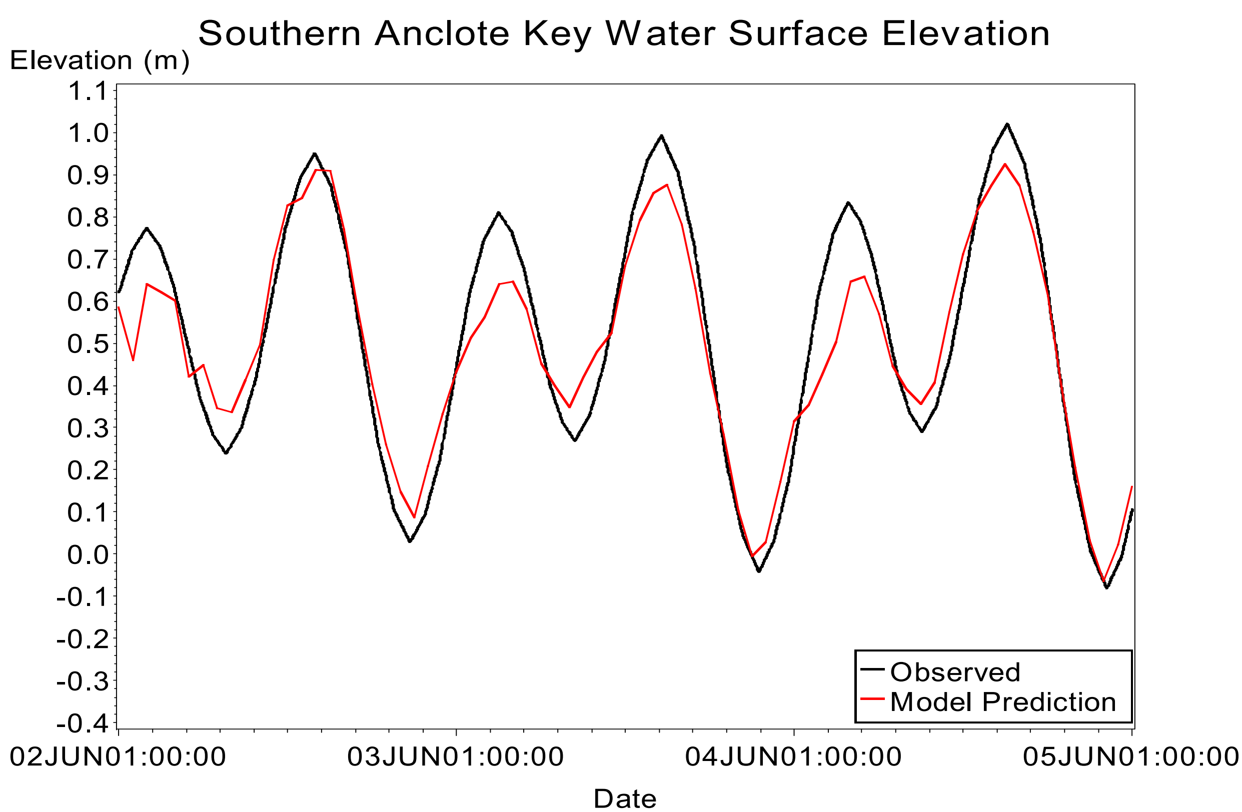

Figure 5.2. Predicted and observed water surface elevation, southern end of Anclote Key.

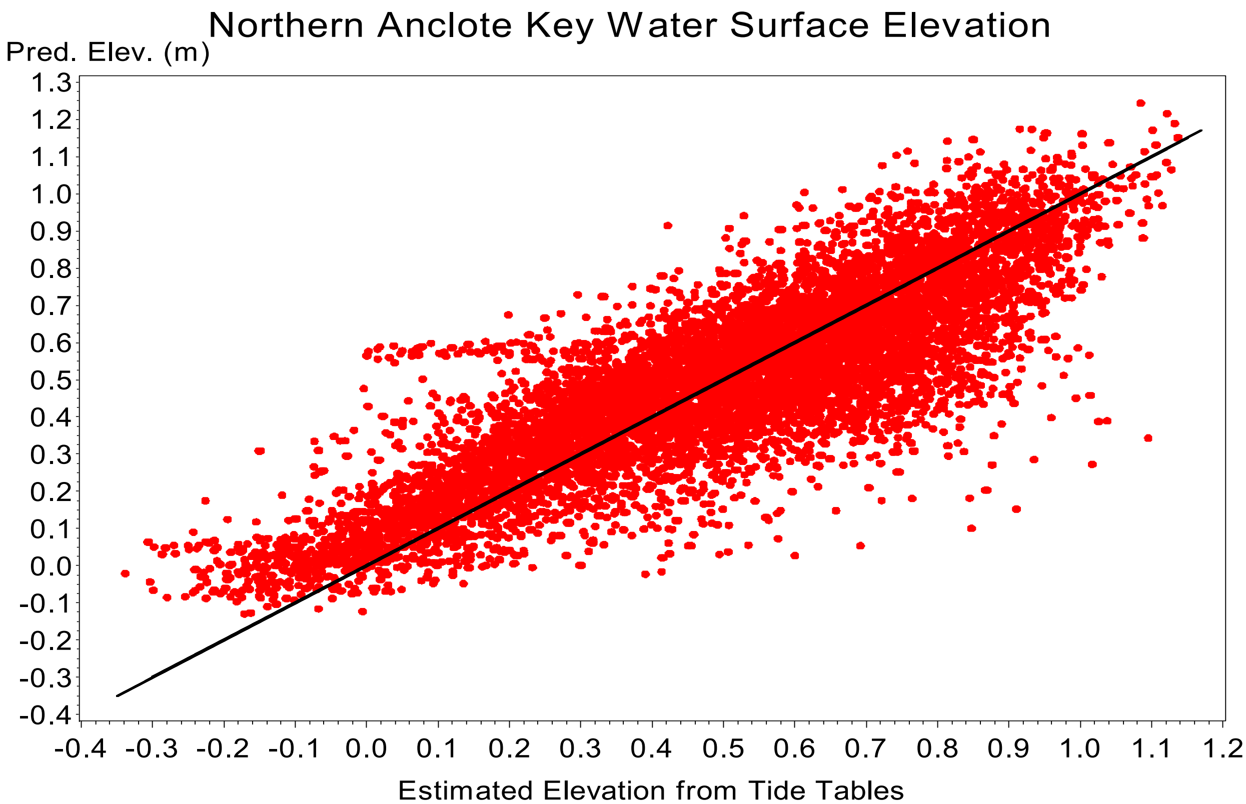

Figure 5.3. Predicted against observed water surface elevation, northern end of Anclote Key.

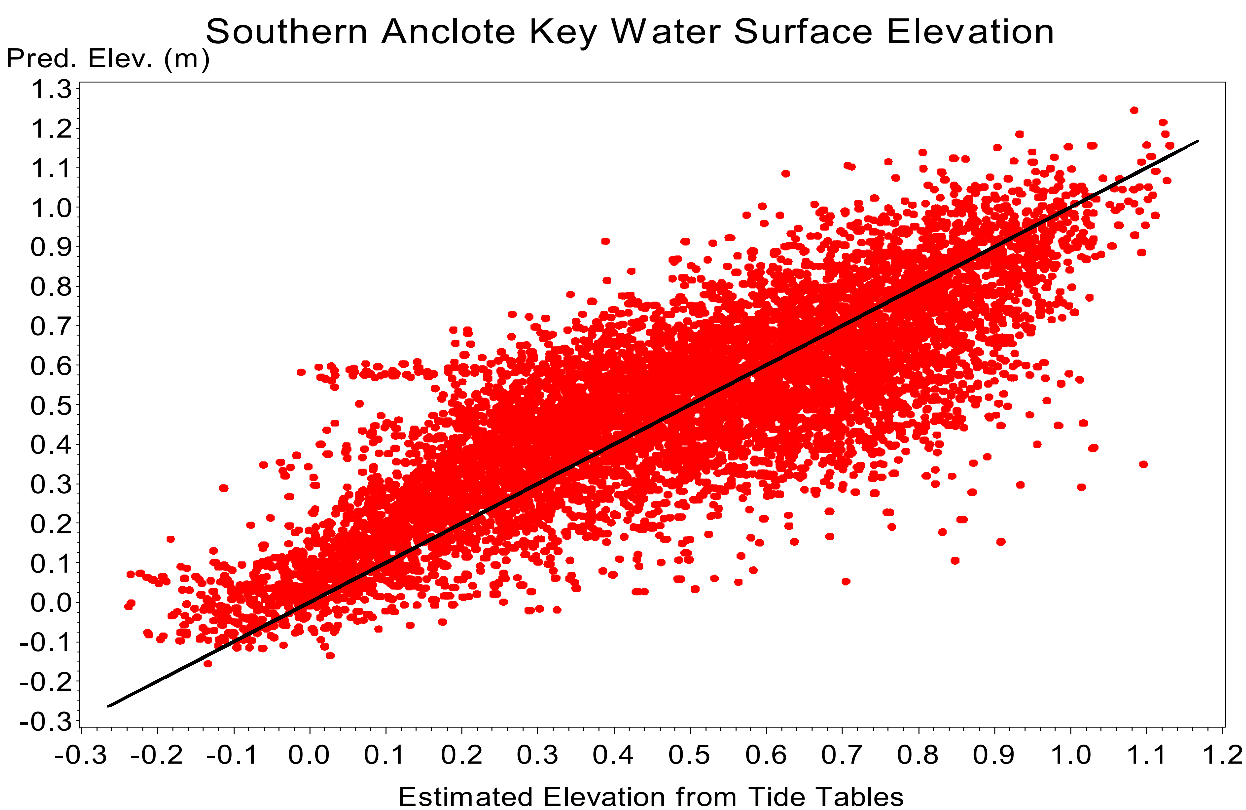

Figure 5.4. Predicted against observed water surface elevation, southern end of Anclote Key.

5.2.2 Salinity and Temperature

Salinity and temperature data were collected as part of the monitoring program designed and implemented in conjunction with model development, as described previously. Data were collected at three continuous recorders, located near the mouth of the power station intake canal, in the dredged river channel offshore, and in the mouth of the power station discharge canal (Figure 4.4). In addition to these data, grab samples were collected throughout the Anchorage during three weeks of every month, on one day each week. Data collection commenced in November 2001. Each month, a total of 60 grab samples were scheduled for collection.

Comparison of model predictions and measured salinity and temperature values from the grab samples were performed for the time period January 2002 – May 2002. The observed salinity and temperature values used were those collected at the randomly generated monitoring sites in the Anchorage. A map of the sites used in this analysis is shown in Figure 5.5 below.

Predicted surface and bottom salinities had overall errors of 5.6% and 5.5%, respectively. For temperature, the errors were 10.0% for surface and 9.4% for bottom.

The predicted salinity values were also compared to the observed values from the grab samples for each month, January-May 2002, to check for monthly variation in predictive capability. The percentage error decreased for each month, with January having the greatest error and May the least. A similar decline in percent errors by month was found for temperature.

A comparison of predicted salinity values to observed values by distance of the grab sample from the mainland shore was also performed. The results of this analysis suggested that model salinity values closest to the shore, in the shallow area of <3 ft MLLW (Figure 2.1), were over-predicting observed salinity values by approximately 10% or less. In the deeper areas, the model still slightly over-predicts observed salinity, but only by 5% or less.

Comparison of the data collected at one continuous recorder in the Anchorage, CR 2 located in the river channel offshore (Figure 4.4) to the predicted salinity and temperature data at that point was also completed. The continuous recorder data record prior to May 2002 was suspect, so only those data collected in May and June 2002 were used for comparison. The May salinity data were also unreliable, so that the salinity comparison is for June 2002 and the temperature comparison is for May and June 2002.

Time series of predicted and observed salinity and temperature data at the continuous recorder are provided in Figures 5.6 and 5.7, respectively. During the period shown, the percent error for salinity predictions was <1%, and for temperature predictions was 6.8%. These error rates are within the calibration criteria for salinity and temperature.

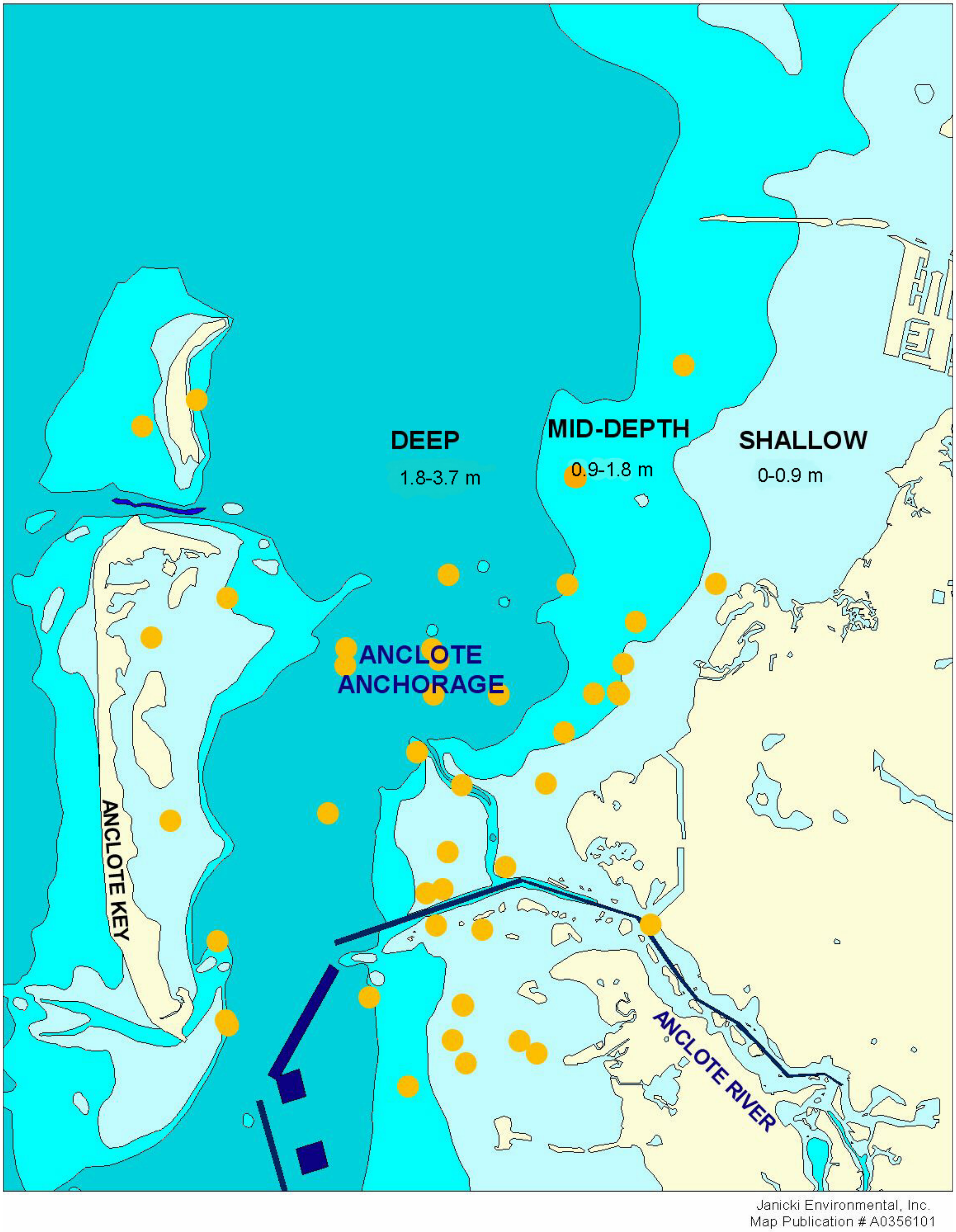

Figure 5.5. Locations of grab samples used in salinity and temperature calibration.

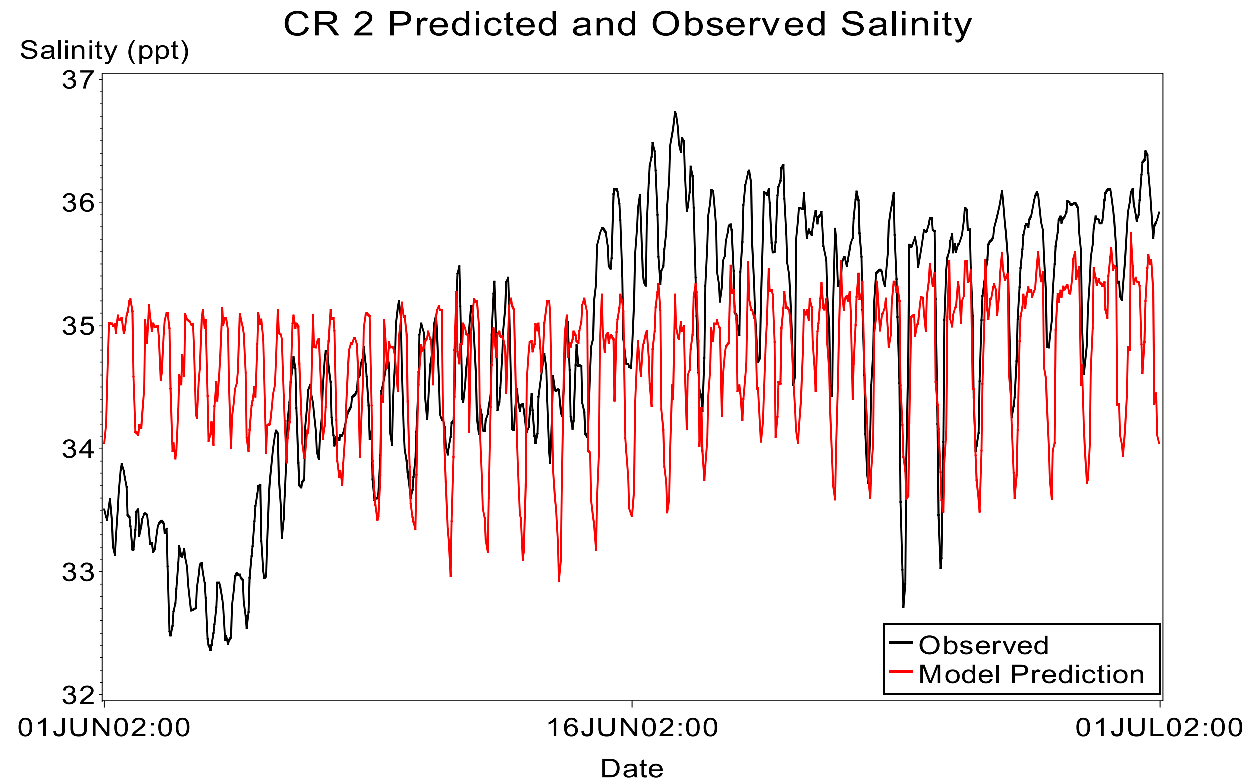

Figure 5.6. Comparison of predicted and observed salinity values at Continuous Recorder 2 in the Anchorage.

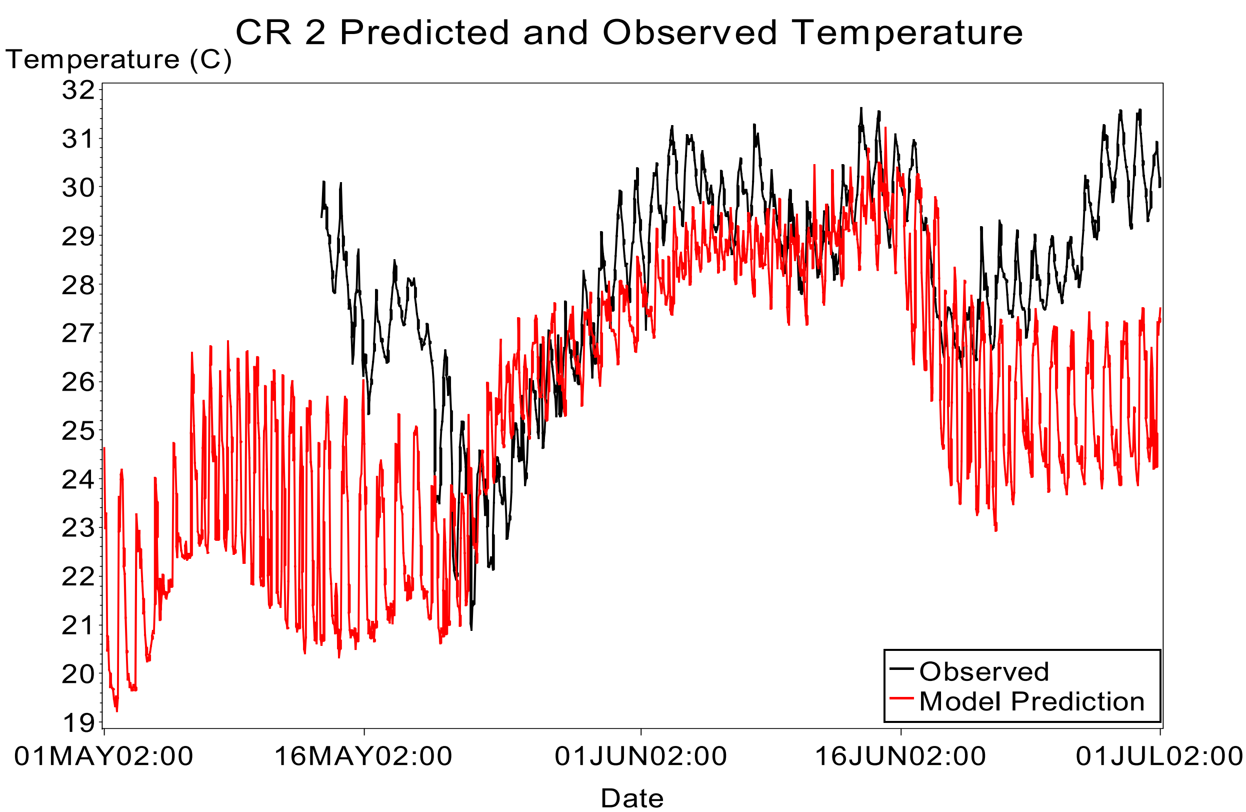

Figure 5.7. Comparison of predicted and observed temperature values at Continuous Recorder 2 in the Anchorage.

5.3 Calibration Conclusions

The calibrated model met the calibration criteria set prior to the calibration process. Given the relatively small amount of data available for this calibration, some degree of bias was expected. A consistent bias of a sufficiently small degree was deemed acceptable, as the results from each product water scenario would reflect this bias, and allow comparison of relative changes in conditions expected. Comparison of predicted and observed salinity values on a monthly basis suggested that the model over-predicts salinity most severely in January, with the percent error decreasing through May. Additional comparisons suggest that the model over-predicts salinity in the shallow nearshore area of the model domain as well.

The over-prediction of salinity may be a result of incomplete inclusion of freshwater inflow points along the shoreline to the model domain. In its current formulation, the model domain only receives freshwater inflow from the Anclote River and the discharge canal. Additionally, the estimate of freshwater inflow from the Anclote River, based on USGS estimated flow at Elfers and a watershed area ratio, may be inaccurate.

The model in its current state does allow comparison of the relative effects of desalination operations on the receiving water bodies (the Anchorage or the offshore region). It is expected that predicted changes in salinity values resulting from the discharge of concentrate will be of the correct magnitude. Thus, this model will allow the relative effects of various concentrate discharge scenarios to be evaluated.

6.0 Model Application

The nearshore and offshore small grid models were driven by boundary conditions supplied from the large grid model (Figure 6.1), as described previously. The output of the large grid model included temperature, salinity, water surface elevation, and currents along the boundaries of the nearshore and offshore small grids. The small grid models allowed better resolution in the areas of interest, the Anchorage and the potential offshore discharge site, to better understand the potential influence of the desalination concentrate discharged. A baseline model run was executed so that comparisons could be made to the potential product water and discharge location scenarios. Tampa Bay Water provided the scenarios to be tested: 10, 15, 18, 21, and 25 MGD of product water from the desalination facility.

To allow sufficient model spin-up time for conditions to equilibrate, the models were run for longer than the period of interest and predicted data from the spin-up time were discarded. The large grid model was run for the period January 2001 through May 2002. The small grid models were run from February 2001 through May 2002. Model predictions presented in this report cover the period June 1, 2001 to May 31, 2002. Daily mean predicted salinity values were calculated from the hourly model output for the nearshore and the offshore models.

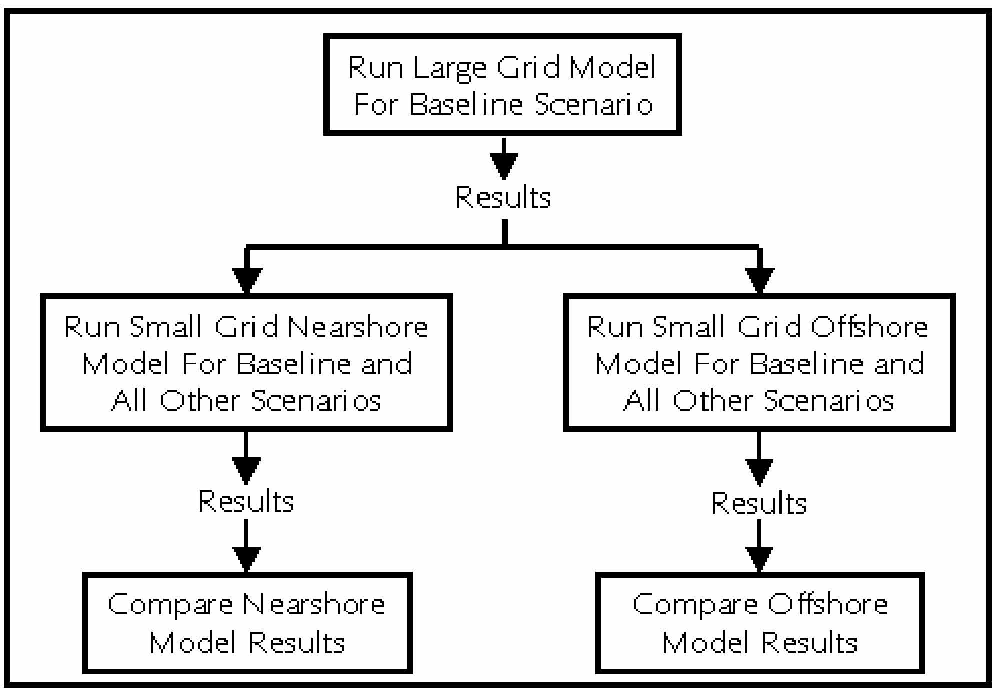

Figure 6.1. Conceptual diagram of application of the hydrodynamic model.

Based on the seasonal signal of freshwater input and power plant cooling water discharge, it is expected that the dry winter months are the period when the greatest predicted salinity changes occur. It is also expected that the 25 MGD product water scenario should result in the greatest change in salinity, in both the nearshore and offshore environments. During the wet season (summer), when freshwater input is high and cooling water discharge is greatest, it is likely that the predicted changes in salinity will be least for all product water scenarios.

6.1 Nearshore

For the nearshore discharge alternative, concentrate from the desalination facility will be mixed with the cooling water from the power station prior to being discharge into the Anclote Anchorage. This provides for an initial level of dilution of the concentrate before it is further diluted when discharged into the Anchorage. For the nearshore alternative, models runs were executed for the baseline condition scenario, and for 10 MGD, 15 MGD, 18 MGD, 21 MGD and 25 MGD product water scenarios. Each of these runs was for a one-year periods.

To address concerns about potential increases in salinity over longer time periods, a five-year 25 MGD product water scenario was also included. The results of this scenario are provided following those of the one-year scenarios.

Each of the product water scenarios utilizes an efficiency factor of 0.385 for conversion of saltwater to freshwater. This results in the concentrate having a salinity of 1.625 times the intake water salinity. For example, if the intake salinity is 33 ppt, the resultant salinity in the concentrate would be approximately 53.6 ppt. The concentrate is then mixed with the cooling water discharge prior to release into the discharge canal. Given a cooling water flow of 1000 MGD, a concentrate volume of 40 MGD for a 25 MGD product water scenario, and an intake salinity of 33 ppt, the resultant salinity of the discharge stream would be 33.8 ppt, or 0.8 ppt greater than the intake salinity.

6.1.1 Nearshore – Baseline Scenario

The nearshore baseline scenario has no input of concentrate from the desalination facility, and is representative of conditions in the Anchorage during the June 2001 through May 2002 period. This scenario was run in order to compare results of the product water scenarios to a set of baseline conditions.

6.1.1.1 Nearshore – Baseline Salinity

The statistics for the daily mean predicted salinity values over the entire Anchorage for the nearshore baseline model are summarized in Table 6.1. Mean values are estimated as volume-weighted means, as the water column depths in each grid cell are different. The mean, extrema, and standard deviation of the predicted daily salinity values for the surface and bottom layers are very similar in this relatively shallow, typically well-mixed environment. Predicted monthly mean salinity maps for all months for the surface and bottom layers, are presented in Figures 6.2-6.25.

Table 6.1. Statistics for the daily mean predicted salinity for the nearshore baseline scenario.

Layer	N	Mean	Standard Deviation	Minimum	Maximum
Surface	365	34.9 ppt	0.3 ppt	33.9 ppt	35.9 ppt
Bottom	365	35.0 ppt	0.3 ppt	34.3 ppt	35.9 ppt

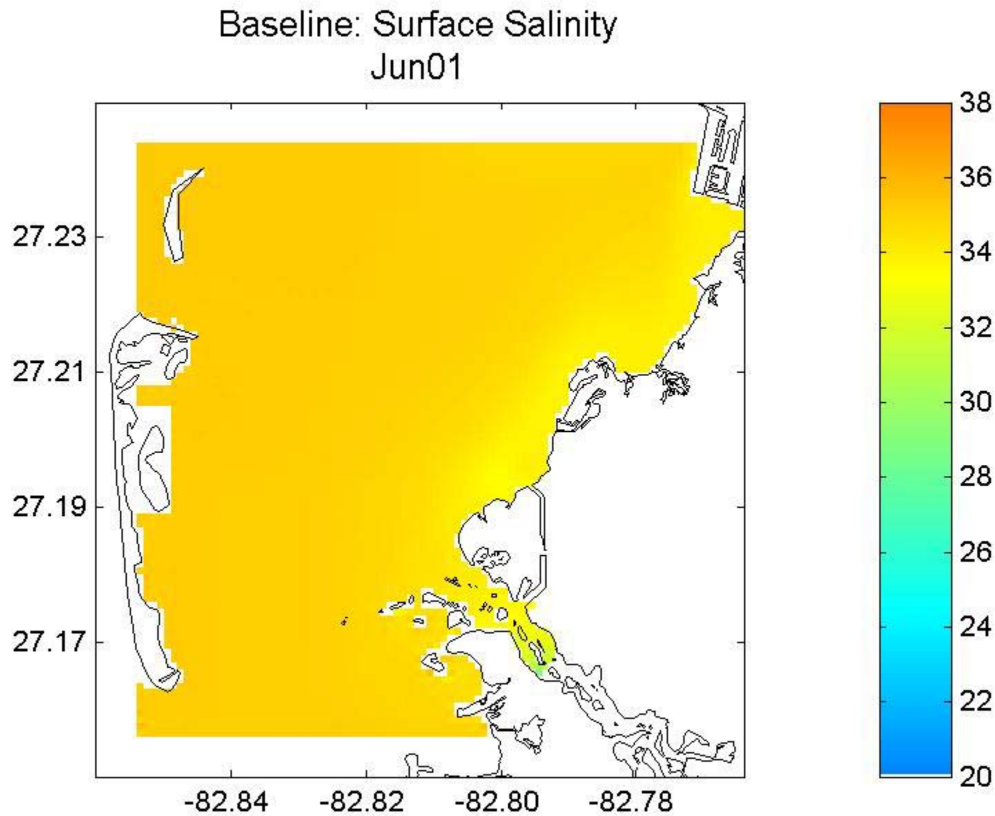

Figure 6.2. Predicted monthly mean surface salinity, baseline scenario, June 2001.

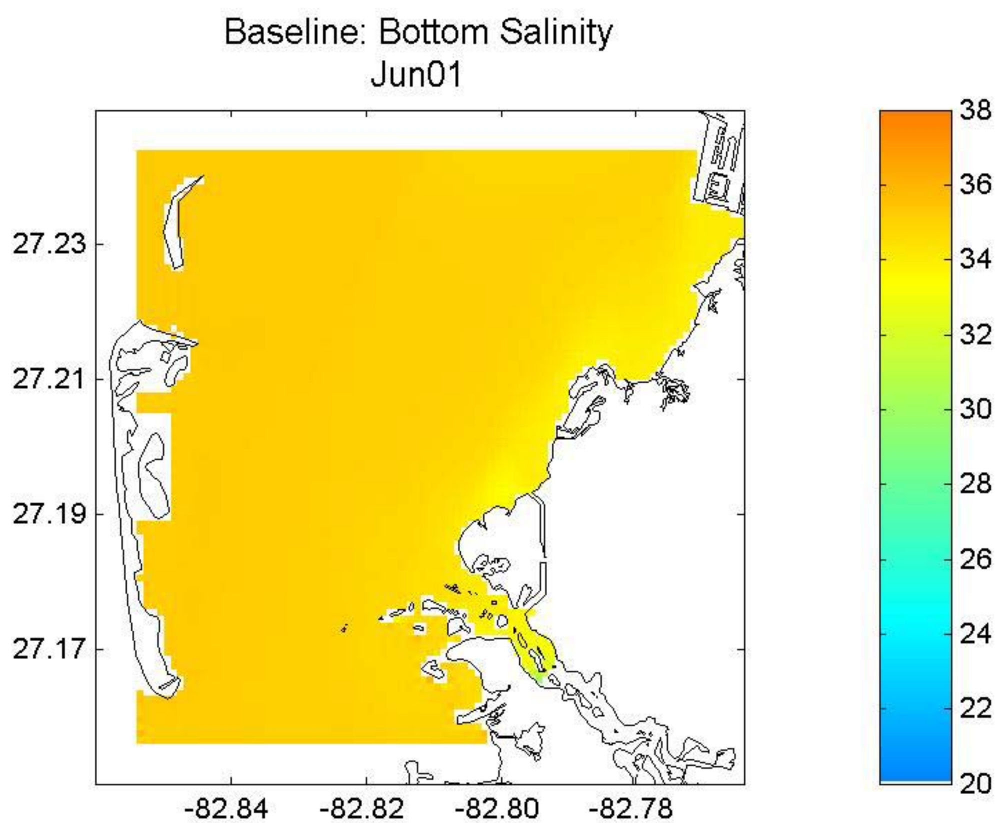

Figure 6.3. Predicted mean monthly mean bottom salinity, baseline scenario, June 2001.

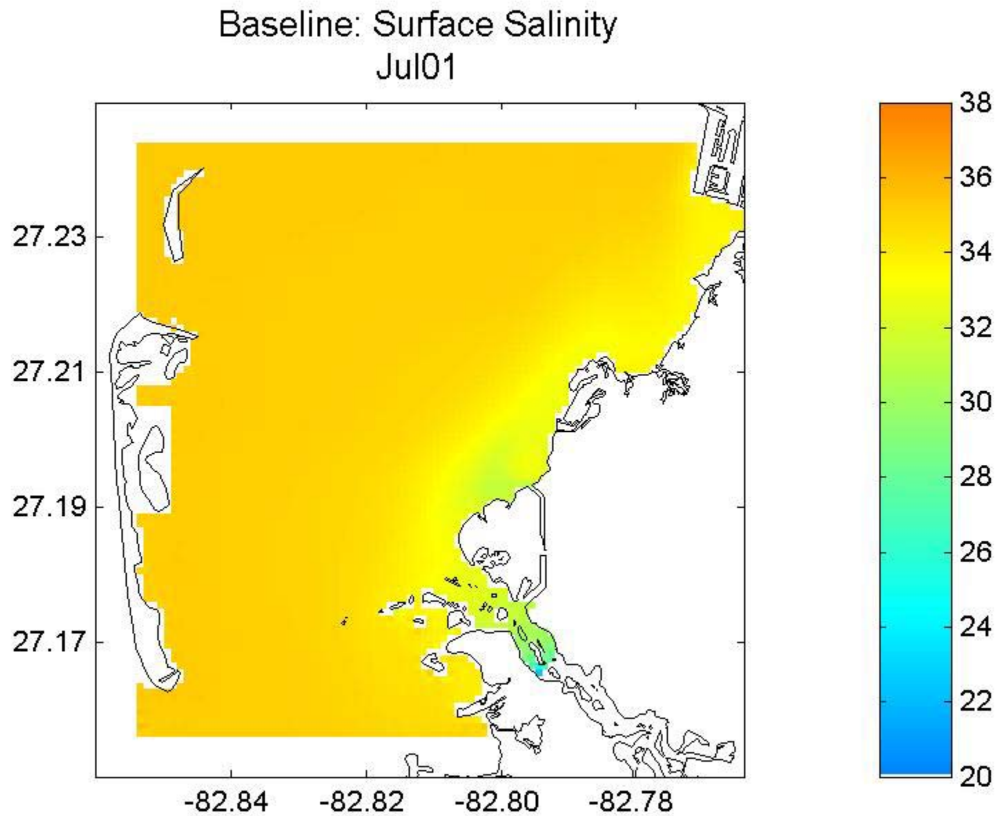

Figure 6.4. Predicted monthly mean surface salinity, baseline scenario, July 2001.

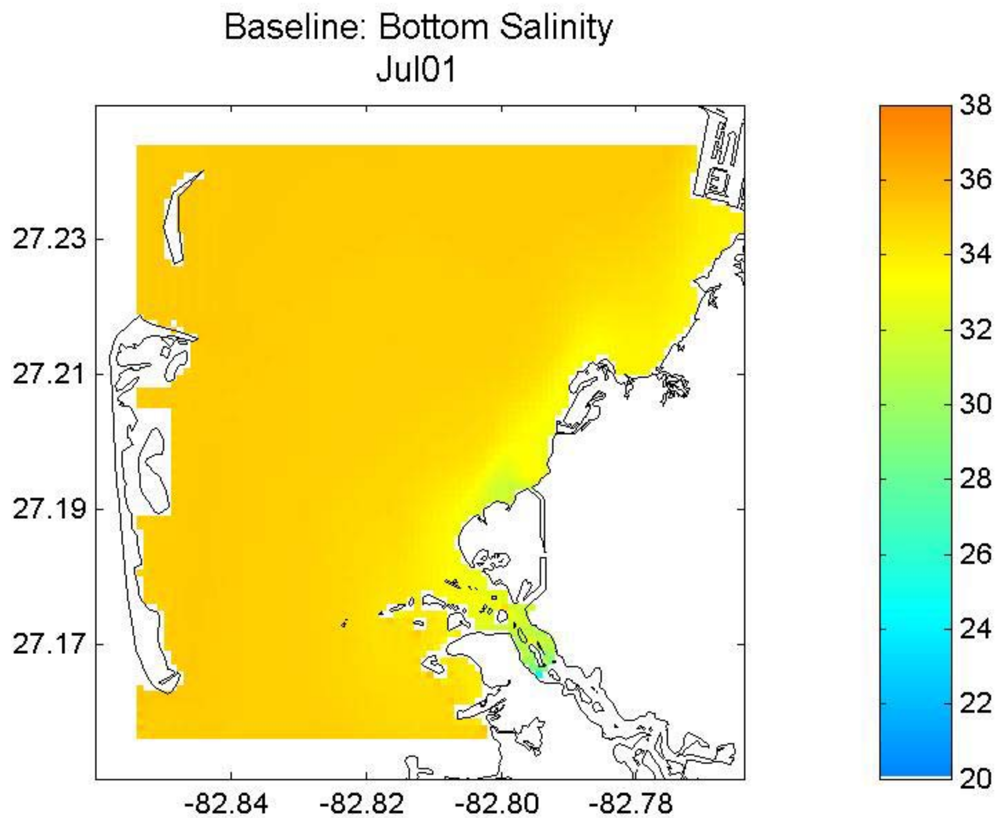

Figure 6.5. Predicted monthly mean bottom salinity, baseline scenario, July 2001.

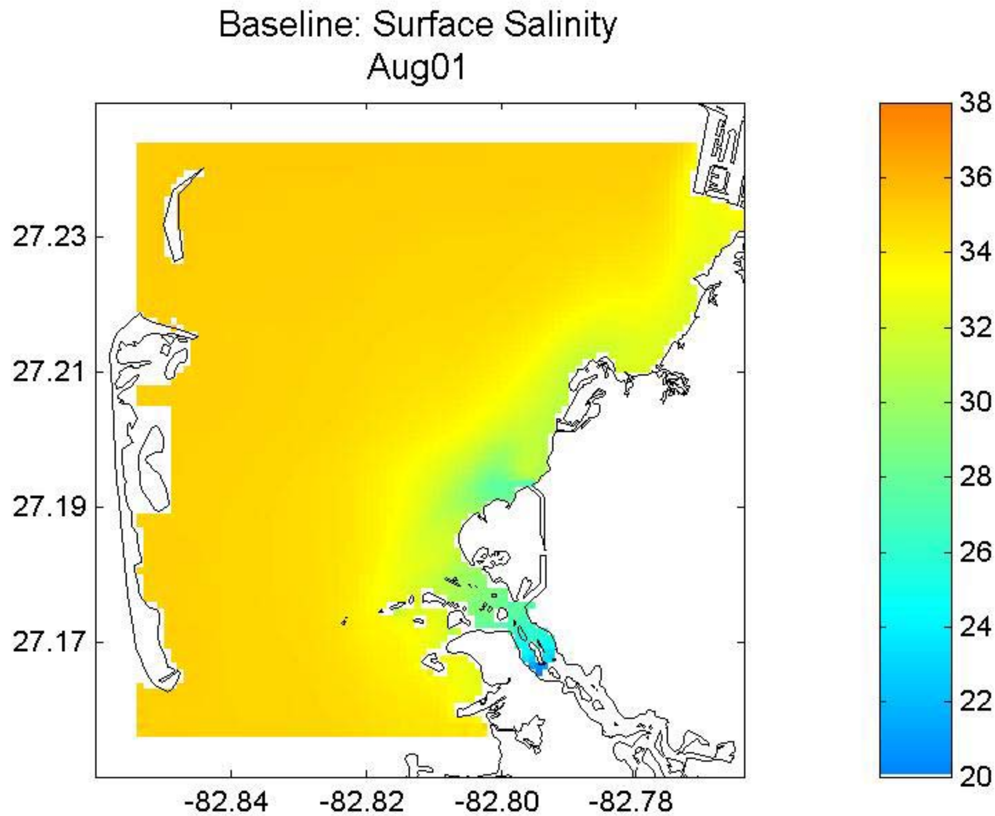

Figure 6.6. Predicted monthly mean surface salinity, baseline scenario, August 2001.

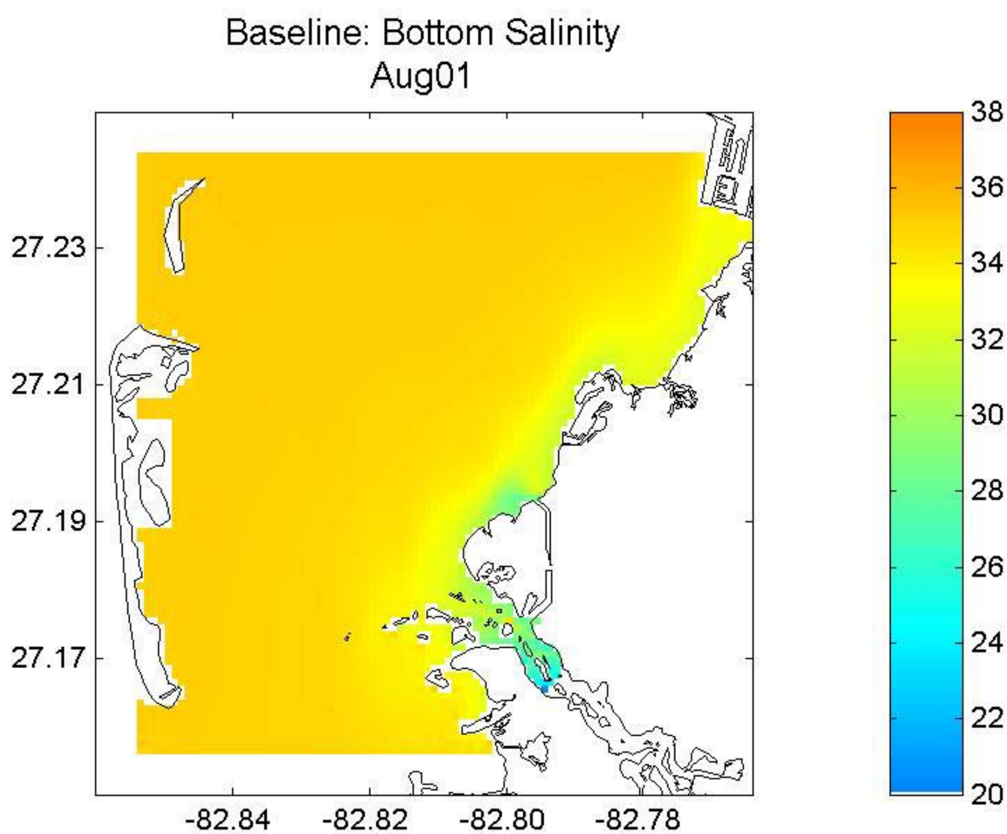

Figure 6.7. Predicted monthly mean bottom salinity, baseline scenario, August 2001.

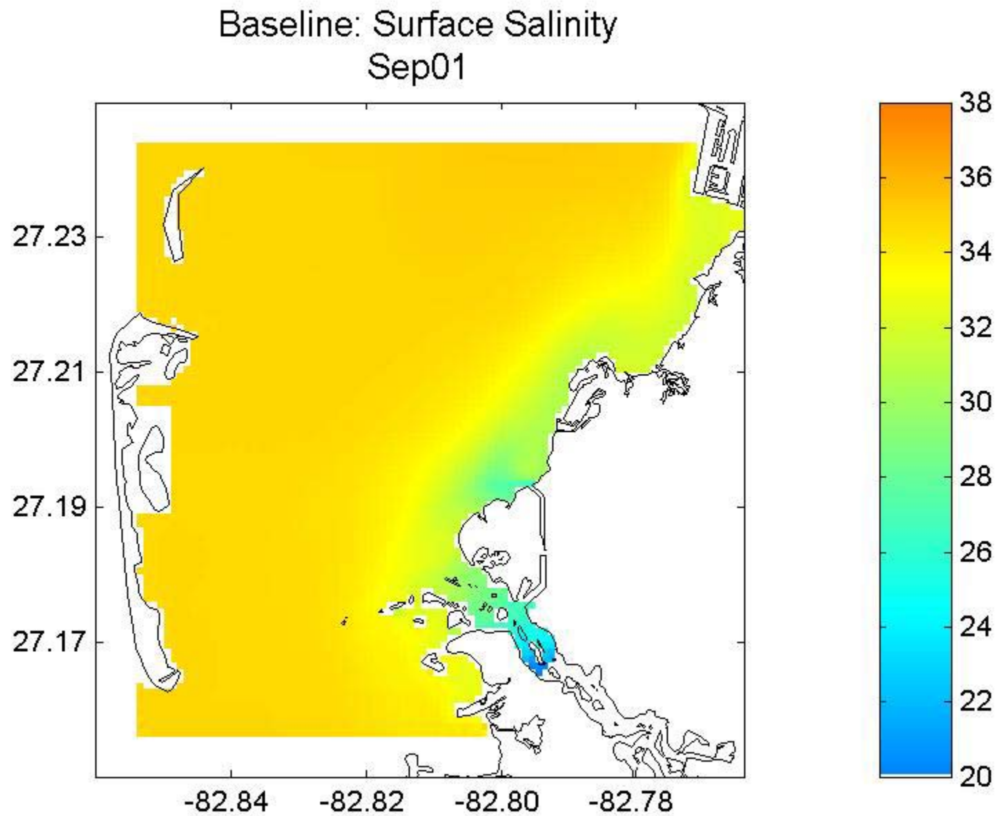

Figure 6.8. Predicted monthly mean surface salinity, baseline scenario, September 2001.

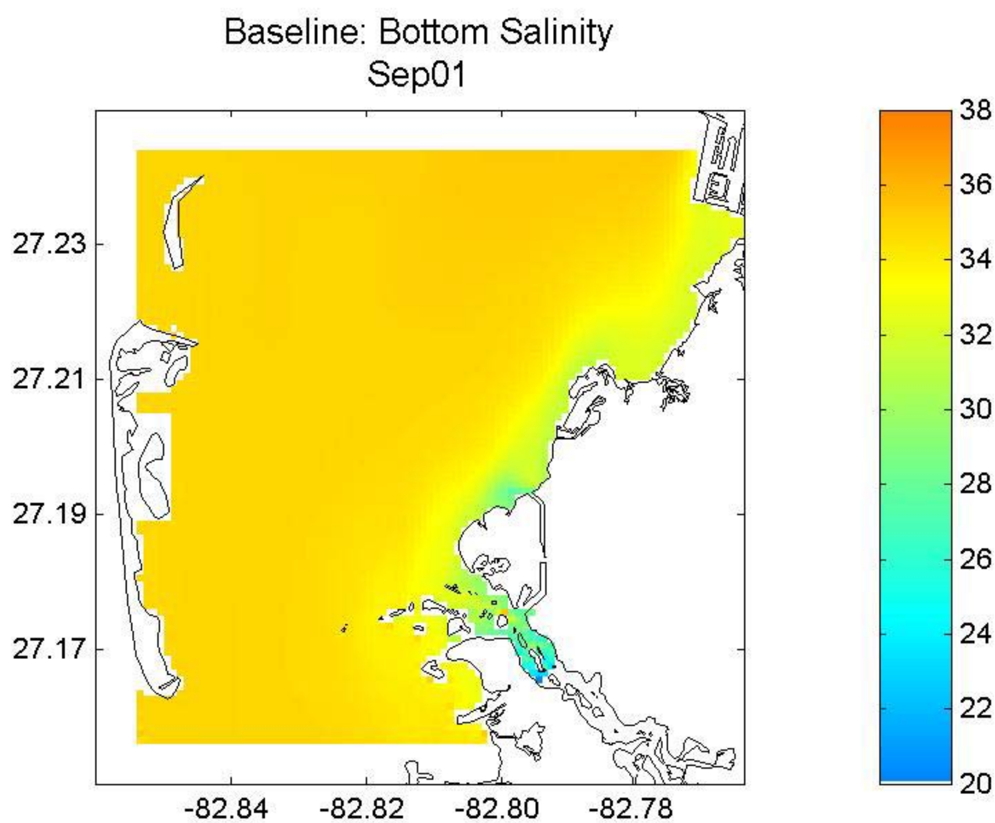

Figure 6.9. Predicted monthly mean bottom salinity, baseline scenario, September 2001.

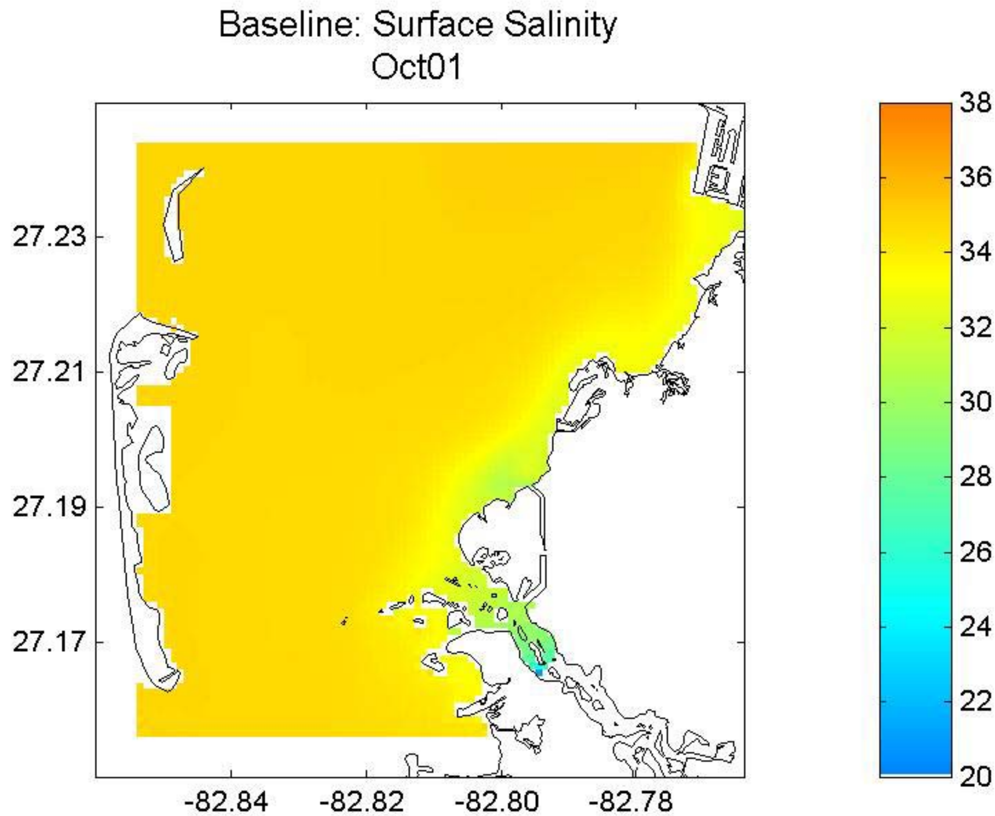

Figure 6.10. Predicted monthly mean surface salinity, baseline scenario, October 2001.

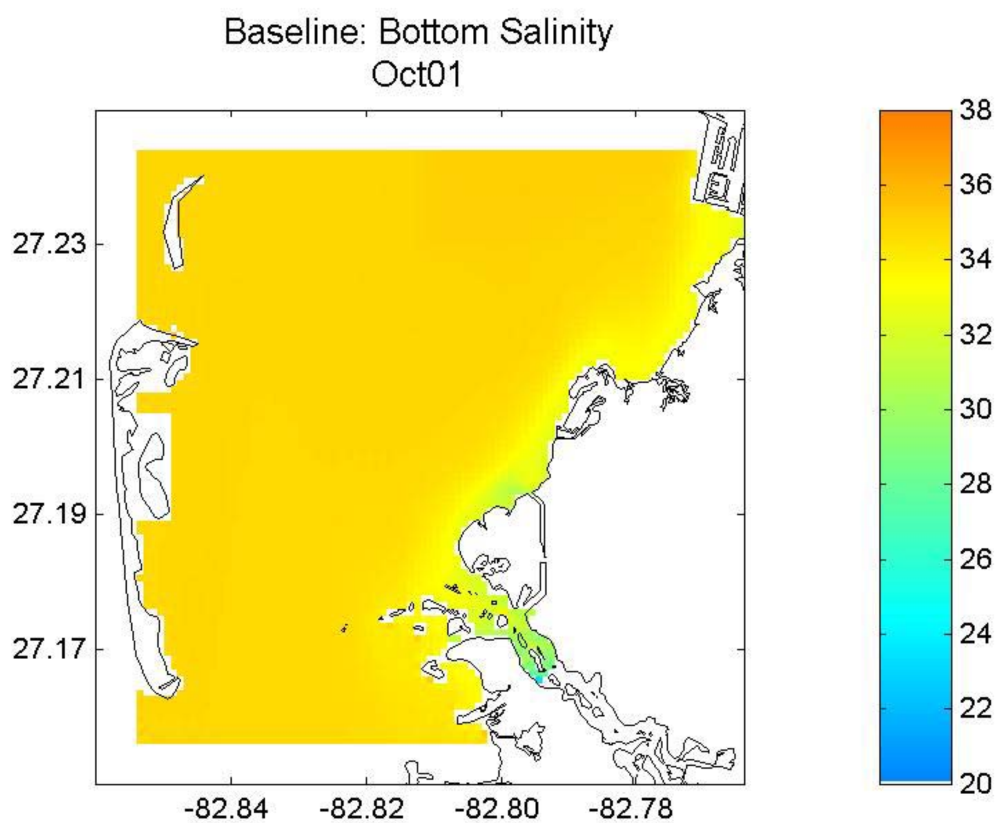

Figure 6.11. Predicted monthly mean bottom salinity, baseline scenario, October 2001.

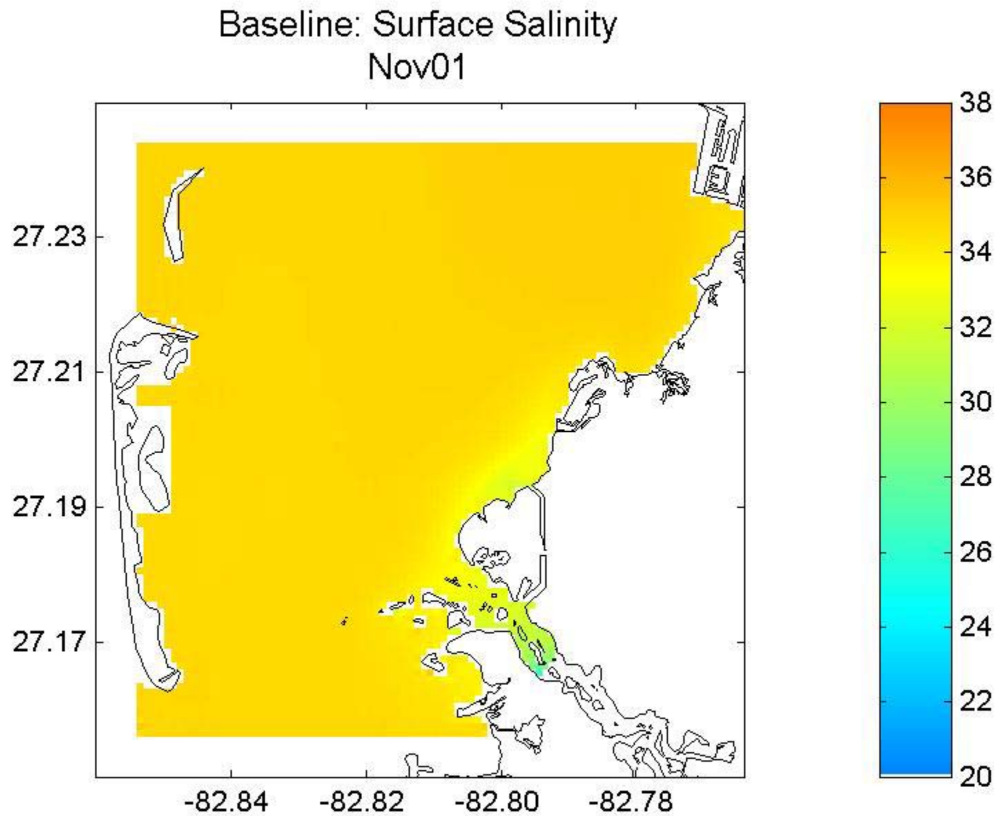

Figure 6.12. Predicted monthly mean surface salinity, baseline scenario, November 2001.

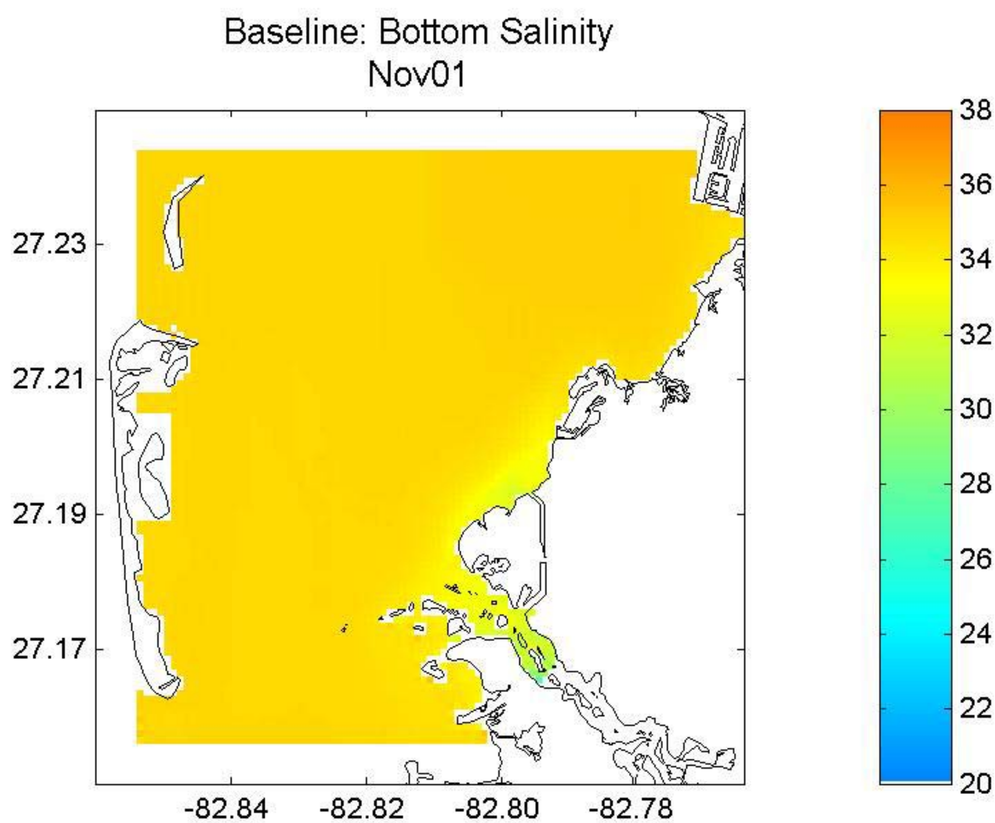

Figure 6.13. Predicted monthly mean bottom salinity, baseline scenario, November 2001.

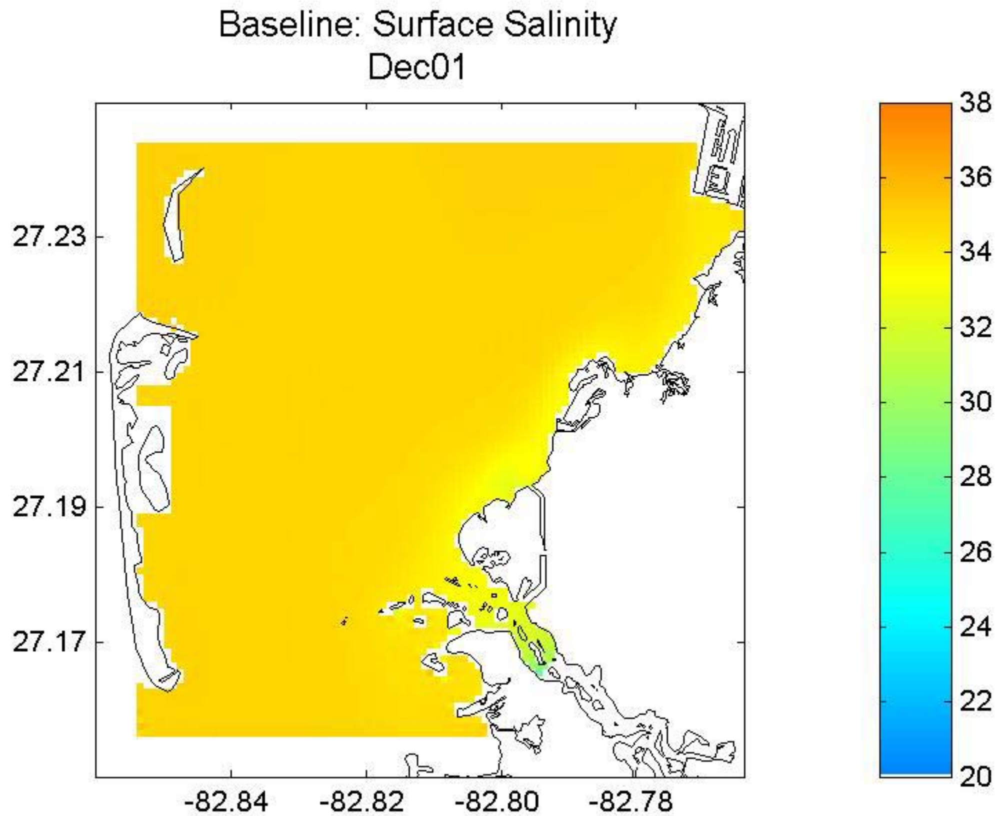

Figure 6.14. Predicted monthly mean surface salinity, baseline scenario, December 2001.

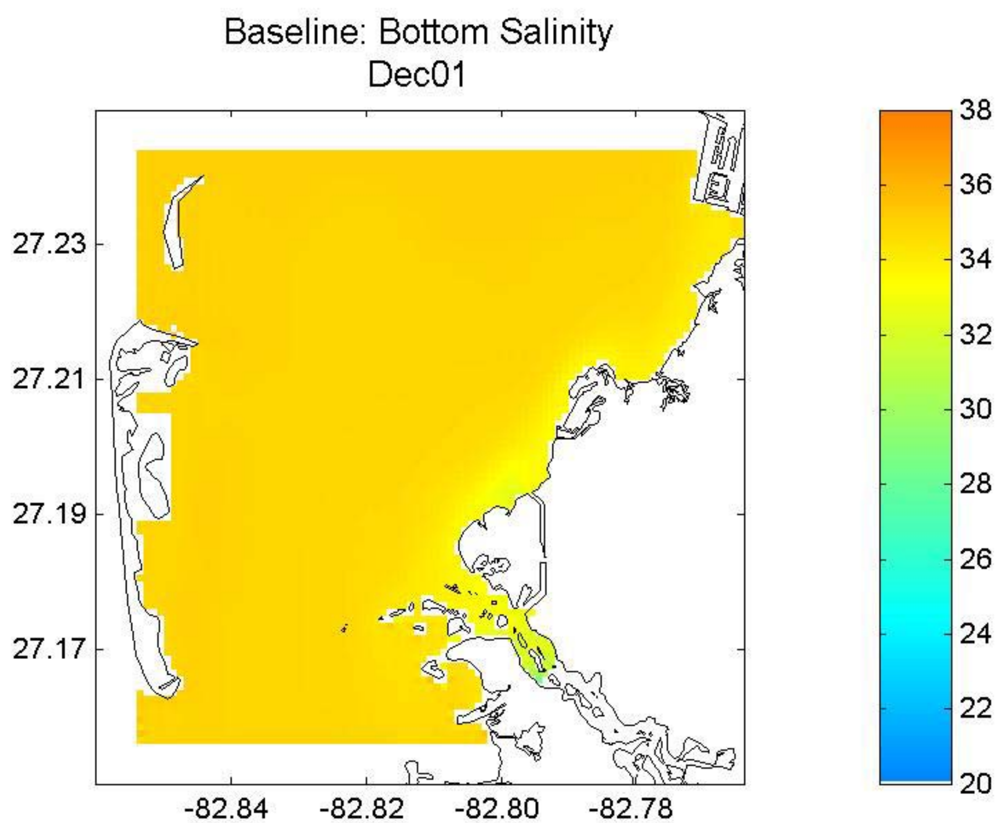

Figure 6.15. Predicted monthly mean bottom salinity, baseline scenario, December 2001.

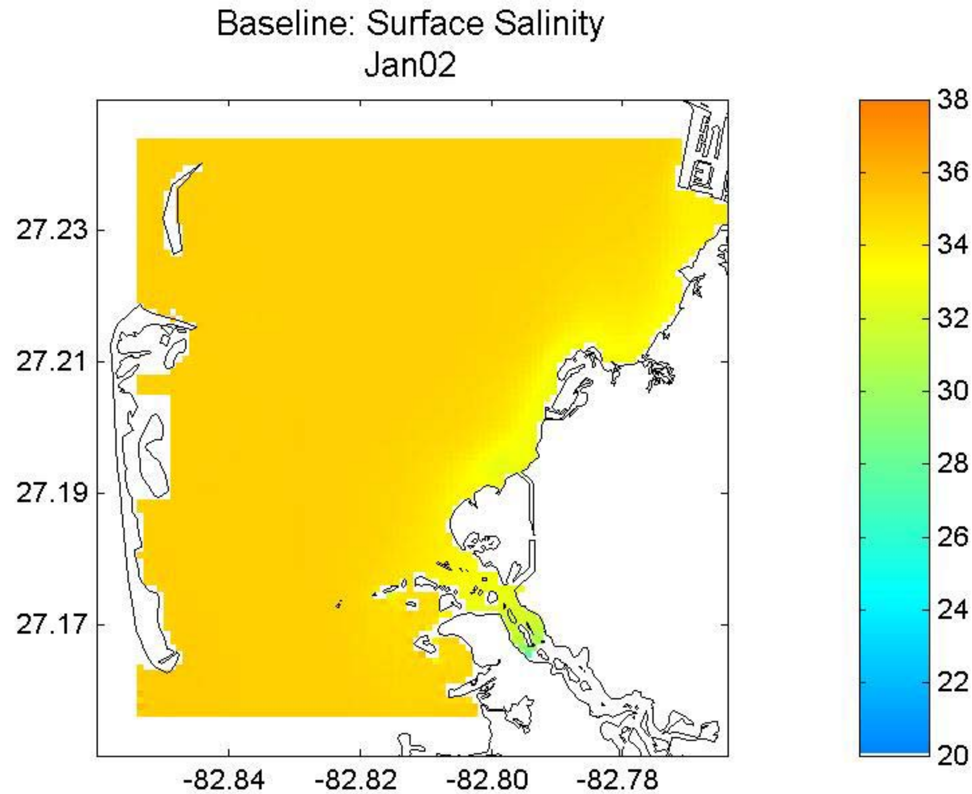

Figure 6.16. Predicted monthly mean surface salinity, baseline scenario, January 2002.

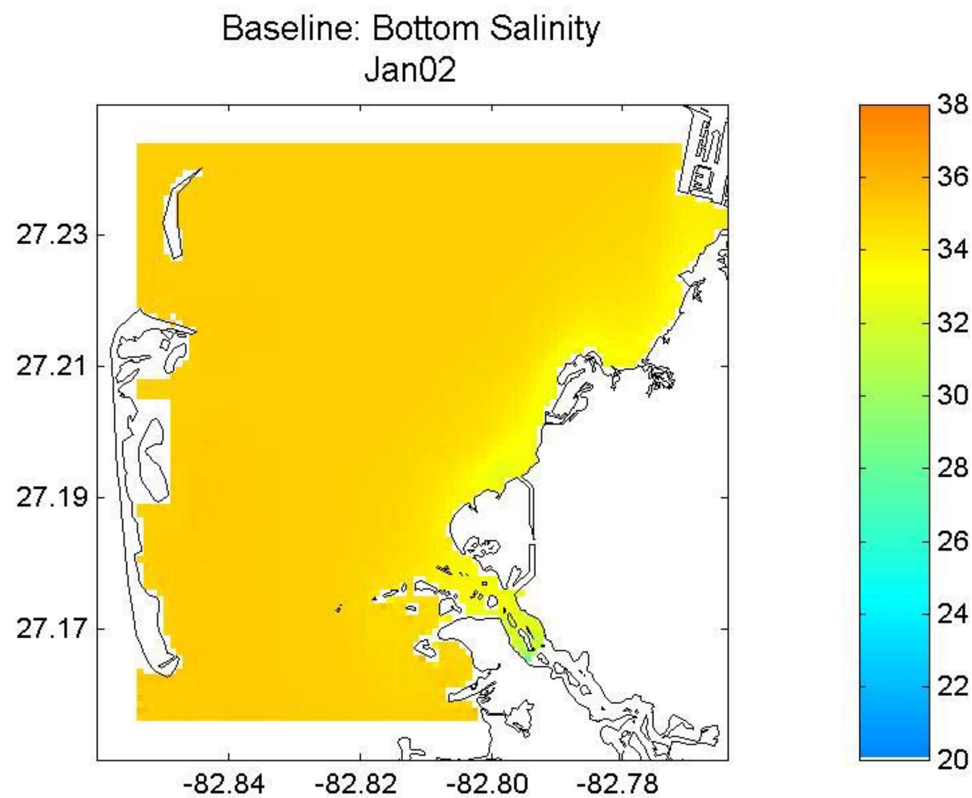

Figure 6.17. Predicted monthly mean bottom salinity, baseline scenario, January 2002.

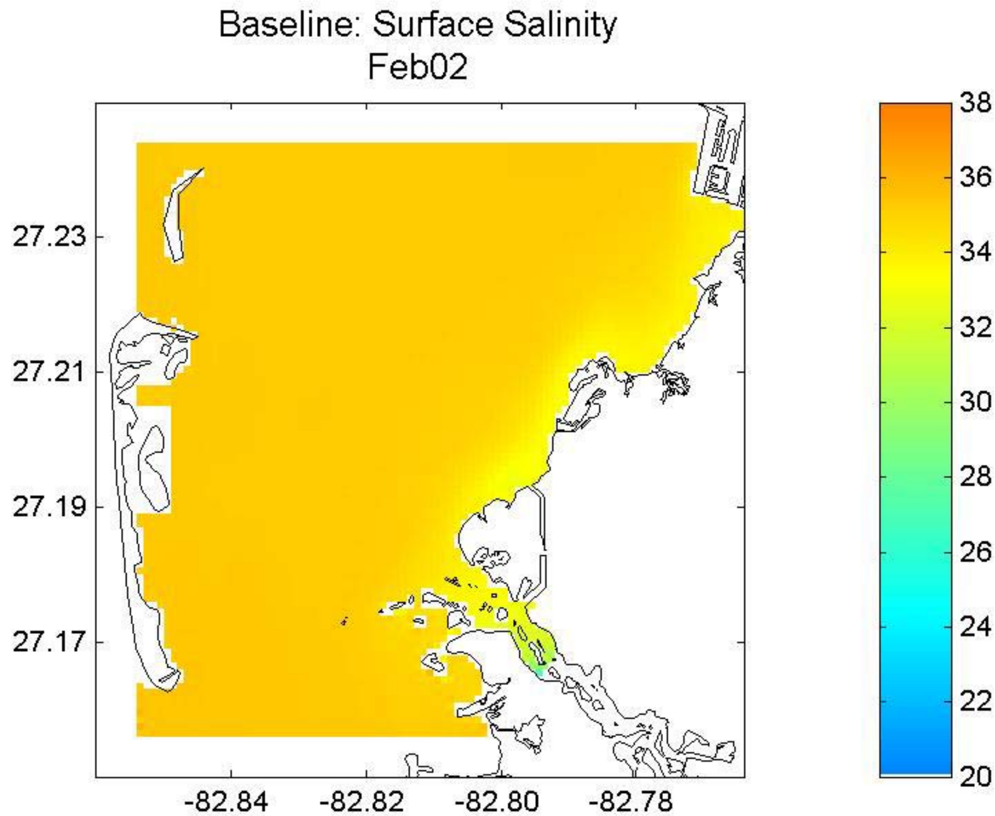

Figure 6.18. Predicted monthly mean surface salinity, baseline scenario, February 2002.

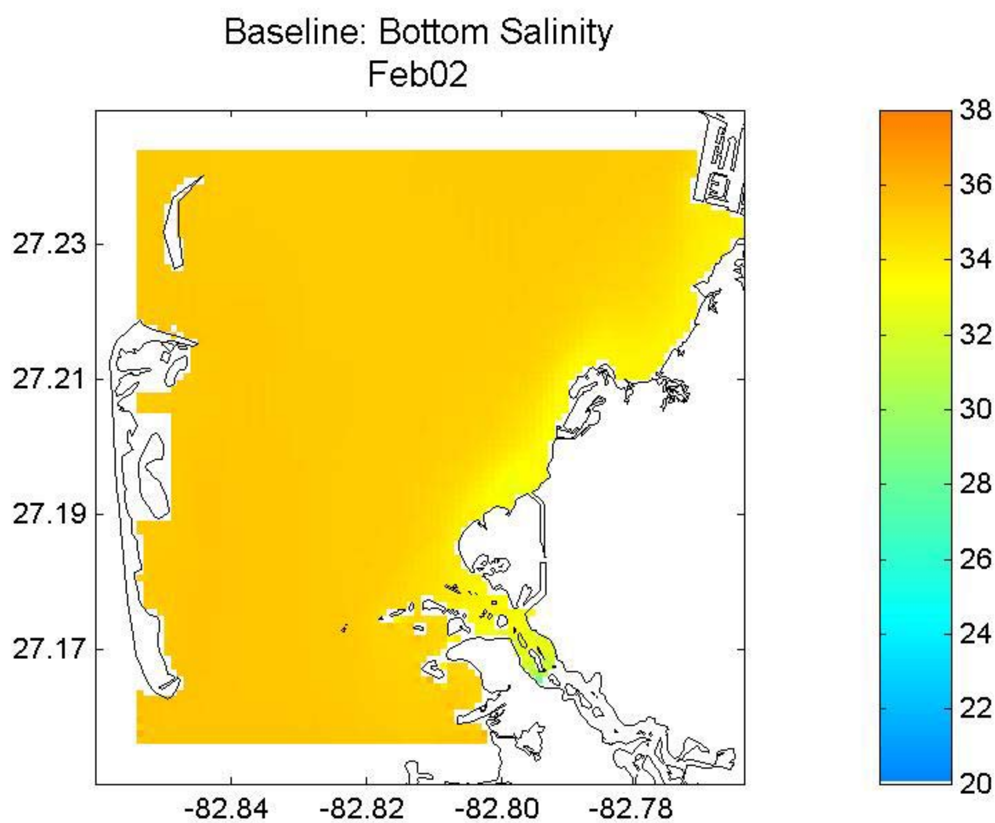

Figure 6.19. Predicted monthly mean bottom salinity, baseline scenario, February 2002.

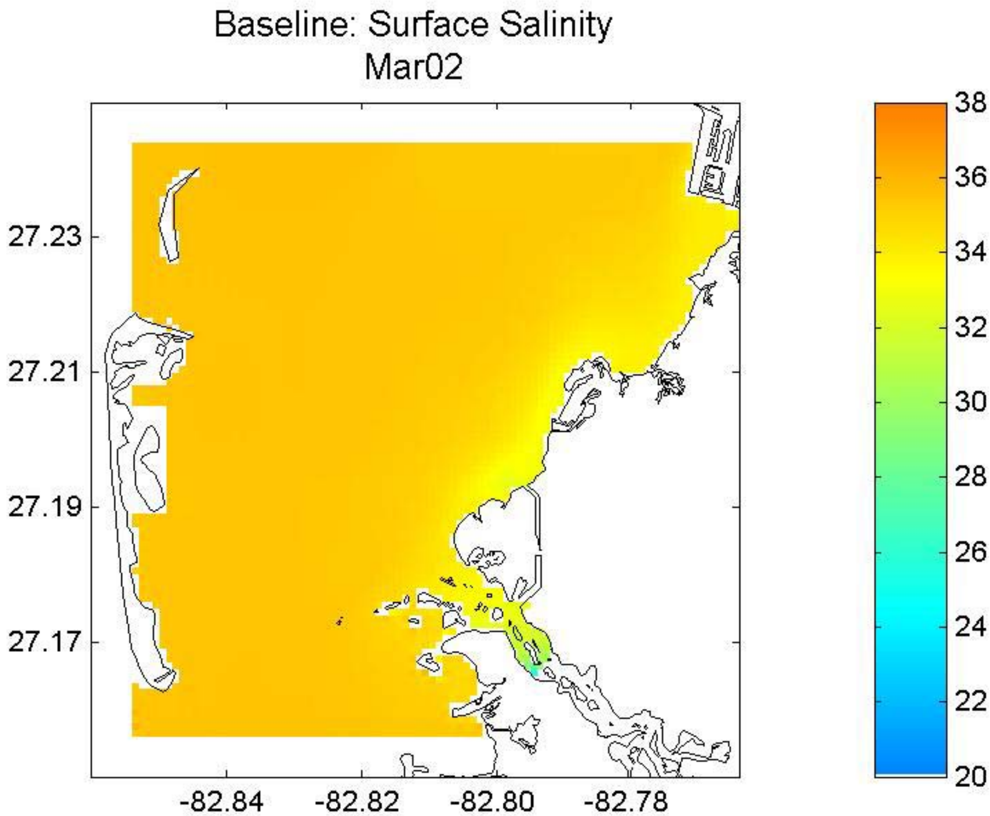

Figure 6.20. Predicted monthly mean surface salinity, baseline scenario, March 2002.

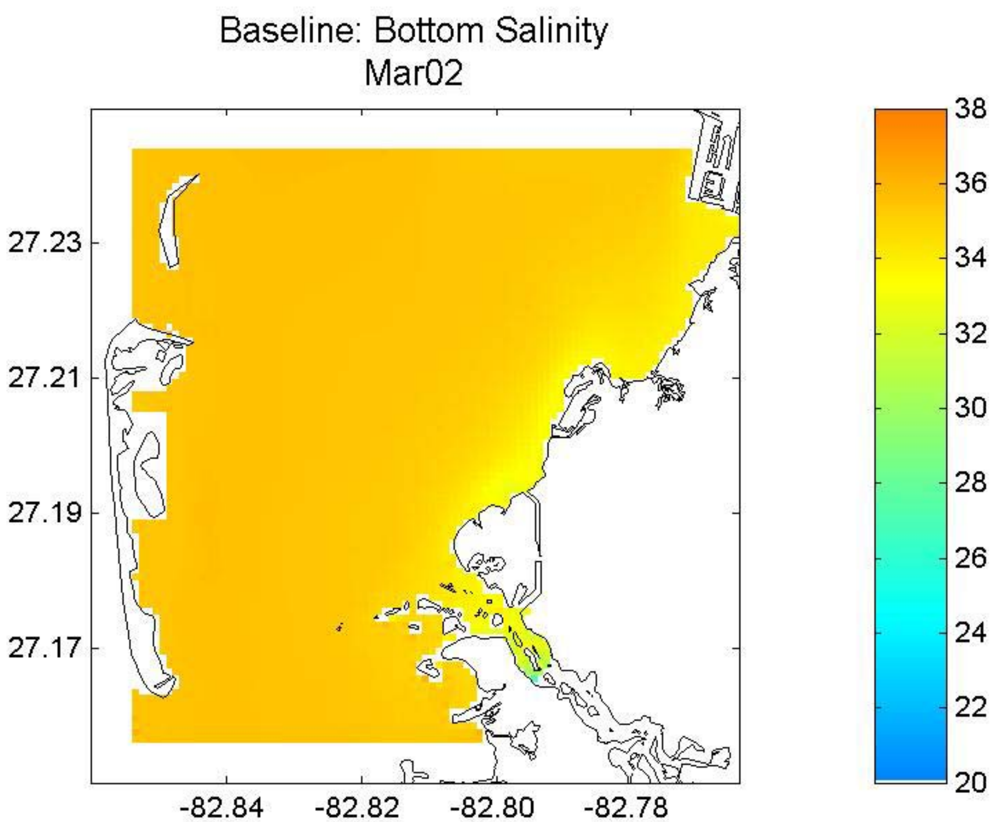

Figure 6.21. Predicted monthly mean bottom salinity, baseline scenario, March 2002.

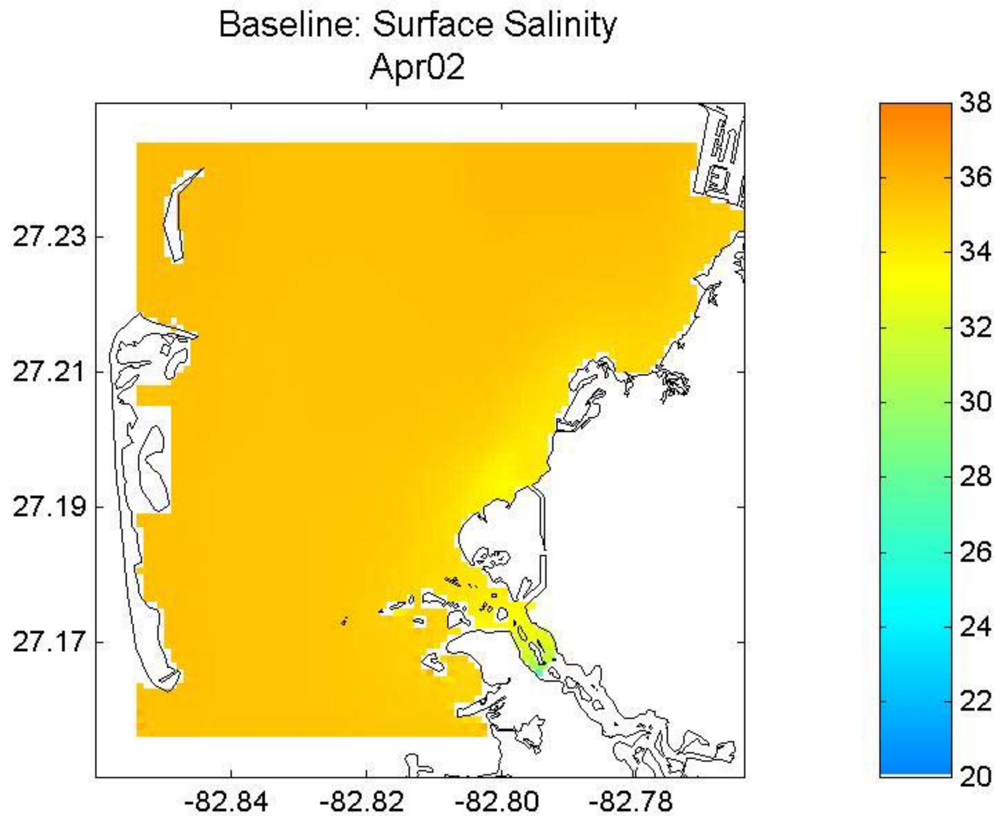

Figure 6.22. Predicted monthly mean surface salinity, baseline scenario, April 2002.

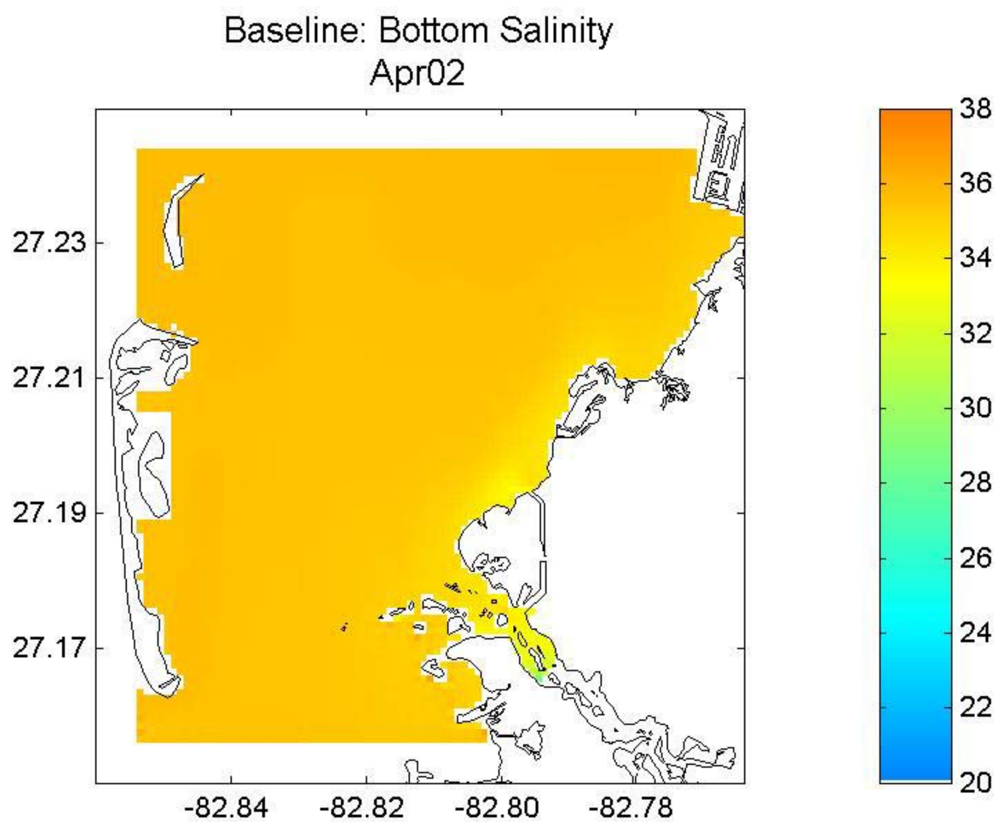

Figure 6.23. Predicted monthly mean bottom salinity, baseline scenario, April 2002.

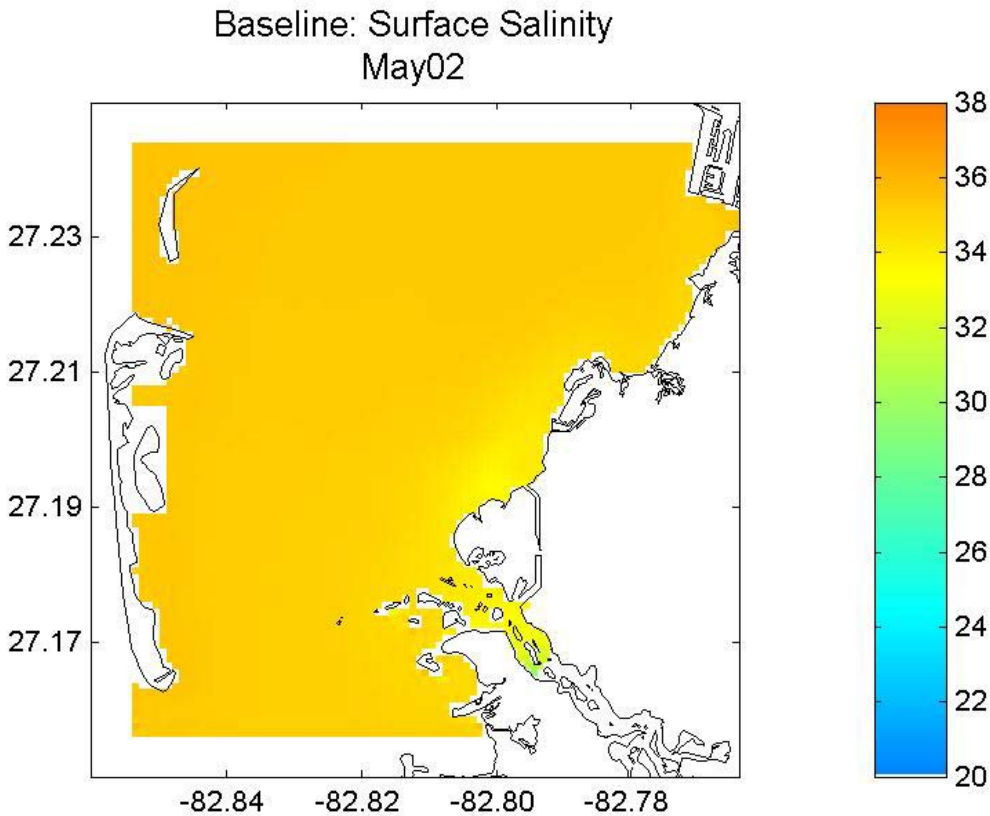

Figure 6.24. Predicted monthly mean surface salinity, baseline scenario, May 2002.

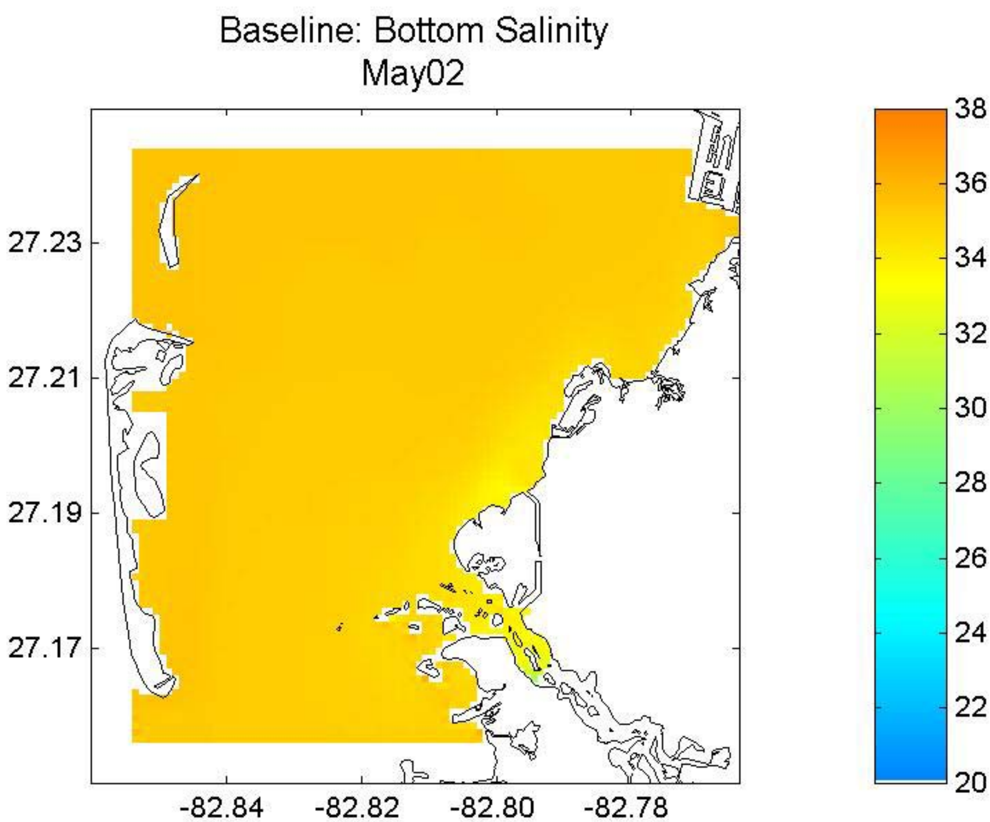

Figure 6.25. Predicted monthly mean bottom salinity, baseline scenario, May 2002.

Examination of the baseline salinity maps show that predicted salinity values are typically in the range of 34-36 ppt across most of the Anchorage, with lower salinity values near shore. The influence of freshwater inflow from the river and power station discharge canal is evident in the wet season, with the most obvious effects in the surface from July through October. Less saline water lies near the coast in the shallow region of the Anchorage during this period, with the discharge from the canal resulting in a lower salinity signal.

A time series plot of the predicted daily mean salinity of the Anchorage for the baseline scenario is presented in Figure 6.26. Predicted salinity in the rainy season (July-October) is lower than in the dry season (November-June). Also, a vertical salinity difference occurs during the rainy season because of the increased freshwater inflow.

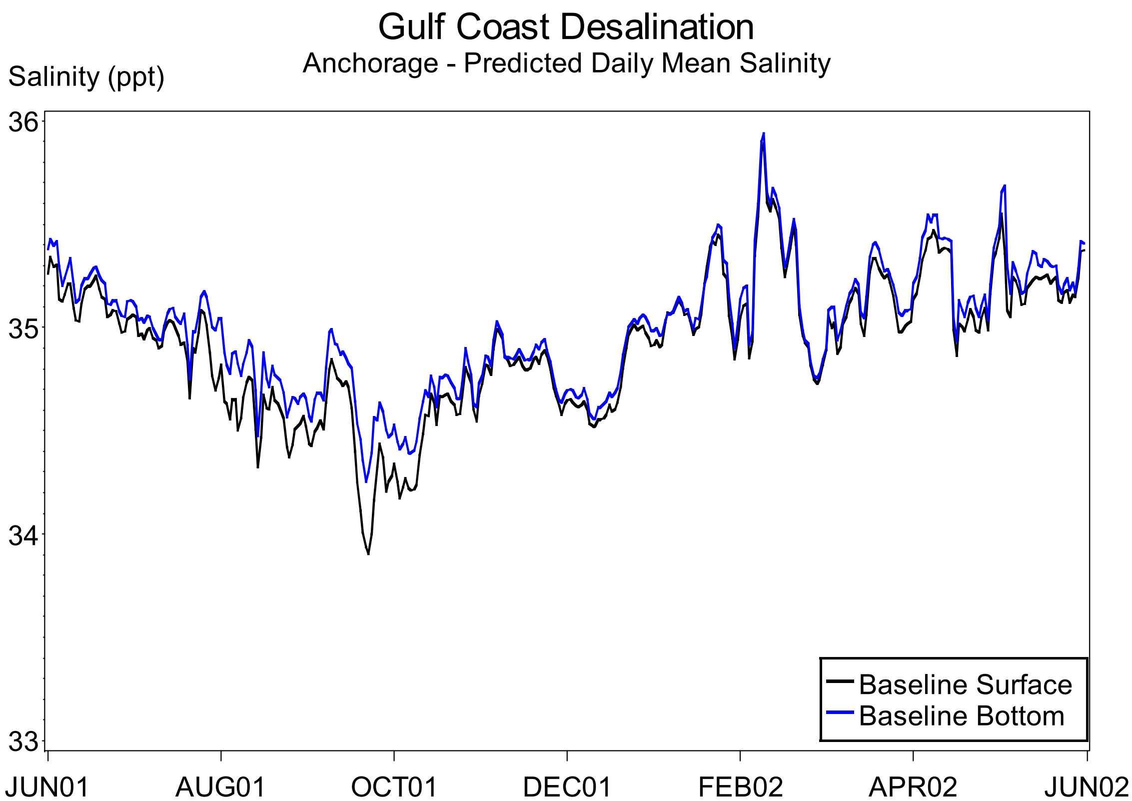

Figure 6.26. Time series of daily mean salinity for surface and bottom layers over the anchorage, baseline, June 2001 to May 2002.

6.1.1.2 Nearshore – Baseline Circulation

Monthly mean predicted circulation maps are presented in Figures 6.27-6.38. The velocity vectors in the figures were derived from the values over a 10 cell by 10 cell area. The length of the longest vector, in the northeastern corner of the Anchorage in September, represents a speed of 0.067 m/s. It is not expected that strong patterns of monthly mean velocities exist in the Anchorage. However, the model results suggest that the mean velocities flow to the north in November, December, and March while the mean velocities flow to the south in May. All other months do not show a consistent pattern.

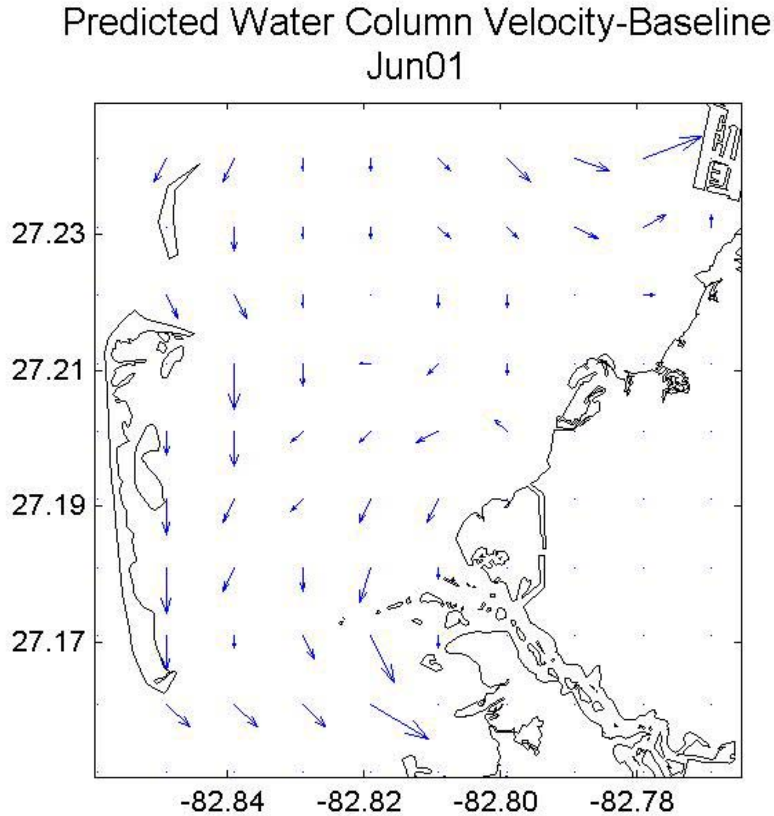

Figure 6.27. Water column monthly mean circulation, baseline scenario, June 2001.

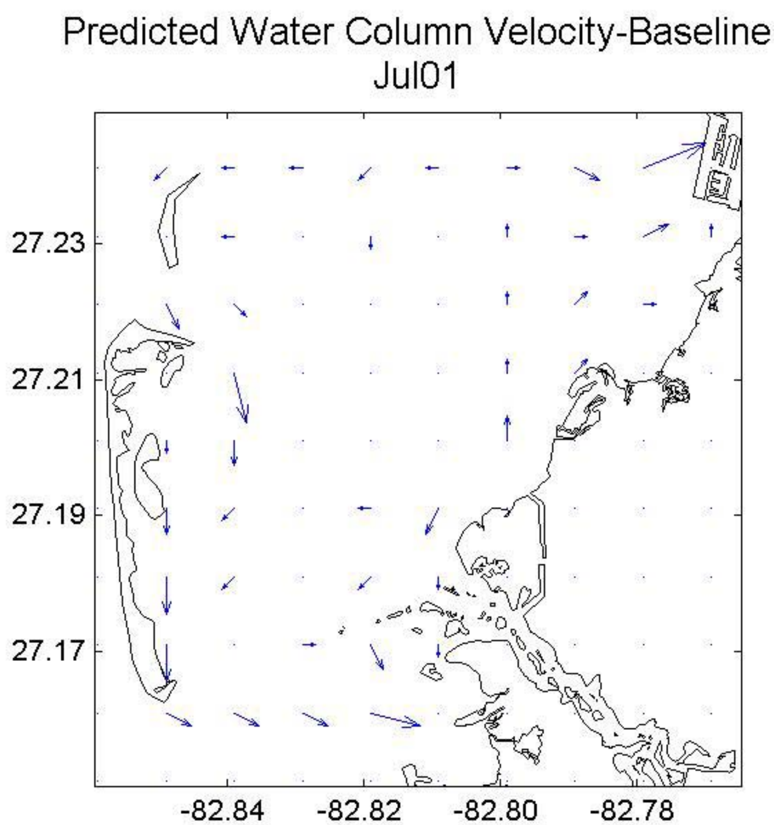

Figure 6.28. Water column monthly mean circulation, baseline scenario, July 2001.

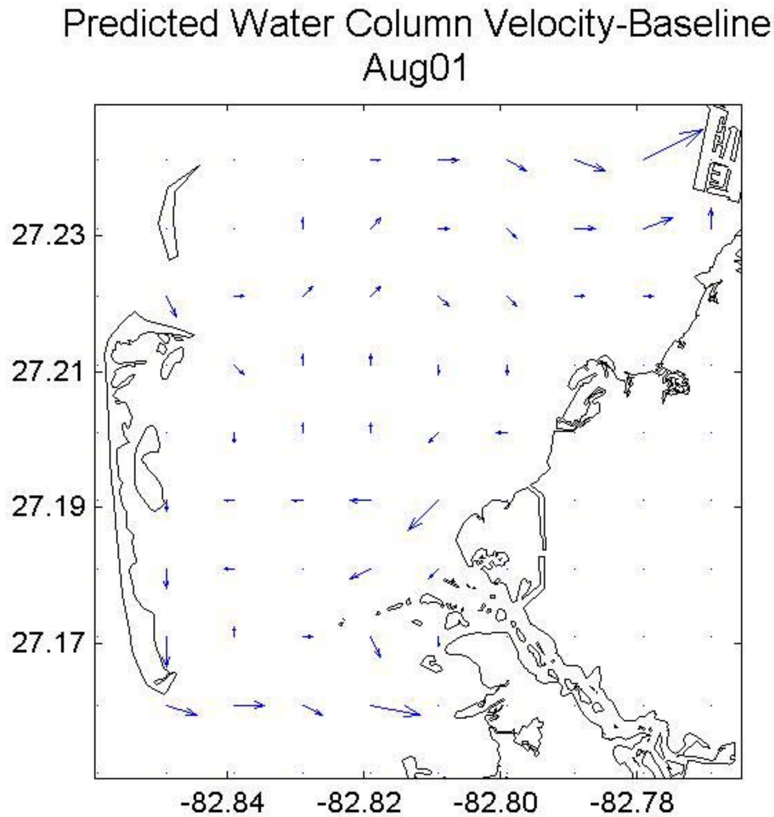

Figure 6.29. Water column monthly mean circulation, baseline scenario, August 2001.

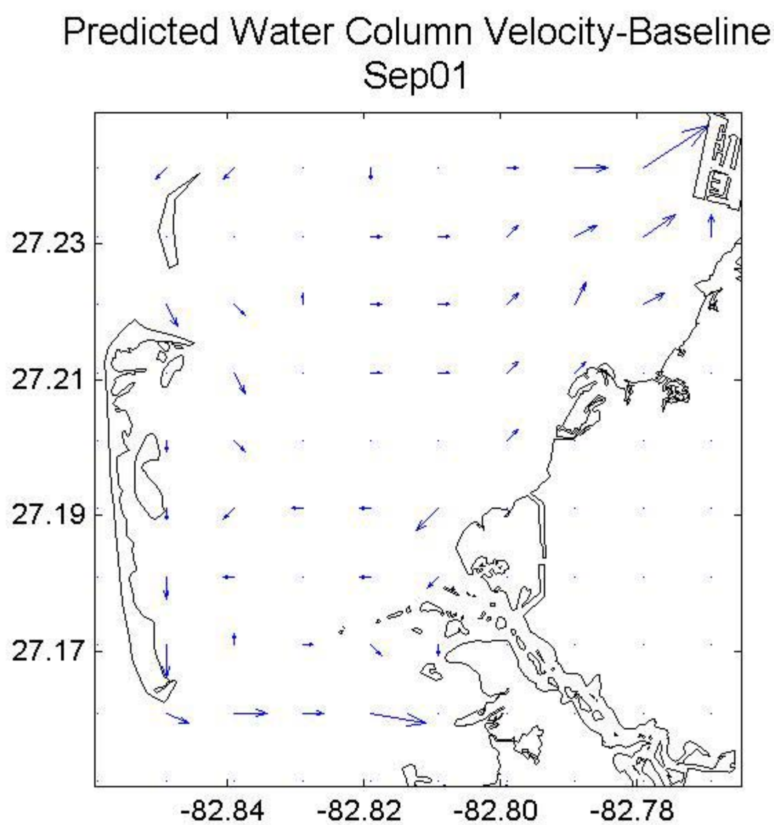

Figure 6.30. Water column monthly mean circulation, baseline scenario, September 2001.

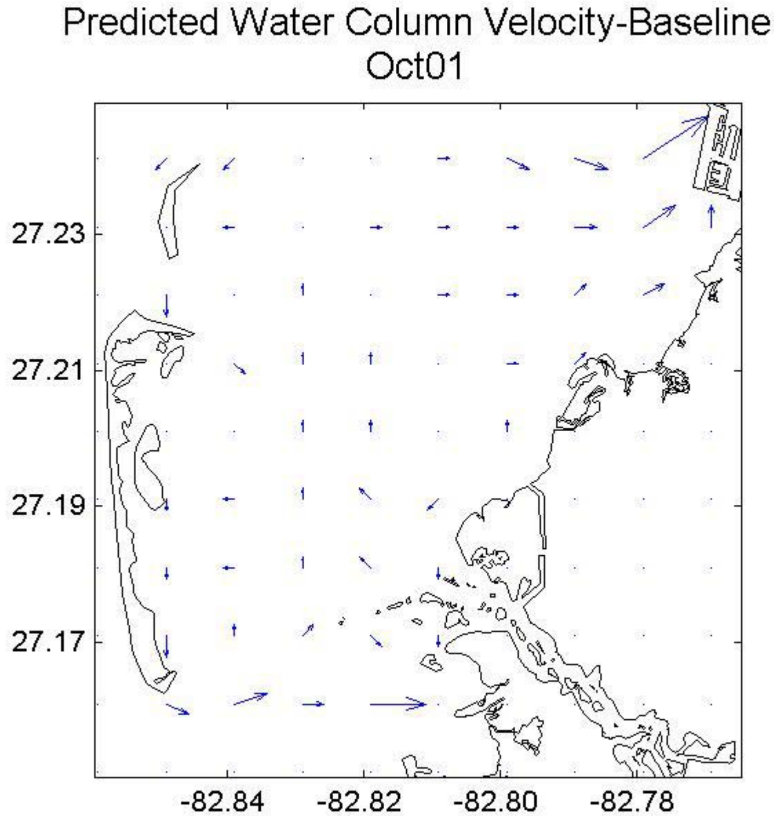

Figure 6.31. Water column monthly mean circulation, baseline scenario, October 2001.

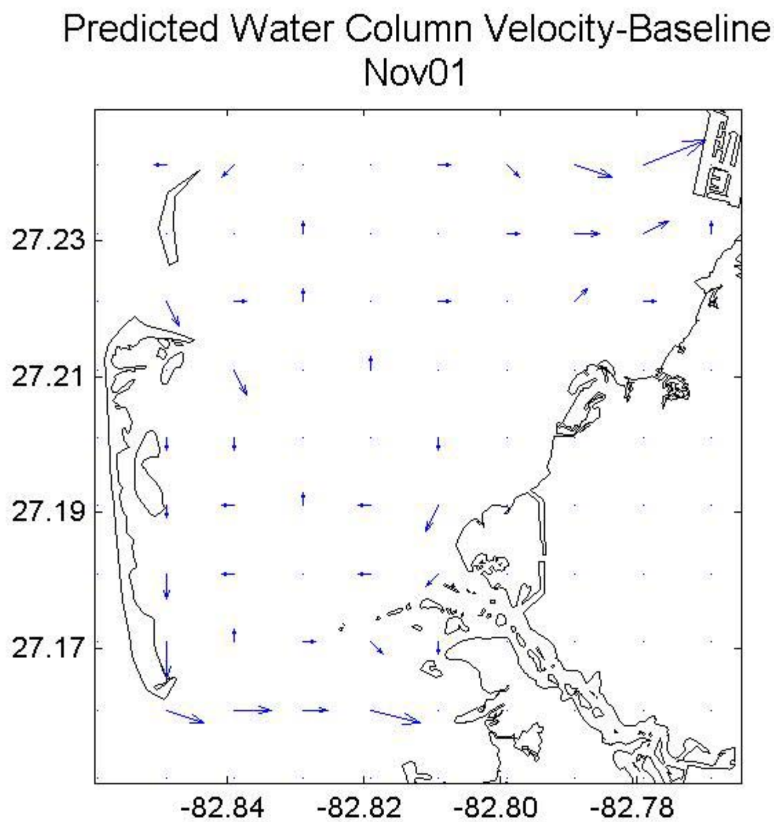

Figure 6.32. Water column monthly mean circulation, baseline scenario, November 2001.

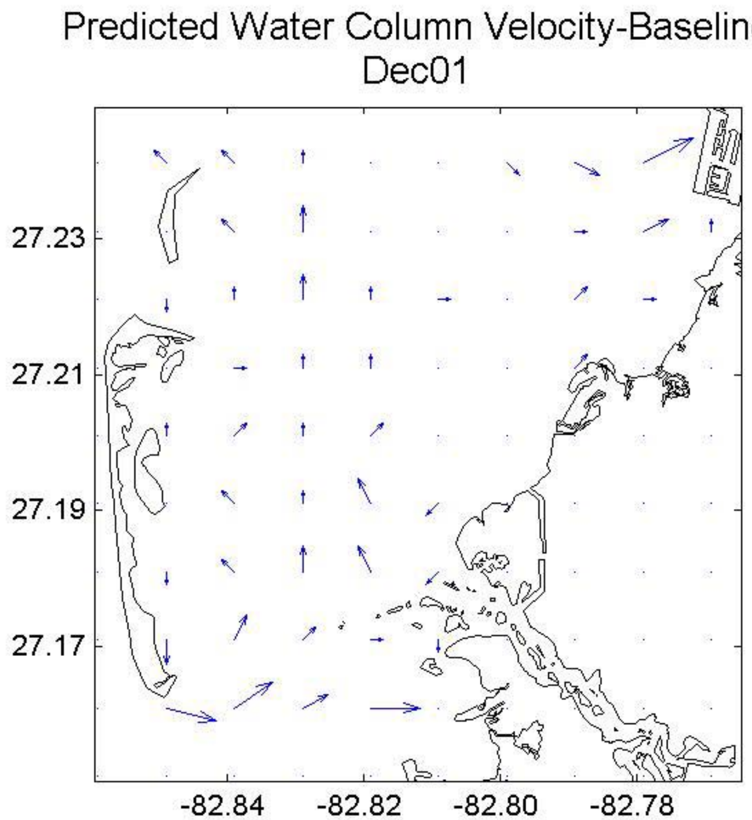

Figure 6.33. Water column monthly mean circulation, baseline scenario, December 2001.

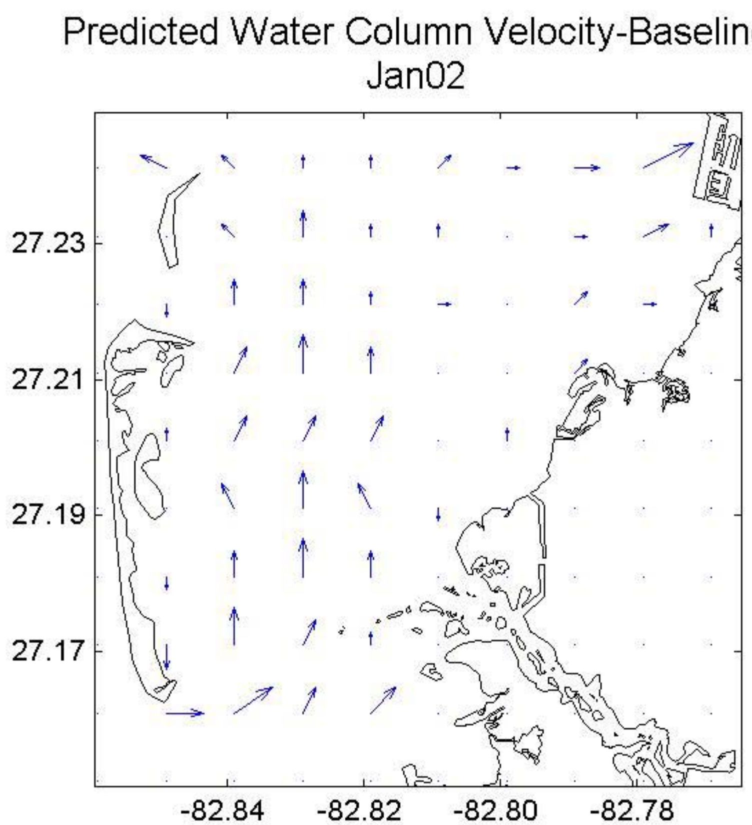

Figure 6.34. Water column monthly mean circulation, baseline scenario, January 2002.

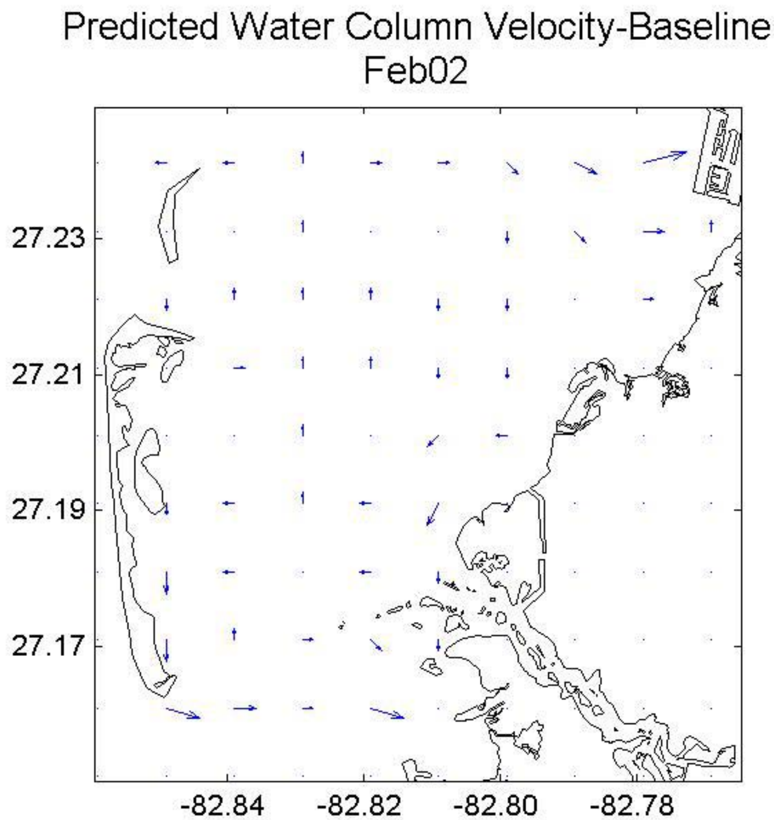

Figure 6.35. Water column monthly mean circulation, baseline scenario, February 2002.

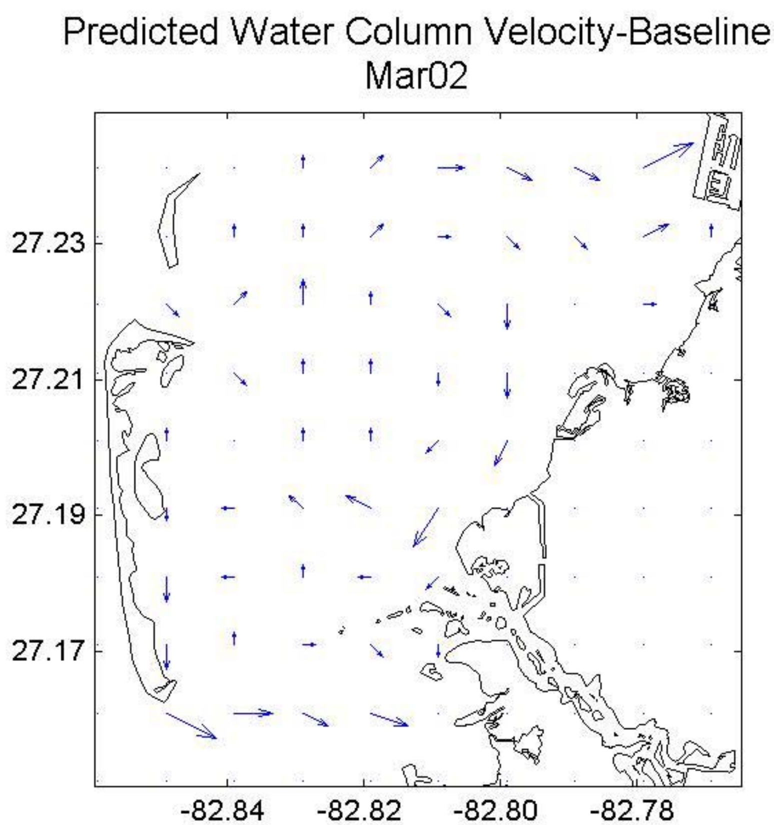

Figure 6.36. Water column monthly mean circulation, baseline scenario, March 2002.

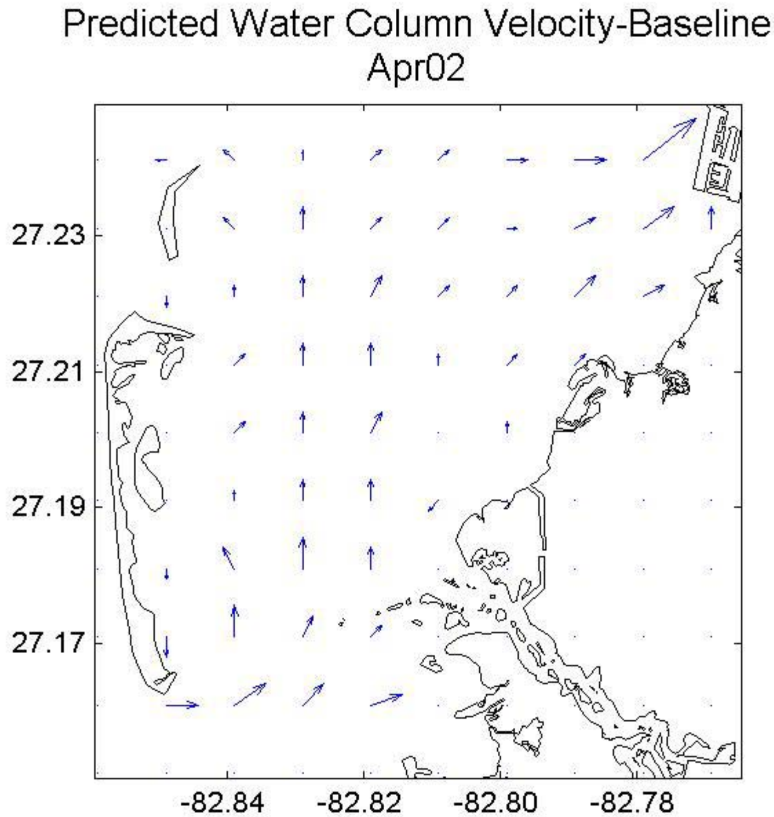

Figure 6.37. Water column monthly mean circulation, baseline scenario, April 2002.

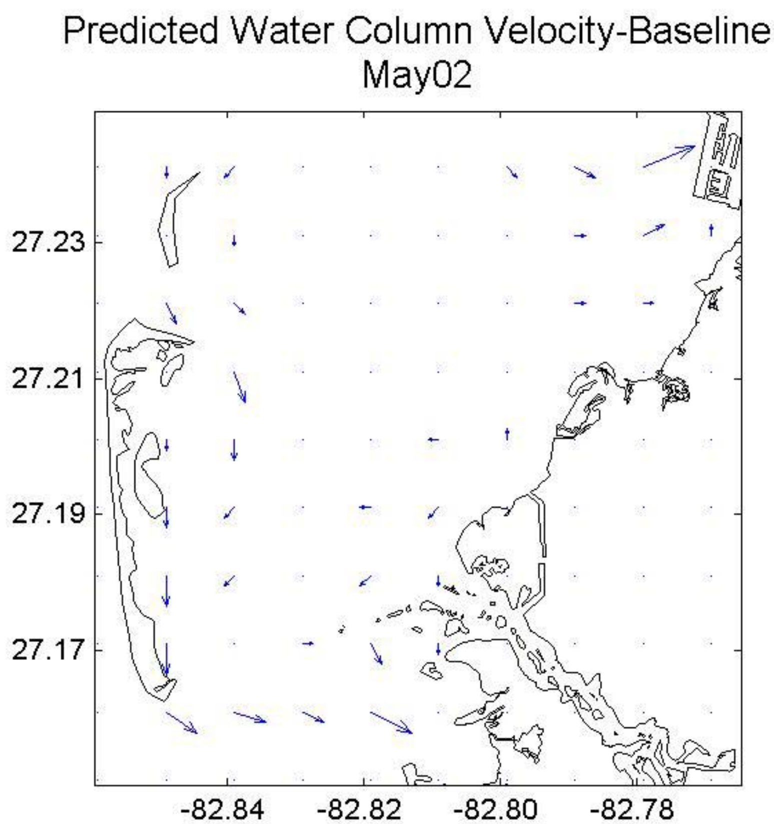

Figure 6.38. Water column monthly mean circulation, baseline scenario, May 2002.

6.1.2 Nearshore - 10 MGD Product Water Scenario

The nearshore 10 MGD product water scenario results in approximately 16 MGD of concentrate mixing with the cooling water release from the power station prior to entering the discharge canal. The resultant effects on salinity across the entire Anchorage are displayed as monthly mean values in maps below, with time series presentations of daily mean surface and bottom salinity predictions in three areas: near the discharge, in the shallow area near the eastern shore of the Anchorage, and in the Anchorage as a whole.

The statistics for the daily mean predicted salinity values for the nearshore 10 MGD product water scenario are summarized in Table 6.2. Changes in salinity (Δ salinity) are derived from the difference of the predicted salinity values for this scenario and those for the baseline. Maps of predicted changes in salinity for all months for the surface and bottom layers are presented in Figures 6.39-6.62. Elevated predicted salinity values in comparison to baseline conditions can be detected in the shallow area near the discharge canal from November to April (the dry season), although the change in salinity is less than 0.5 ppt near the discharge. Greatest increases in salinity values are in March in comparison to the baseline condition, with the least change occurring in September. The mean of the daily values for the Anchorage over the entire year is no different from the same statistic for the baseline scenario (see Table 6.1).

The salinity change maps in Figures 6.39-6.62 suggest that the effects on salinity of the 10 MGD product water scenario are confined to the shallow area near the eastern shore of the Anchorage. The increased salinity levels are most prevalent during the winter and early spring, and cover the shallow area from the northern boundary of the small grid system southward to the mouth of the Anclote River. Elevated salinity is found inside the mouth of the river during some months, as may be seen during March 2002 (Figure 6.57).

Table 6.2. Statistics for the mean daily predicted salinity for the nearshore 10 MGD product water scenario.

Layer	N	Mean	Standard Deviation	Minimum	Maximum
Surface	365	34.9 ppt	0.3 ppt	33.9 ppt	35.9 ppt
Bottom	365	35.0 ppt	0.3 ppt	34.3 ppt	36.0 ppt

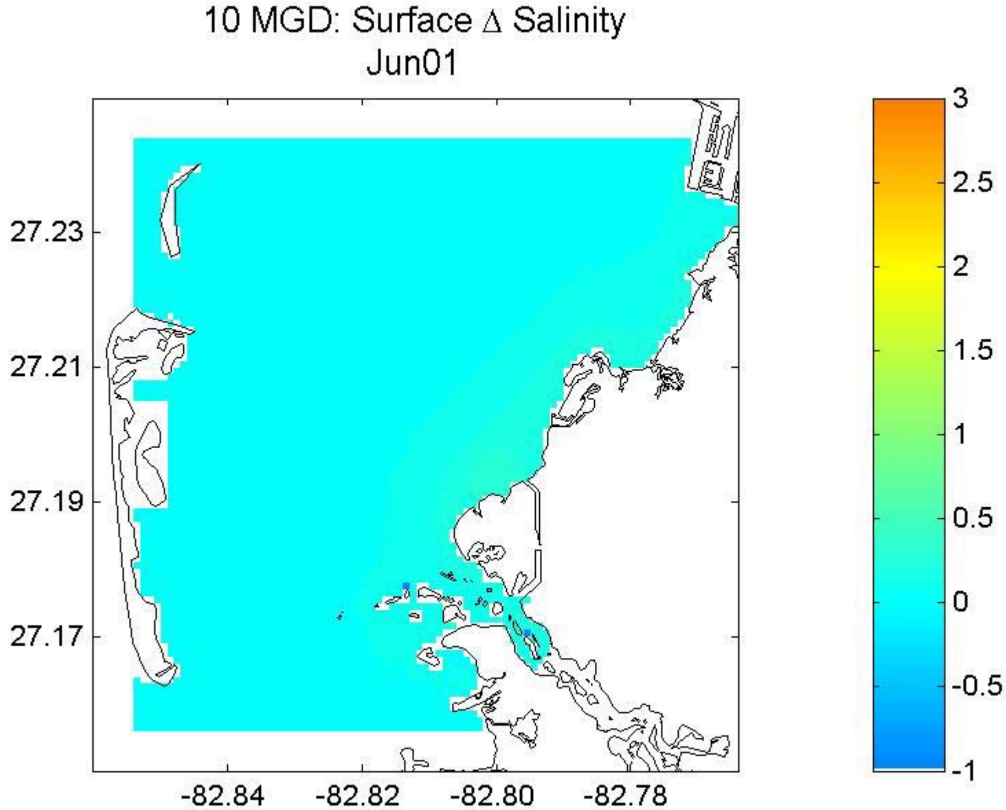

Figure 6.39. Predicted monthly mean surface salinity change, 10 MGD product water scenario, June 2001.

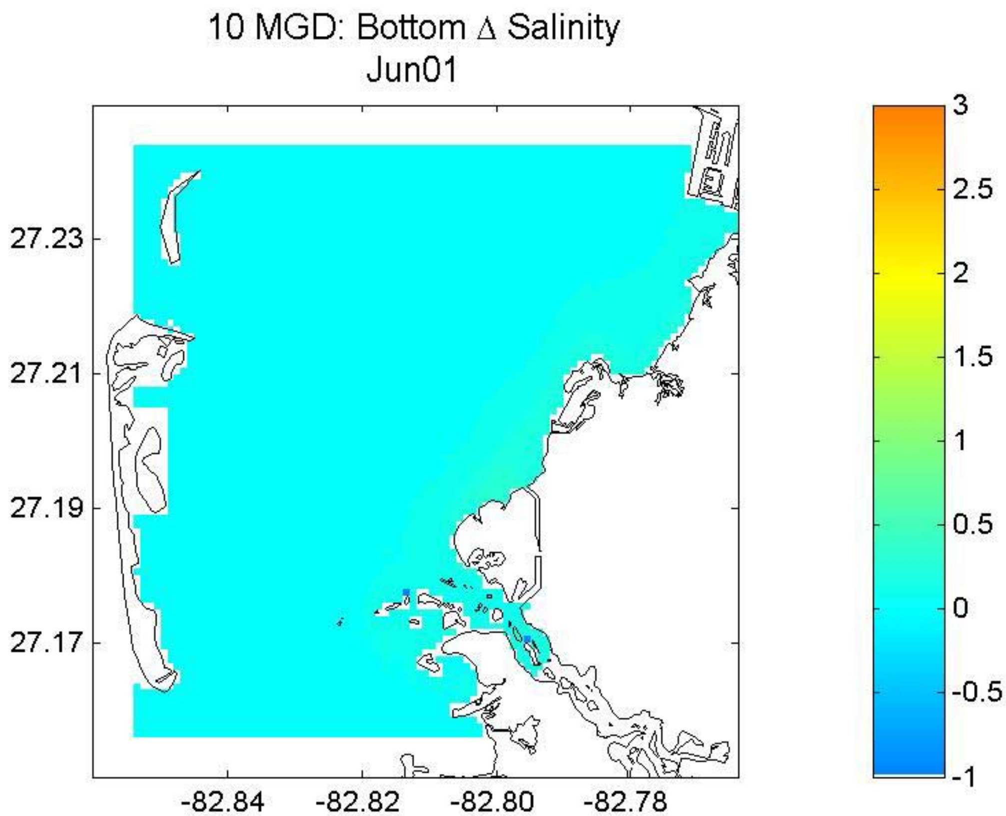

Figure 6.40. Predicted monthly mean bottom salinity change, 10 MGD product water scenario, June 2001.

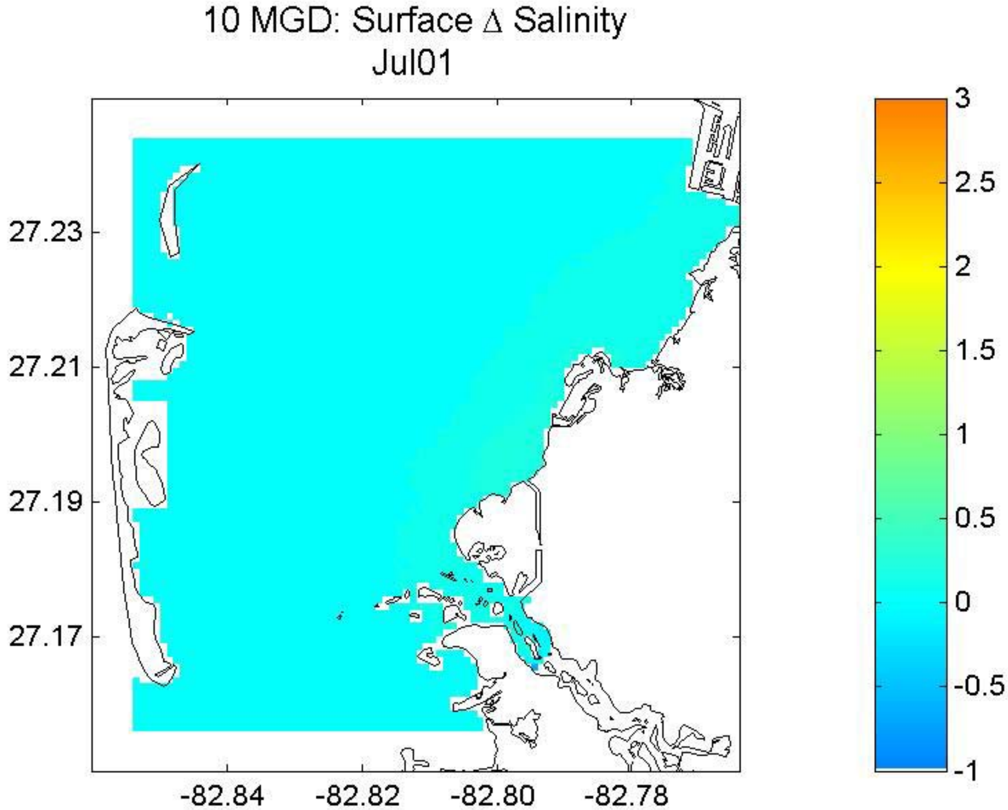

Figure 6.41. Predicted monthly mean surface salinity change, 10 MGD product water scenario, July 2001.

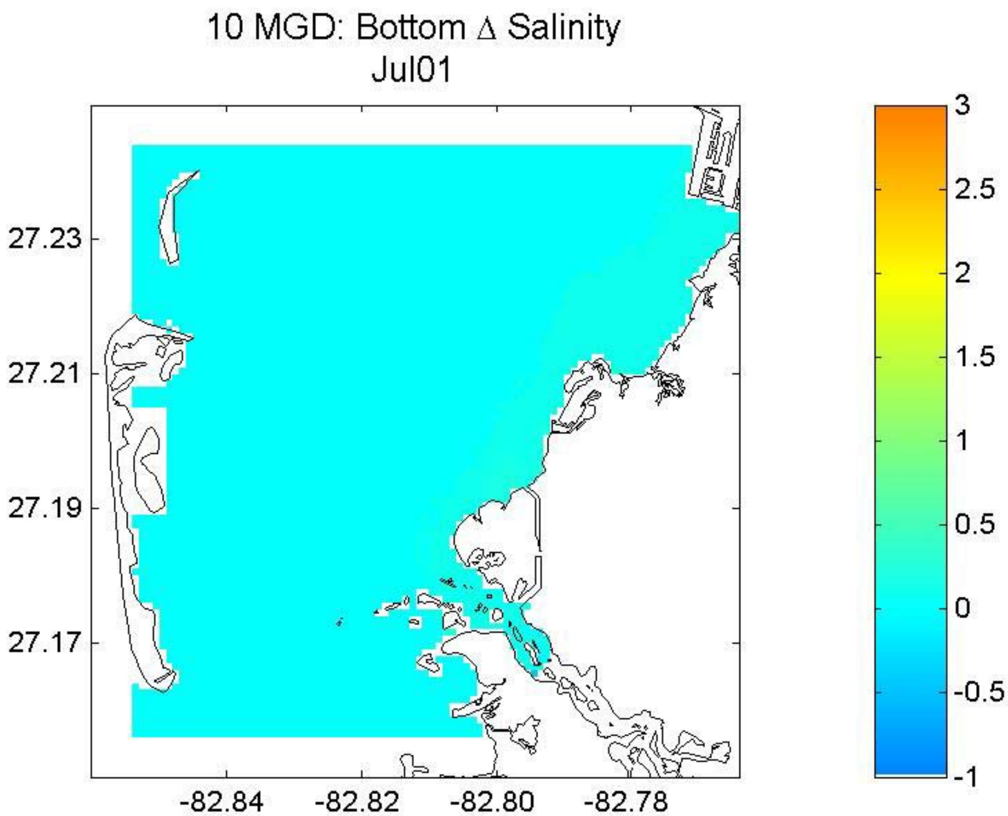

Figure 6.42. Predicted monthly mean bottom salinity change, 10 MGD product water scenario, July 2001.

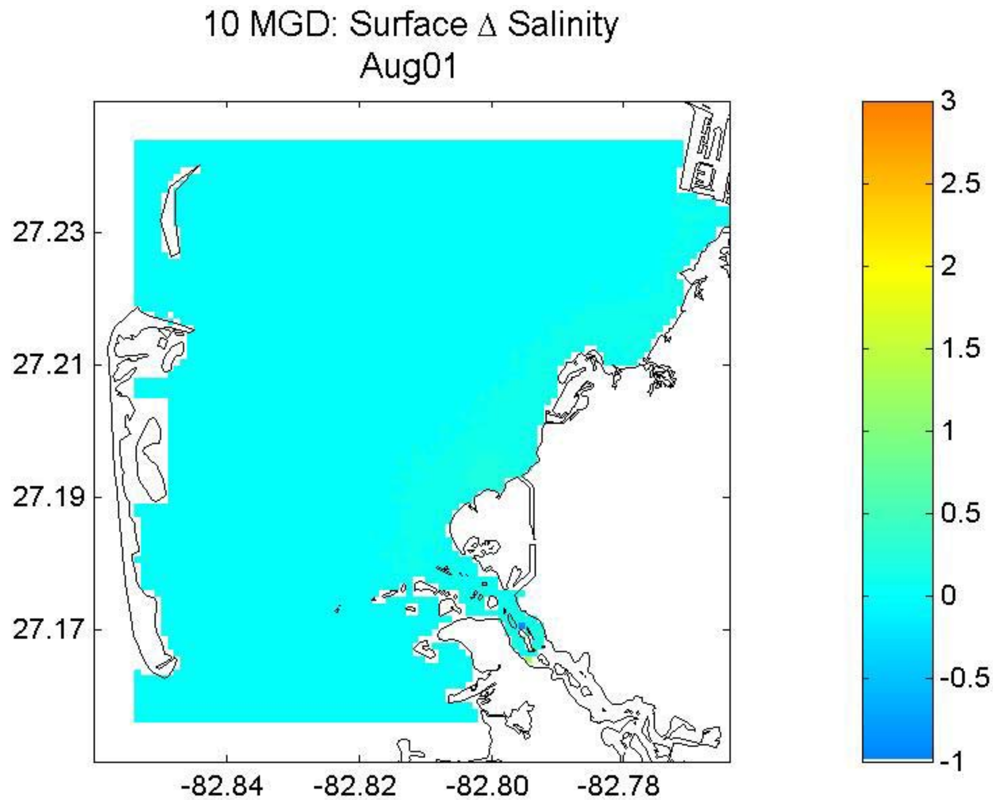

Figure 6.43. Predicted monthly mean surface salinity change, 10 MGD product water scenario, August 2001.

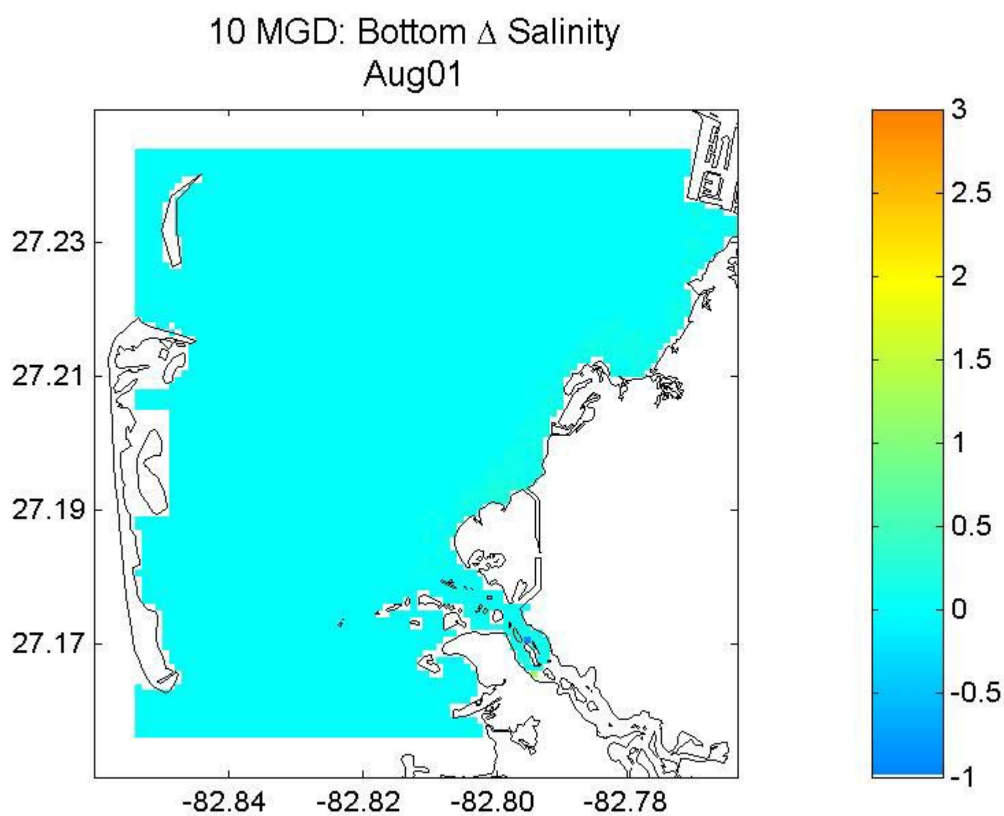

Figure 6.44. Predicted monthly mean bottom salinity change, 10 MGD product water scenario, August 2001.

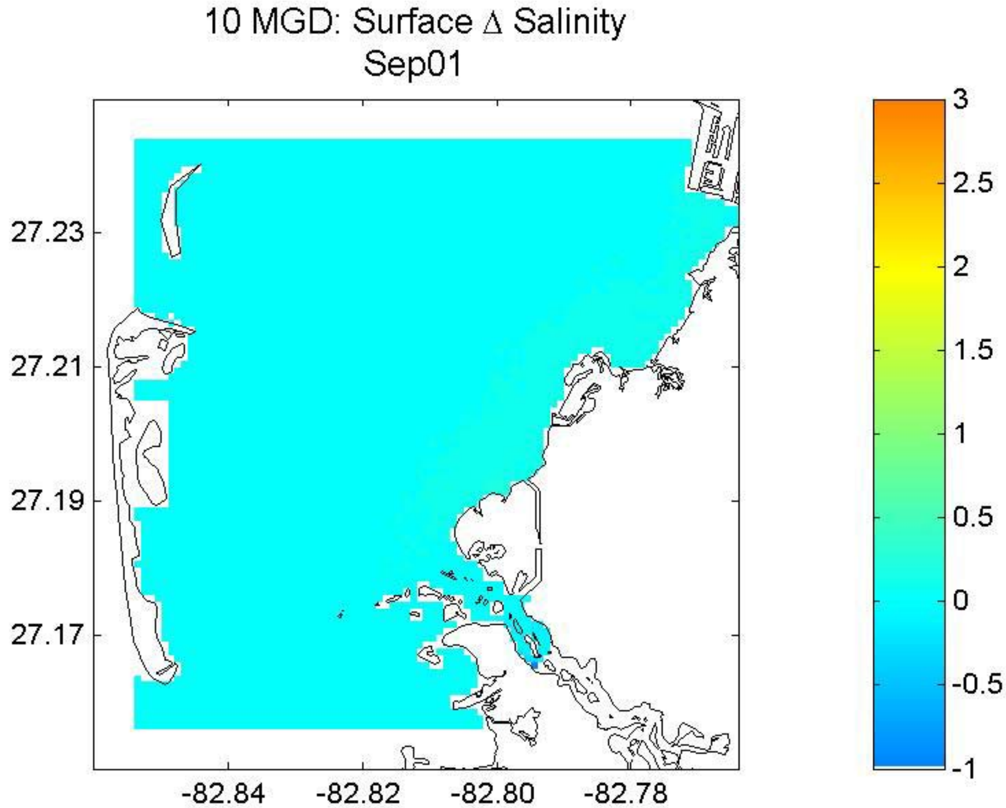

Figure 6.45. Predicted monthly mean surface salinity change, 10 MGD product water scenario, September 2001.

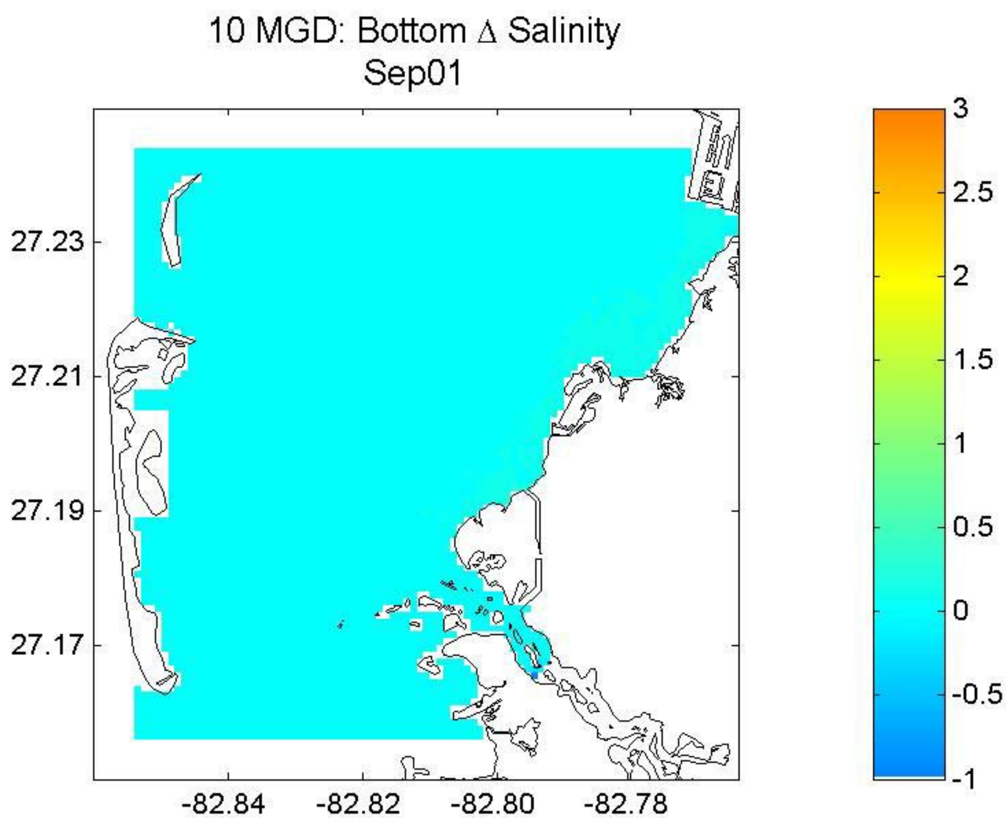

Figure 6.46. Predicted monthly mean bottom salinity change, 10 MGD product water scenario, September 2001.

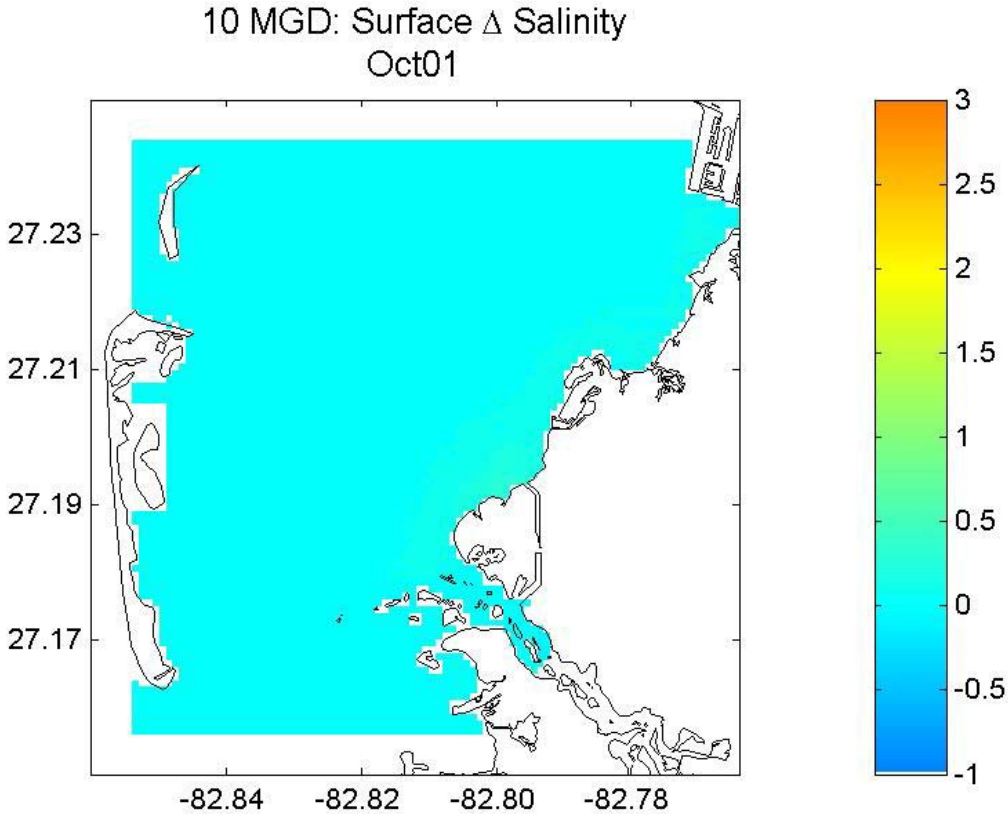

Figure 6.47. Predicted monthly mean surface salinity change, 10 MGD product water scenario, October 2001.

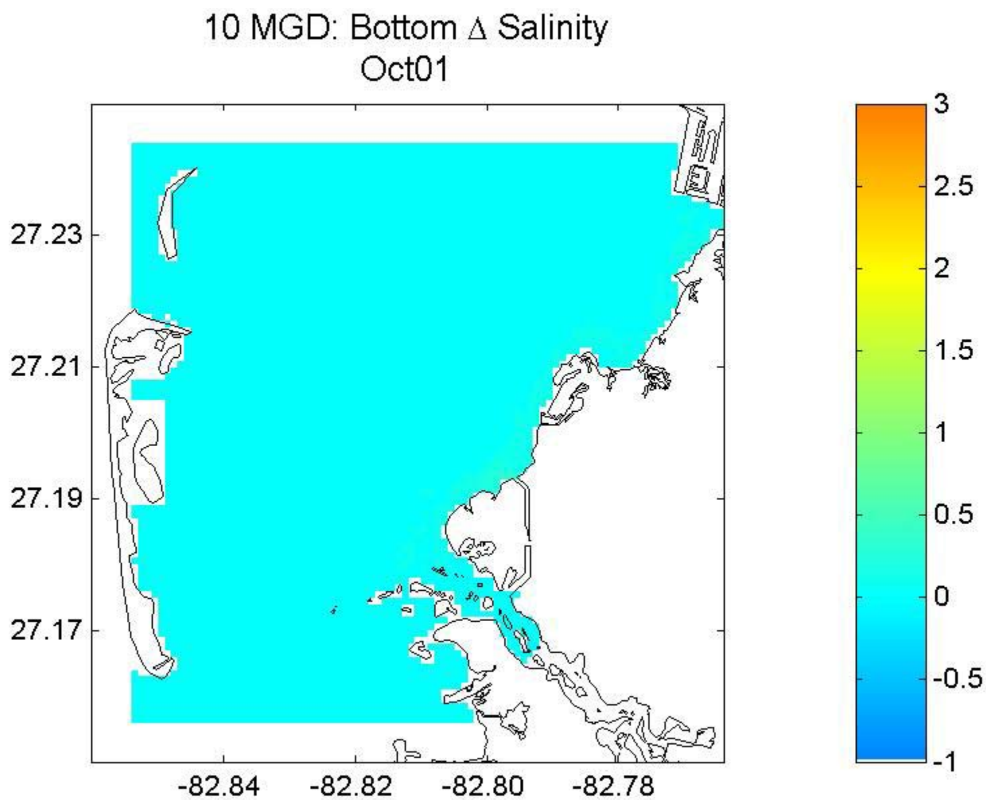

Figure 6.48. Predicted monthly mean bottom salinity change, 10 MGD product water scenario, October 2001.

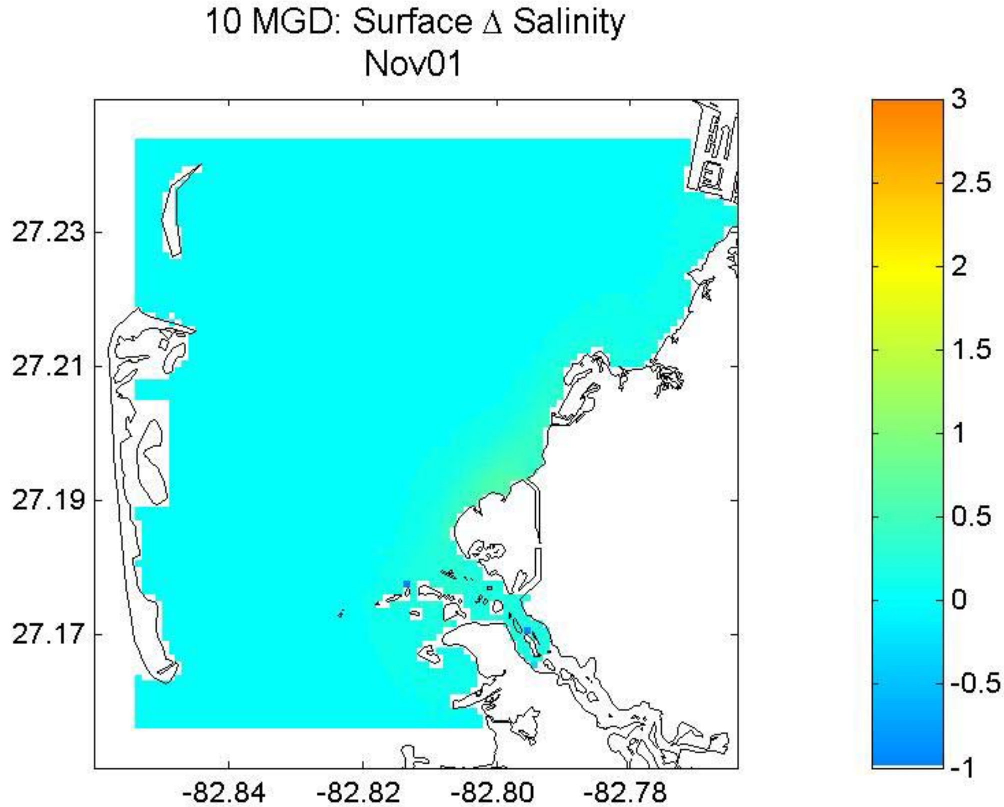

Figure 6.49. Predicted monthly mean surface salinity change, 10 MGD product water scenario, November 2001.

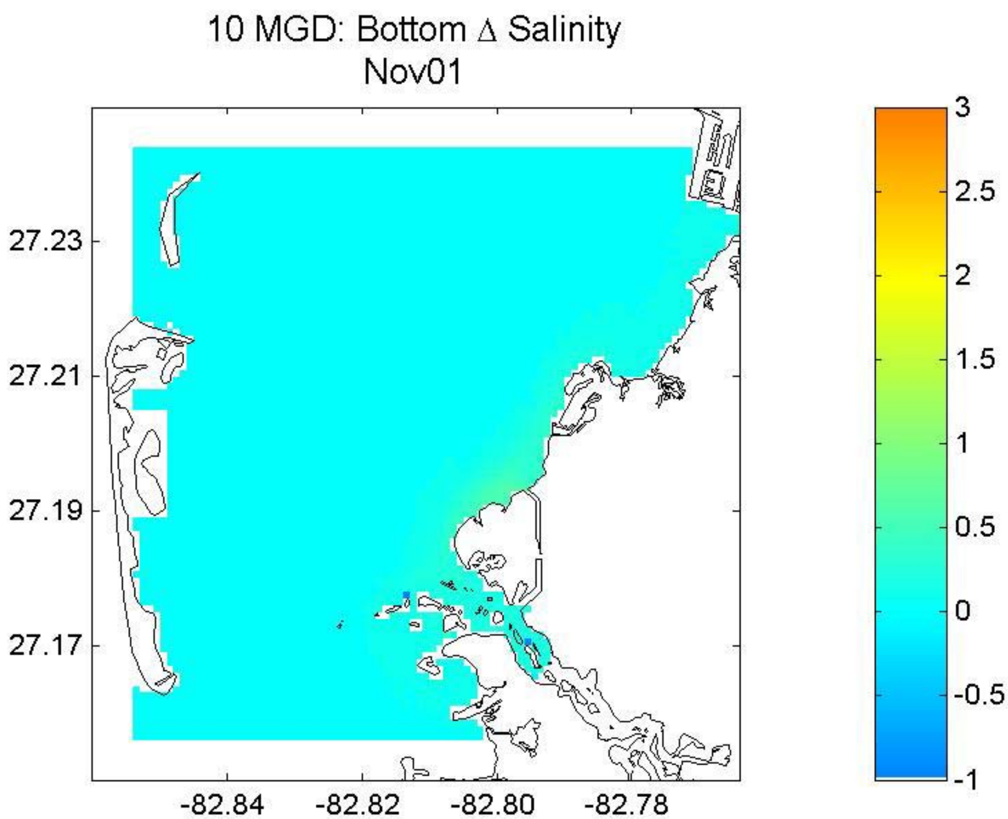

Figure 6.50. Predicted monthly mean bottom salinity change, 10 MGD product water scenario, November 2001.

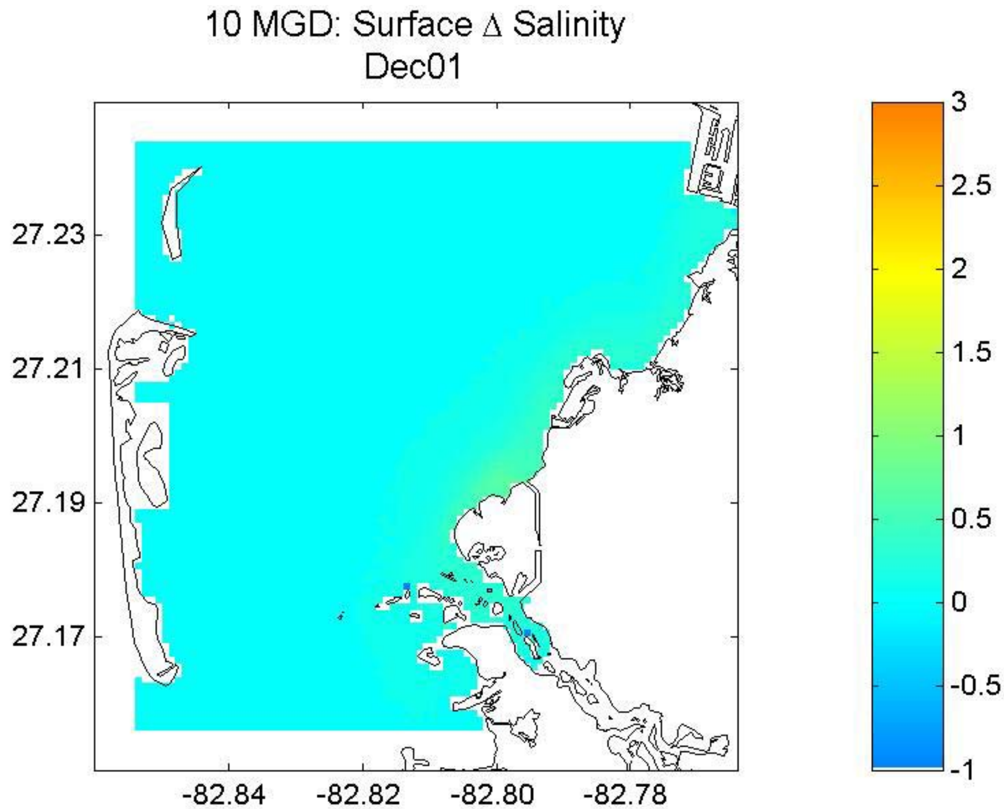

Figure 6.51. Predicted monthly mean surface salinity change, 10 MGD product water scenario, December 2001.

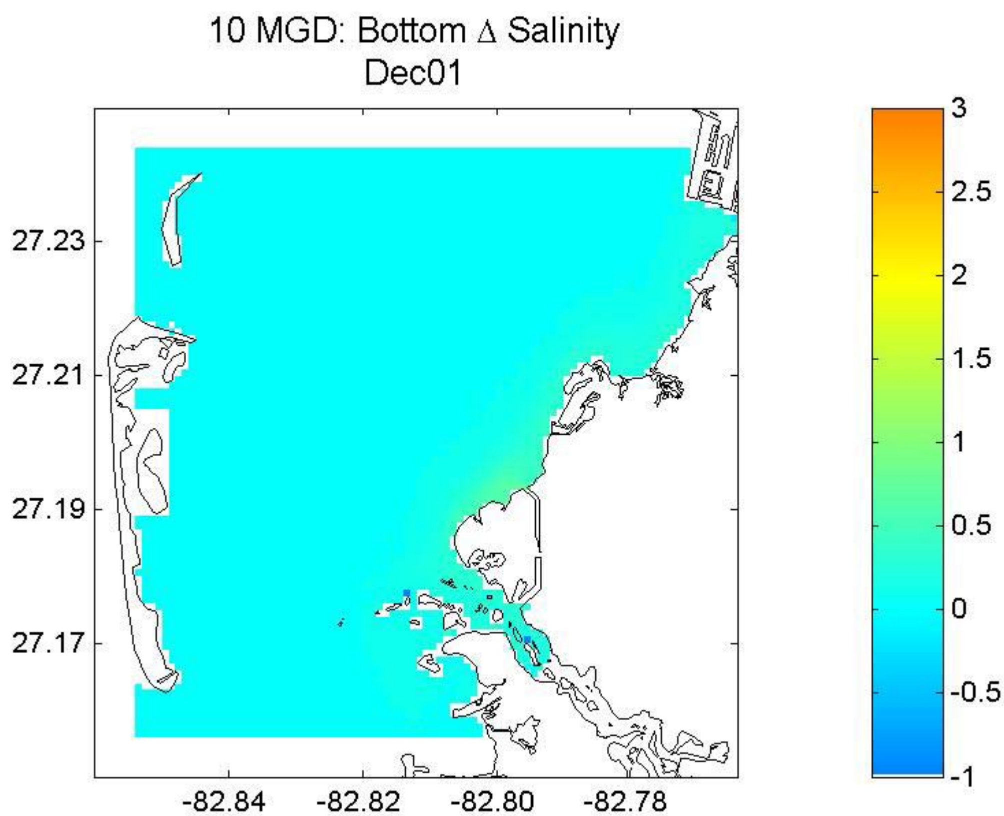

Figure 6.52. Predicted monthly mean bottom salinity change, 10 MGD product water scenario, December 2001.

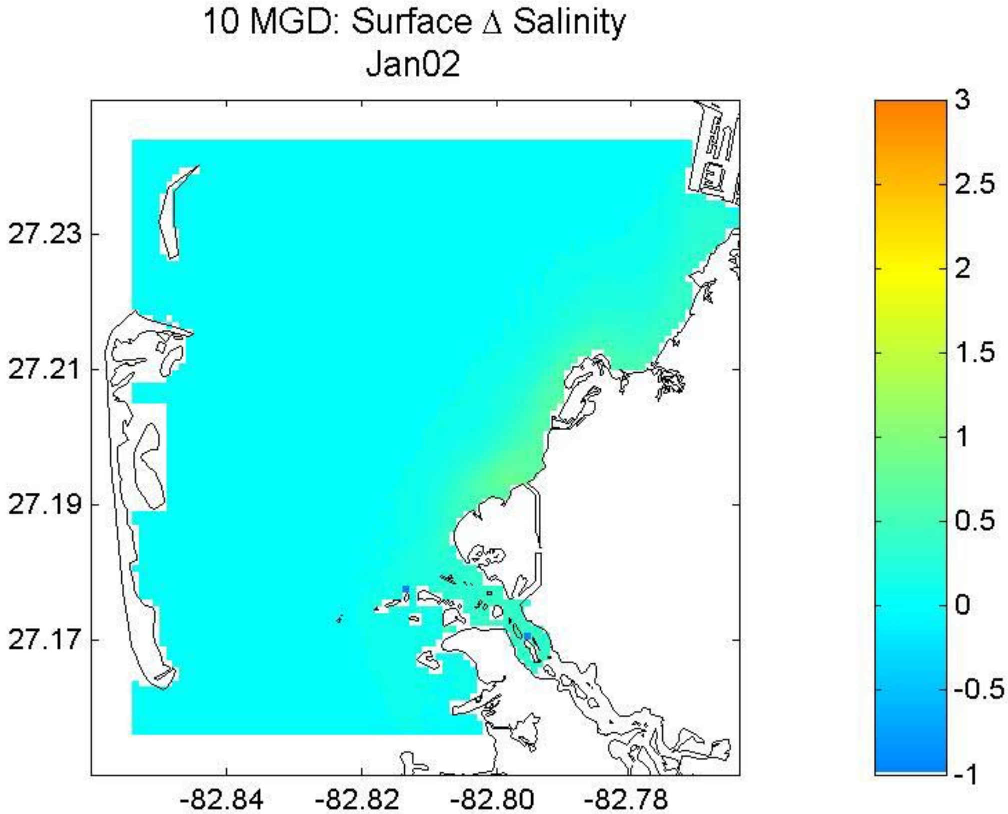

Figure 6.53. Predicted monthly mean surface salinity change, 10 MGD product water scenario, January 2002.

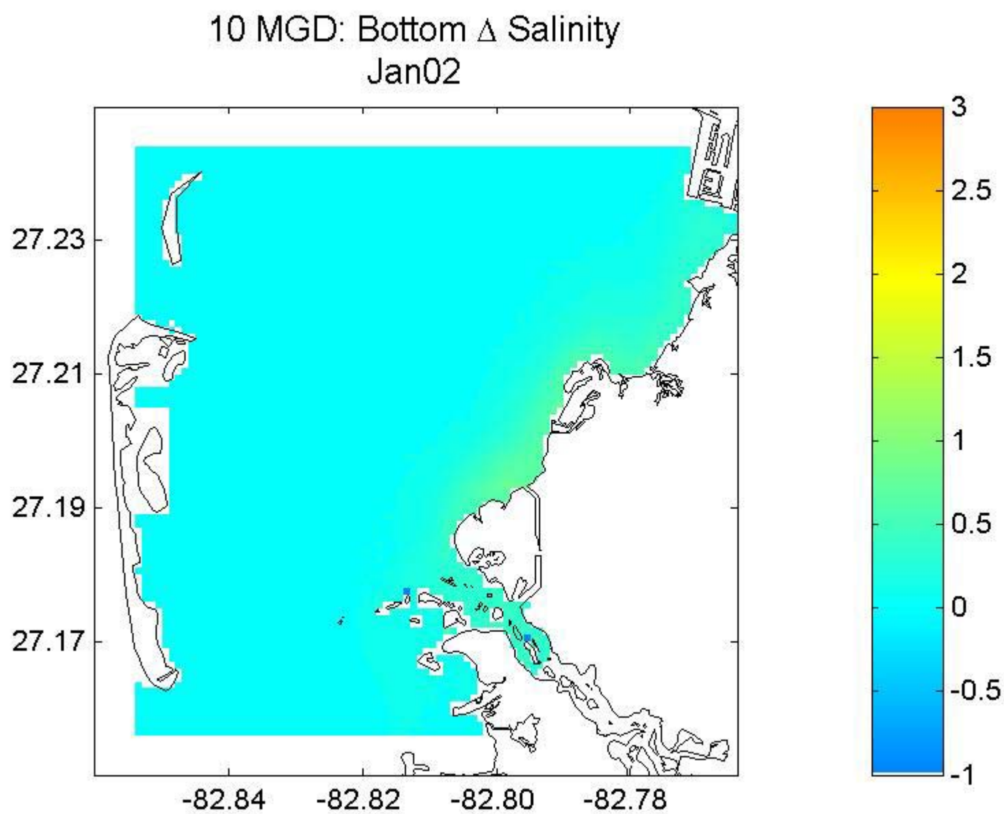

Figure 6.54. Predicted monthly mean bottom salinity change, 10 MGD product water scenario, January 2002.

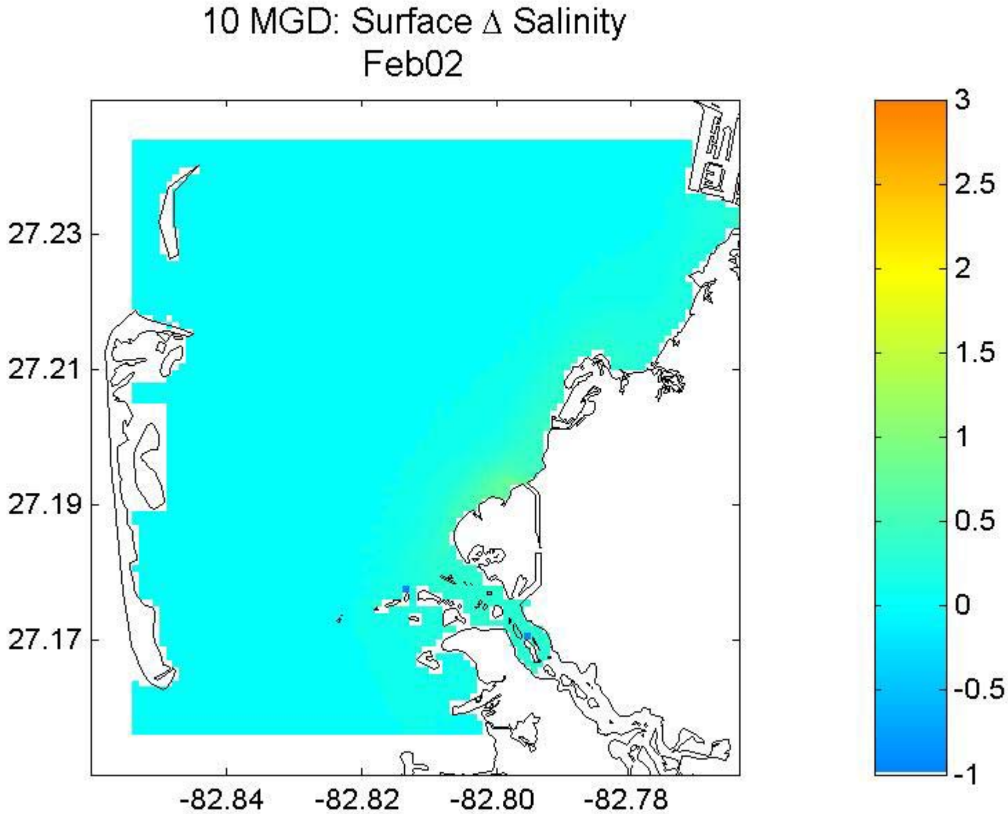

Figure 6.55. Predicted monthly mean surface salinity change, 10 MGD product water scenario, February 2002.

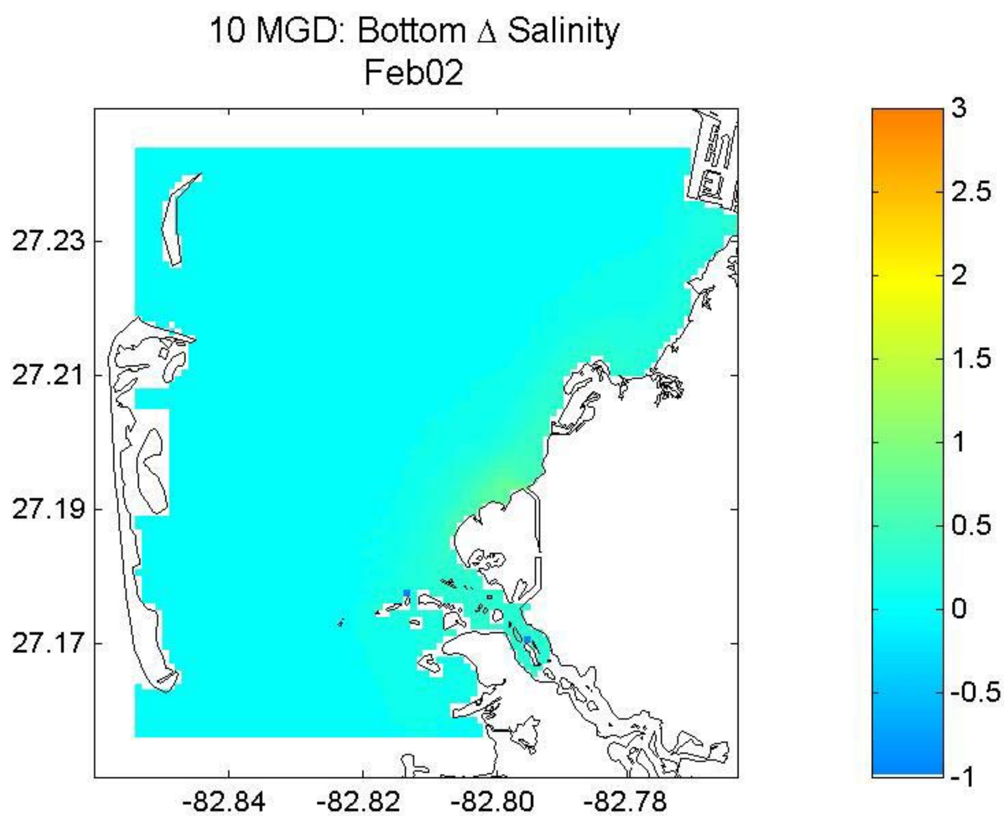

Figure 6.56. Predicted monthly mean bottom salinity change, 10 MGD product water scenario, February 2002.

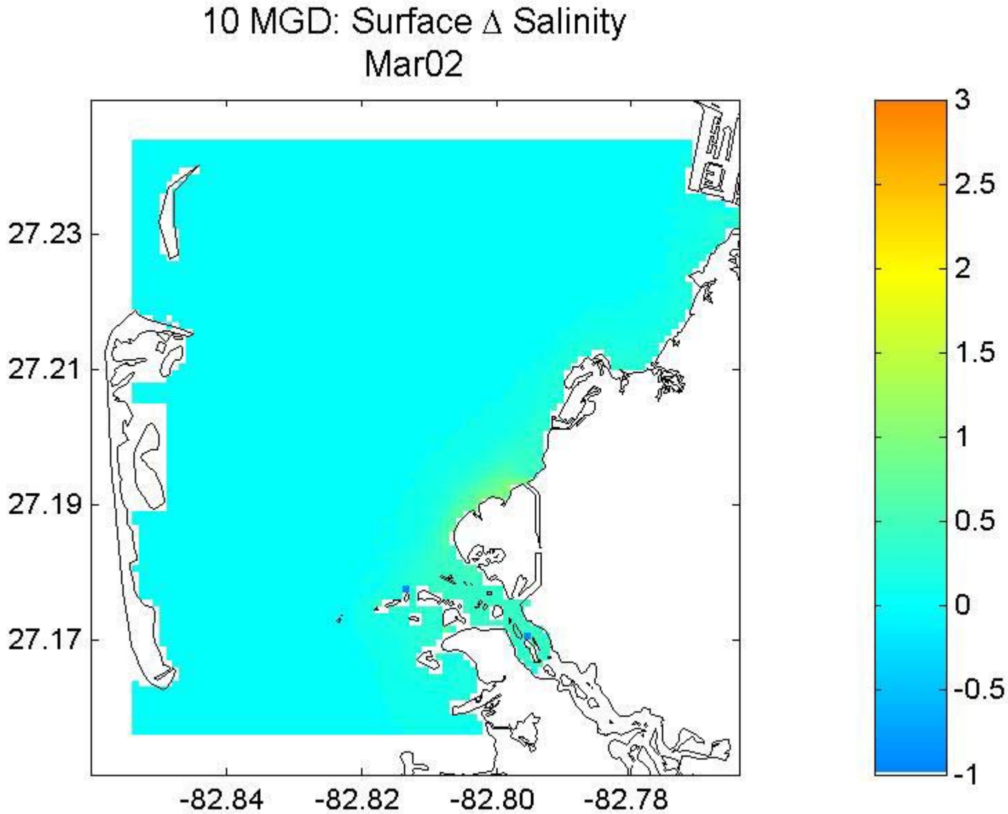

Figure 6.57. Predicted monthly mean surface salinity change, 10 MGD product water scenario, March 2002.

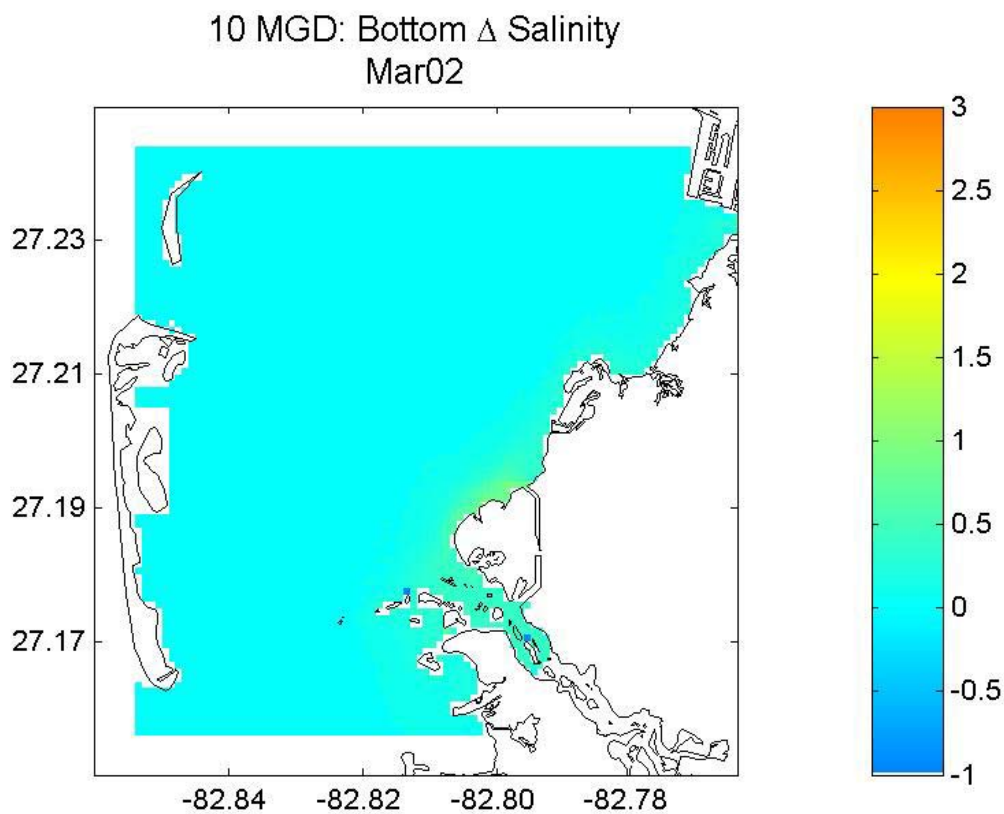

Figure 6.58. Predicted monthly mean bottom salinity change, 10 MGD product water scenario, March 2002.

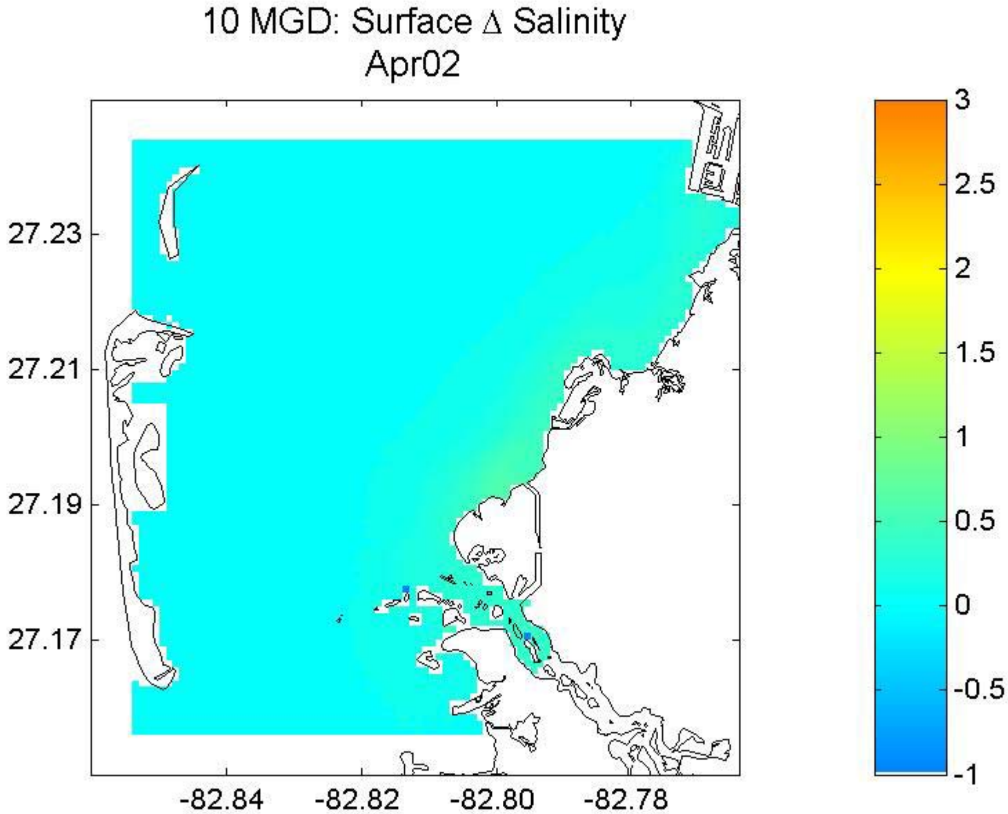

Figure 6.59. Predicted monthly mean surface salinity change, 10 MGD product water scenario, April 2002.

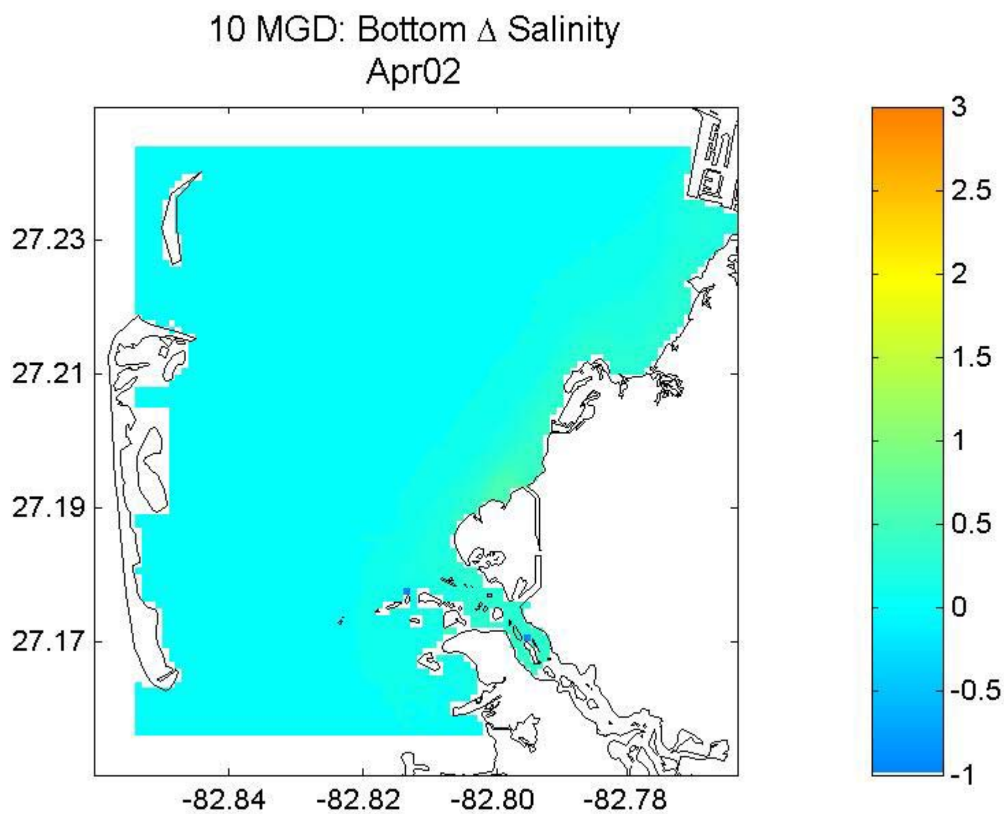

Figure 6.60. Predicted monthly mean bottom salinity change, 10 MGD product water scenario, April 2002.

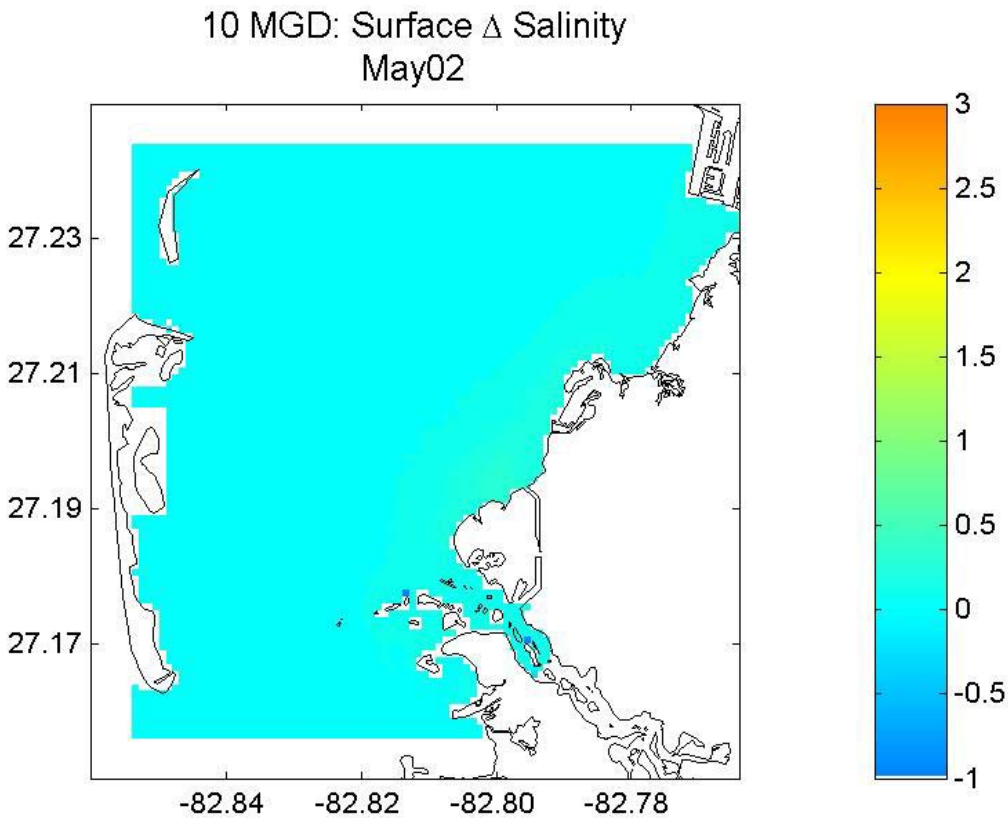

Figure 6.61. Predicted monthly mean surface salinity change, 10 MGD product water scenario, May 2002.

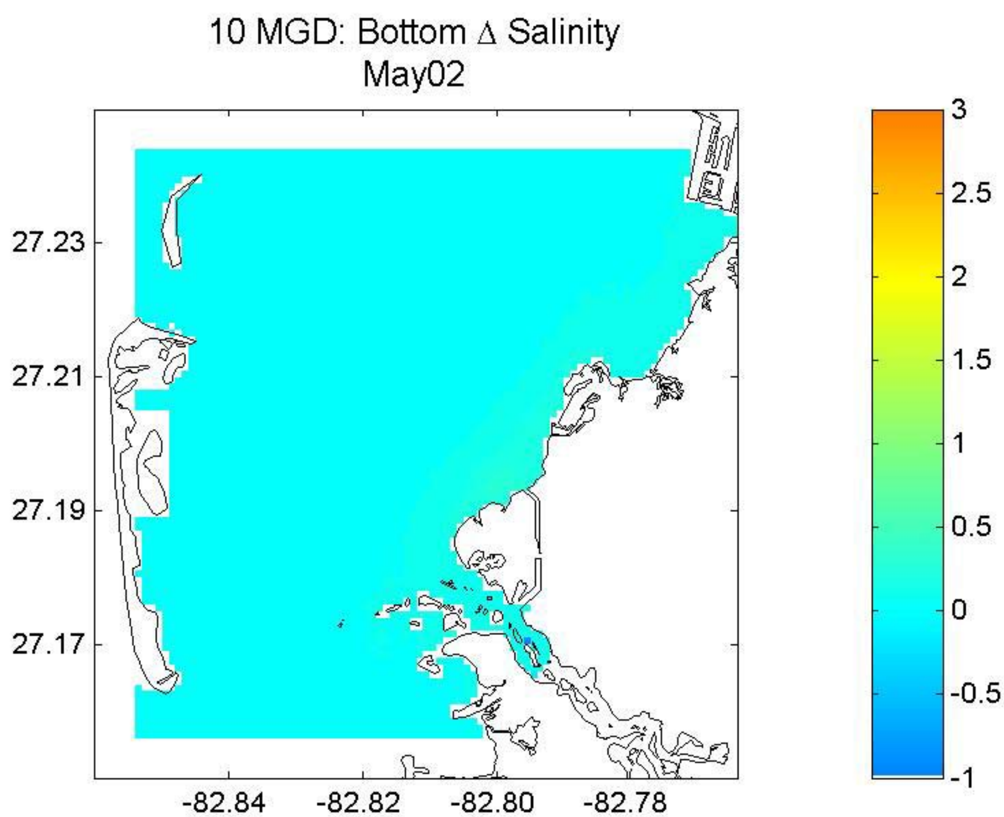

Figure 6.62. Predicted monthly mean bottom salinity change, 10 MGD product water scenario, May 2002.

A time series plot of the predicted daily mean salinity of the Anchorage for the 10 MGD product water scenario is presented in Figure 6.63. The daily mean salinity follows the same seasonal pattern as does the baseline scenario (Figure 6.26). Greatest differences between surface and bottom salinity predictions occur during the wet season, when freshwater inflows are greatest.

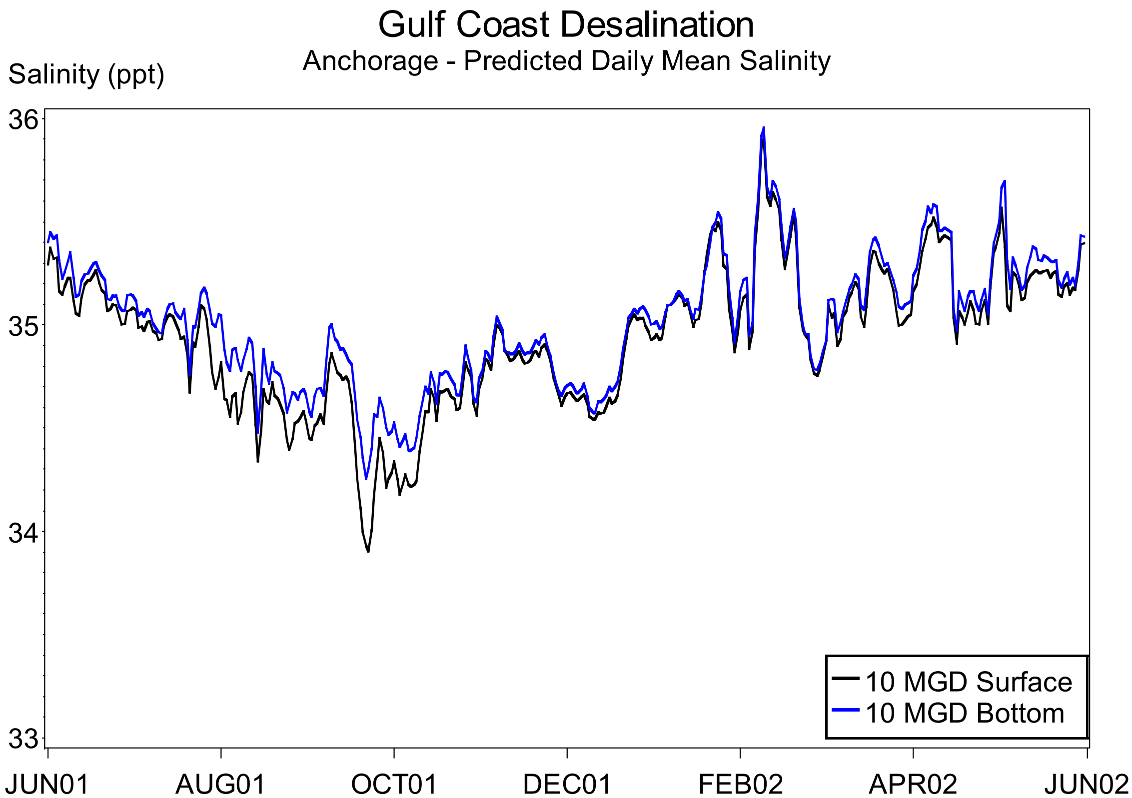

Figure 6.63. Time series of daily mean salinity for surface and bottom layers over the Anchorage, 10 MGD product water scenario, June 2001 to May 2002.

Because of the increase in predicted salinity values in the shallow area near the discharge canal, as shown in Figures 6.39 through 6.62, further analyses were performed for the shallow area (< 1 m) and the area immediately adjacent to the discharge canal. The extents of these areas are shown in Figure 6.64.

A time series plot of the predicted daily mean salinity for the shallow area (Figure 6.65) shows values slightly less than those predicted for the entire anchorage, with values below 33 ppt predicted at times during August and September. This is as expected, given that the coastal region of the Anchorage is fresher than the Anchorage as a whole as shown in the maps of the baseline condition. A comparison of the predicted annual mean salinity of the baseline and 10 MGD product water scenarios for the shallow area reveals an increase in salinity of 0.1 ppt for the surface layer (34.2 to 34.3) and the bottom layer (34.3 to 34.4).

A time series plot of the predicted daily mean salinity for the area near the mouth of the discharge canal (Figure 6.66) shows lower salinity than that predicted for the shallow area, with values below 30 ppt predicted during times in August and September. A comparison of the predicted mean annual salinity of the baseline and 10 MGD product water scenarios for the area near the discharge canal reveals an increase in salinity of 0.4 ppt for the surface layer (32.8 to 33.2) and the bottom layer (33.0 to 33.4).

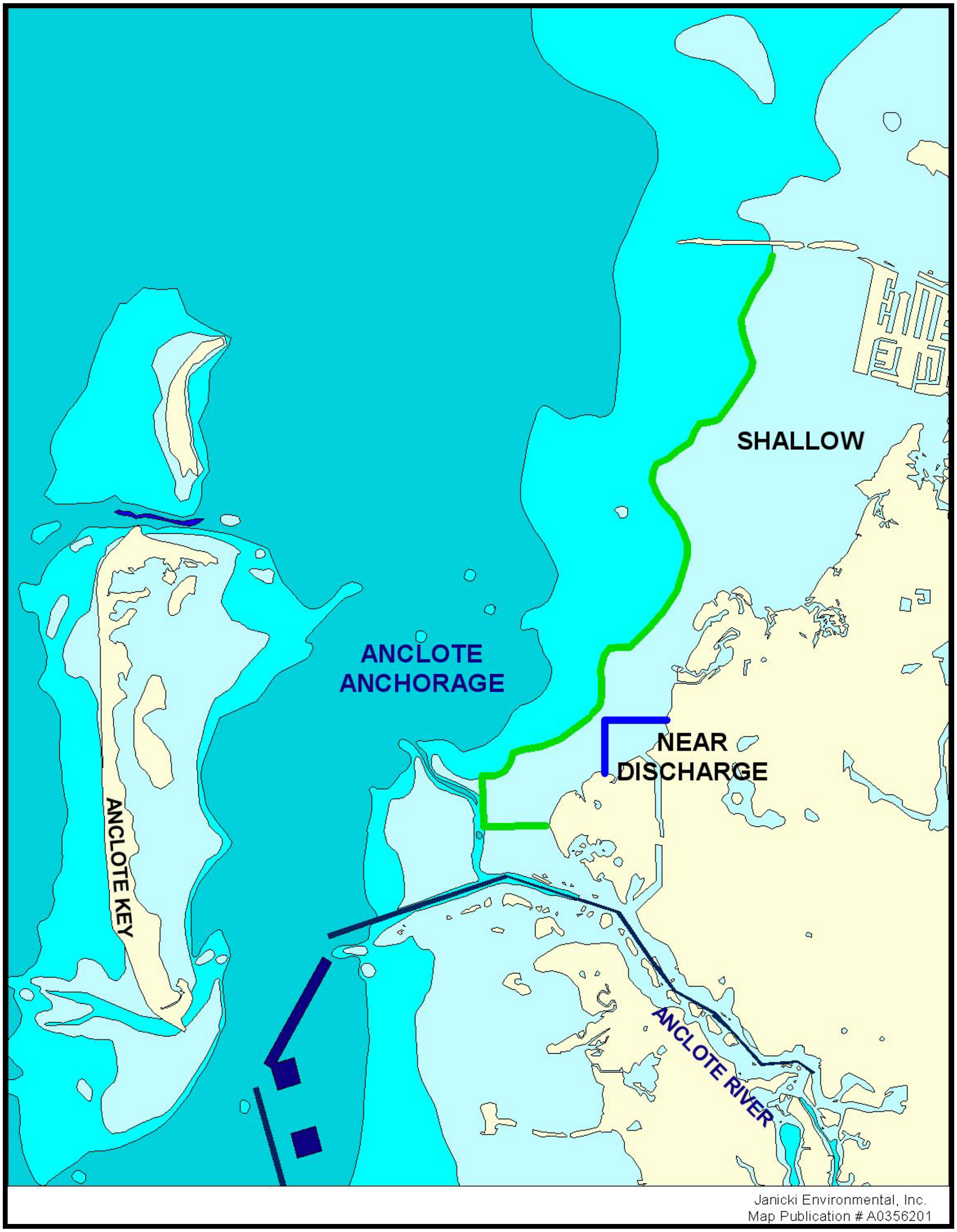

Figure 6.64. Map of Anclote Anchorage depicting the shallow area (cell depth < 1 m MLLW) and the area near the mouth of the discharge canal.

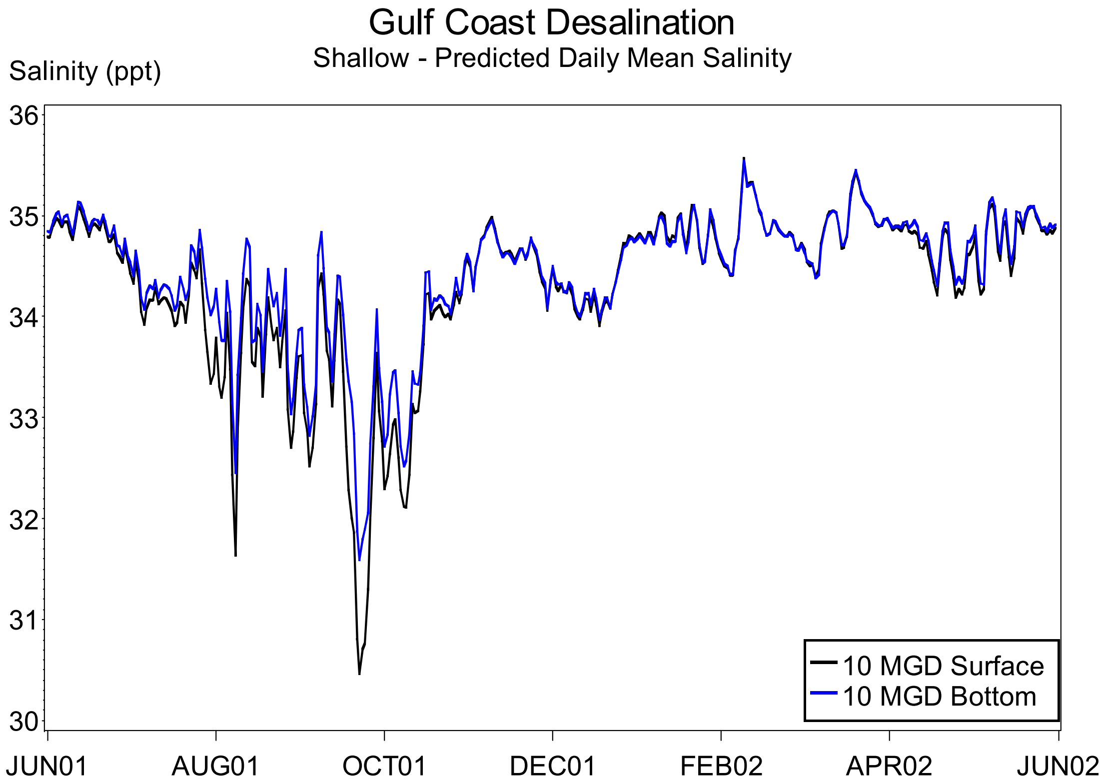

Figure 6.65. Time series of daily mean salinity, shallow area surface and bottom layers, 10 MGD product water scenario, June 2001 to May 2002.

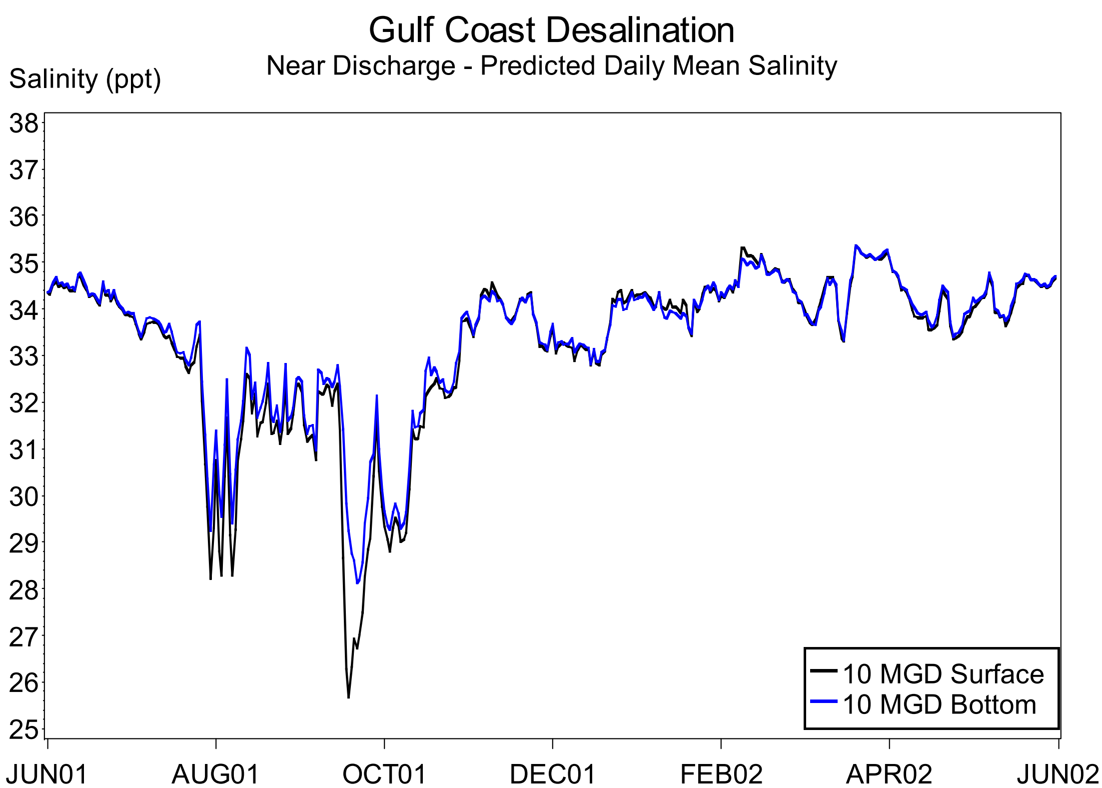

Figure 6.66. Time series of daily mean salinity, near discharge surface and bottom layers, 10 MGD product water scenario, June 2001 to May 2002.

6.1.3 Nearshore - 15 MGD Product Water Scenario

The nearshore 15 MGD product water scenario results in approximately 24 MGD of concentrate mixing with the cooling water release from the power station prior to entering the discharge canal. The resultant effects on salinity across the entire Anchorage are displayed as monthly mean values in maps below, with time series presentations of daily mean surface and bottom salinity predictions in three areas: near the discharge, in the shallow area near the eastern shore of the Anchorage, and in the Anchorage as a whole.

The statistics for the daily mean predicted salinity values for the nearshore 15 MGD product water scenario are summarized in Table 6.3. Changes in salinity (Δ salinity) are derived from the difference of the predicted salinity values for this scenario and those for the baseline. As shown for the 10 MGD product water scenario, predicted salinity changes during March are the greatest, while those during September are the least. Maps of predicted changes in salinity for the month with the greatest change in salinity (March) and the month with the least change in salinity (September) for the surface and bottom layers are presented in Figures 6.67-6.70. Maps of predicted change in salinity for all months, surface and bottom, are presented in Appendix I. The mean of the daily values for the Anchorage over the entire year is 0.1 ppt greater than that for the baseline in the surface, and no different from the same statistic for the baseline scenario bottom layer (see Table 6.1).

Table 6.3. Statistics for the daily mean predicted salinity for the nearshore 15 MGD product water scenario.

Layer	N	Mean	Standard Deviation	Minimum	Maximum
Surface	365	35.0 ppt	0.3 ppt	33.9 ppt	35.9 ppt
Bottom	365	35.0 ppt	0.3 ppt	34.3 ppt	36.0 ppt

A time series plot of the daily mean predicted salinity of the Anchorage for the 15 MGD product water scenario is presented in Figure 6.71. The vertical salinity difference during the wet season remains present in this scenario.

A time series plot of the predicted daily mean salinity for the shallow area (Figure 6.72) shows values below 33 ppt predicted during August and September. A comparison of the predicted daily mean salinity of the baseline and 15 MGD scenarios for the shallow area reveals an increase in salinity of 0.2 ppt for the surface layer (34.2 to 34.4) and the bottom layer (34.3 to 34.5).

A time series plot of the predicted daily mean salinity for the area near the discharge canal (Figure 6.73) shows values below 30 ppt predicted during August and September. A comparison of the predicted daily mean salinity of the baseline and 15 MGD product water scenarios for the area near the discharge canal reveals an increase in salinity of 0.6 ppt for the surface layer (32.8 to 33.4) and the bottom layer (33.0 to 33.6).

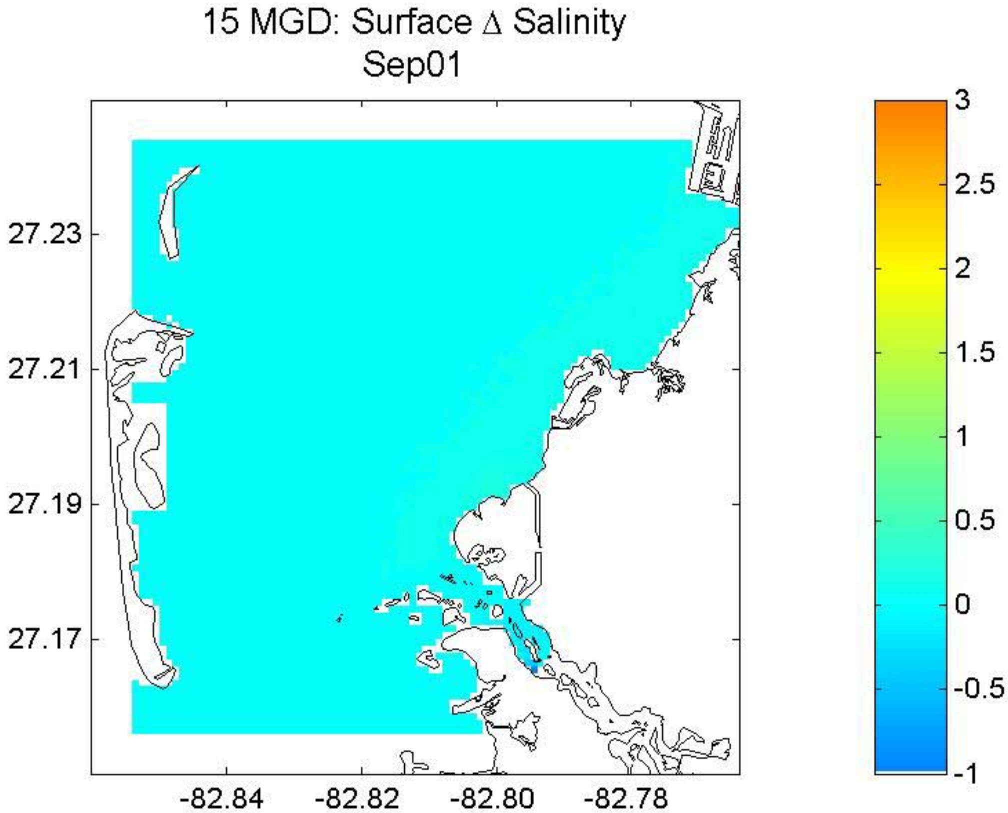

Figure 6.67. Predicted monthly mean surface salinity change, 15 MGD product water scenario, September 2001.

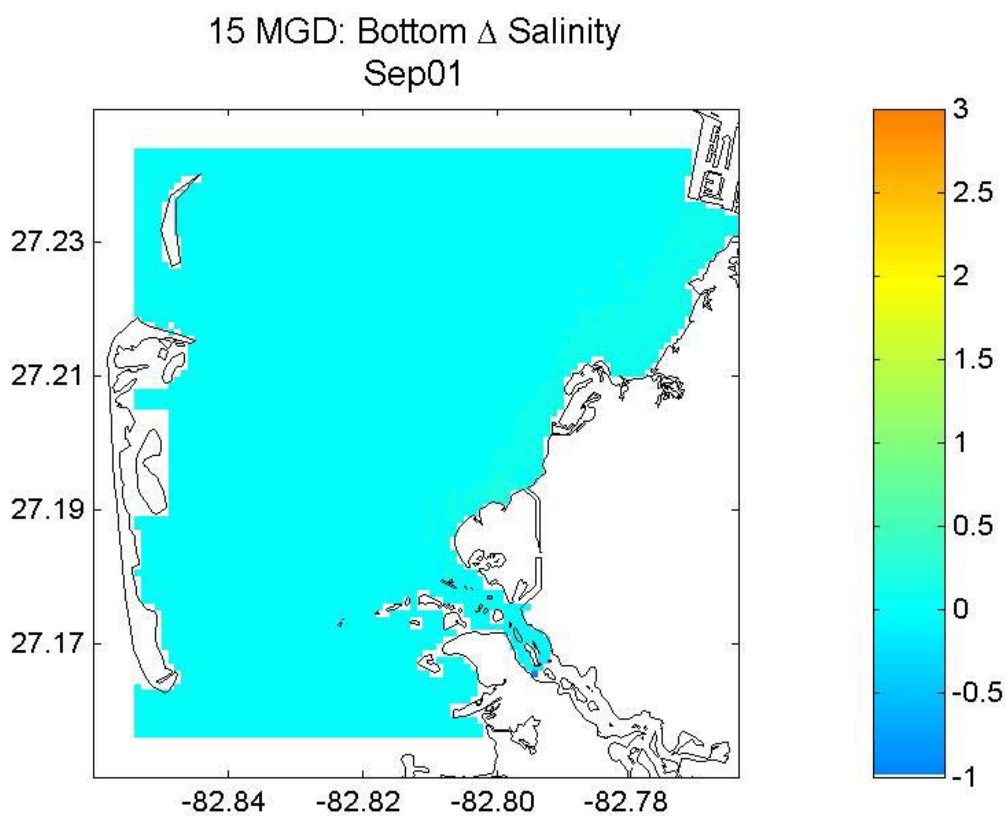

Figure 6.68. Predicted monthly mean bottom salinity change, 15 MGD product water scenario, September 2001.

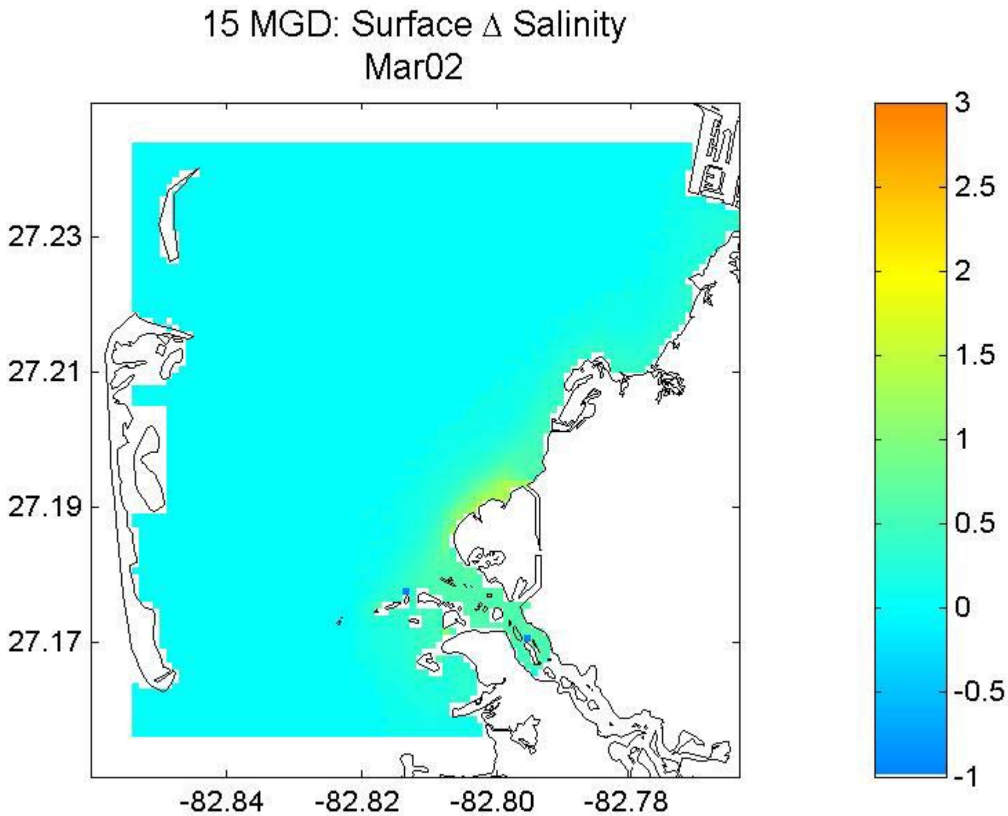

Figure 6.69. Predicted monthly mean surface salinity change, 15 MGD product water scenario, March 2002.

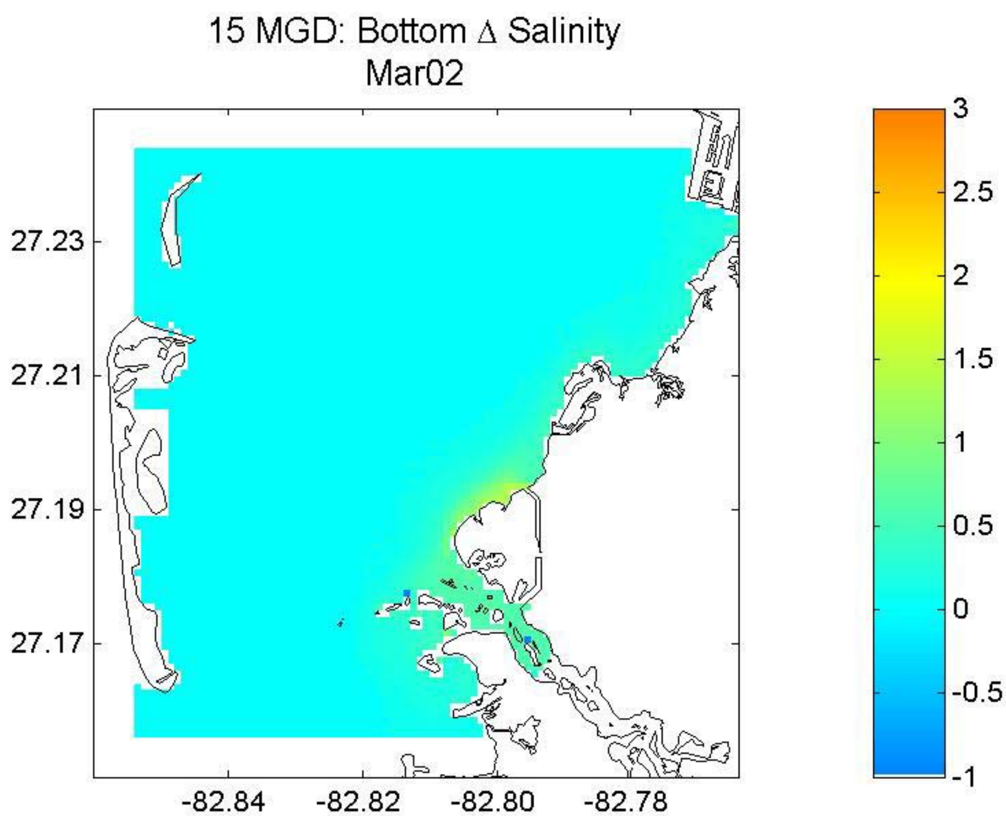

Figure 6.70. Predicted monthly mean bottom salinity change, 15 MGD product water scenario, March 2002.

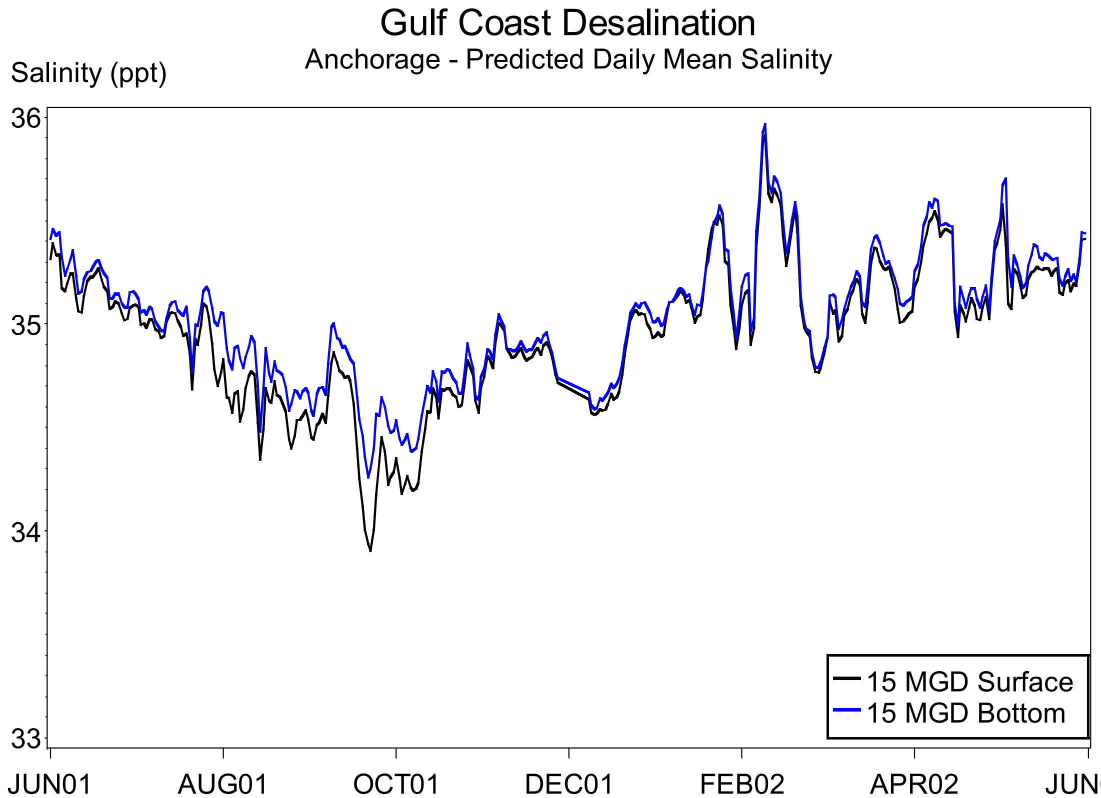

Figure 6.71. Time series of daily mean salinity for surface and bottom layers over the Anchorage, 15 MGD product water scenario, June 2001 to May 2002.

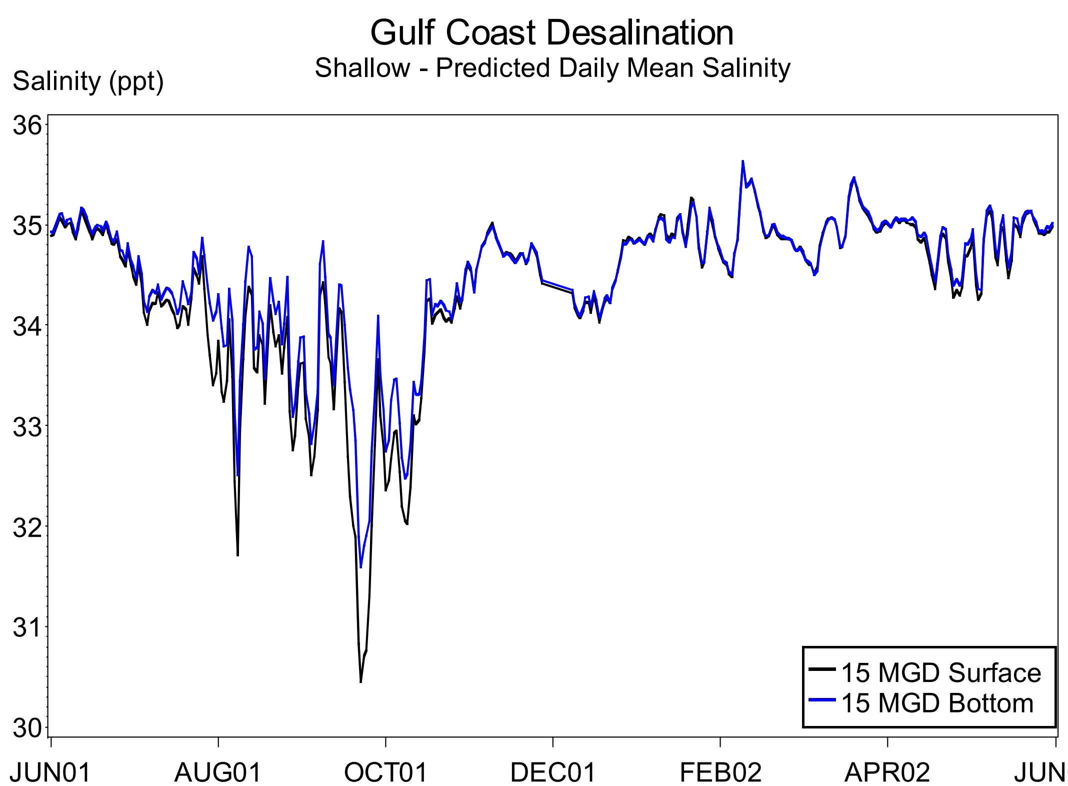

Figure 6.72. Time series of daily mean salinity, shallow area surface and bottom layers, 15 MGD product water scenario, June 2001 to May 2002.

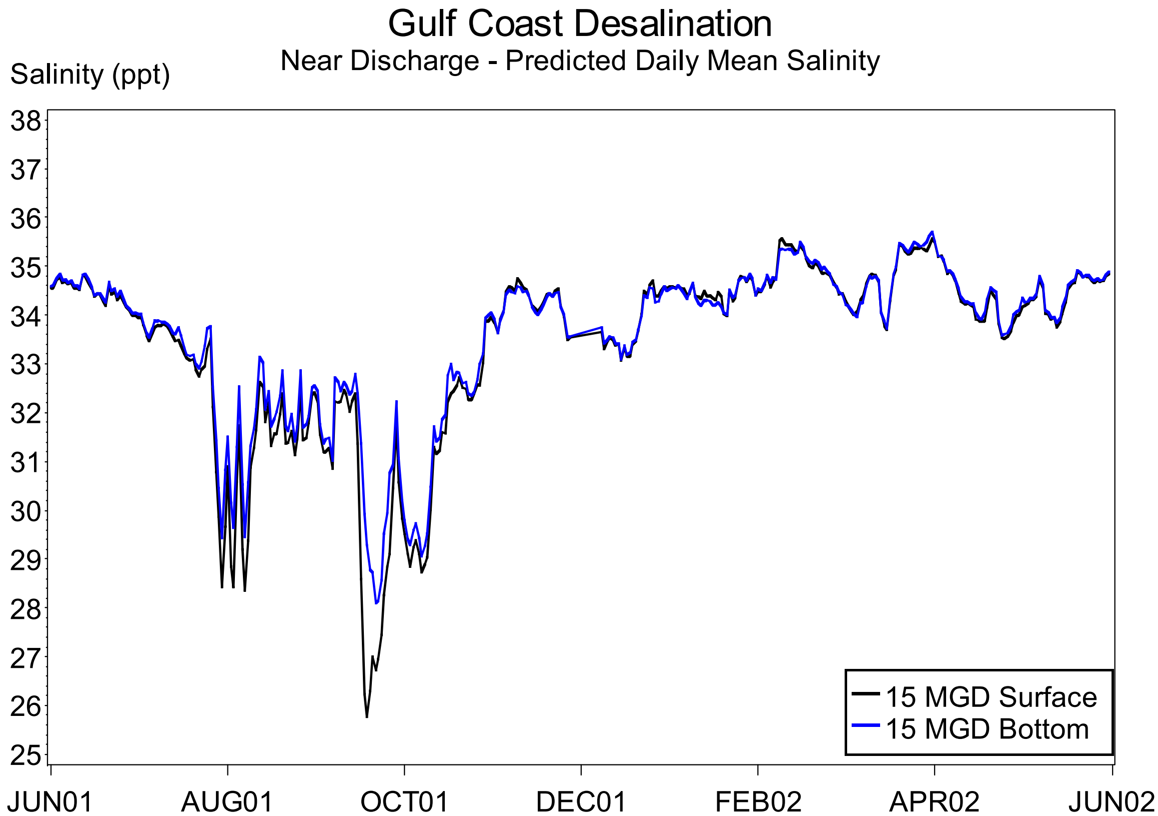

Figure 6.73. Time series of daily mean salinity, near discharge surface and bottom layers, 15 MGD product water scenario, June 2001 to May 2002.

6.1.4 Nearshore - 18 MGD Product Water Scenario

The nearshore 18 MGD product water scenario results in approximately 29 MGD of concentrate mixing with the cooling water release from the power station prior to entering the discharge canal. The resultant effects on salinity across the entire Anchorage are displayed as monthly mean values in maps below, with time series presentations of daily mean surface and bottom salinity predictions in three areas: near the discharge, in the shallow area near the eastern shore of the Anchorage, and in the Anchorage as a whole.

The statistics for the daily mean predicted salinity values for the nearshore 18 MGD product water scenario are summarized in Table 6.4. Changes in salinity (Δ salinity) are derived from the difference of the predicted salinity values for this scenario and those for the baseline. Maps of predicted changes in salinity for the month with the greatest change in salinity (March) and the month with the least change in salinity (September) for the surface and bottom layers are presented in Figures 6.74-6.77. Maps of predicted change in salinity for all months, surface and bottom, are presented in Appendix II. The mean of the daily values for the Anchorage over the entire year is 0.1 ppt greater than that for the baseline in the surface, and no different from the same statistic for the baseline scenario bottom layer (see Table 6.1).

Table 6.4. Statistics for the daily mean predicted salinity for the nearshore 18 MGD product water scenario.

Layer	N	Mean	Standard Deviation	Minimum	Maximum
Surface	365	35.0 ppt	0.3 ppt	33.9 ppt	35.9 ppt
Bottom	365	35.0 ppt	0.3 ppt	34.3 ppt	36.0 ppt

A time series plot of the daily mean predicted salinity of the Anchorage for the 18 MGD product water scenario is presented in Figure 6.78. The vertical salinity difference during the wet season remains present in this scenario.

A time series plot of the predicted daily mean salinity for the shallow area (Figure 6.79) shows values below 33 ppt predicted during August and September. A comparison of the predicted daily mean salinity of the baseline and 18 MGD scenarios for the shallow area reveals an increase in salinity of 0.2 ppt for the surface layer (34.2 to 34.4) and the bottom layer (34.3 to 34.5). These changes are the same as those for the 15 MGD product water scenario.

A time series plot of the predicted daily mean salinity for the area near the discharge canal (Figure 6.80) shows values below 30 ppt predicted during August and September. A comparison of the predicted daily mean salinity of the baseline and 18 MGD product water scenarios for the area near the discharge canal reveals an increase in salinity of 0.7 ppt for the surface layer (32.8 to 33.5) and the bottom layer (33.0 to 33.7).

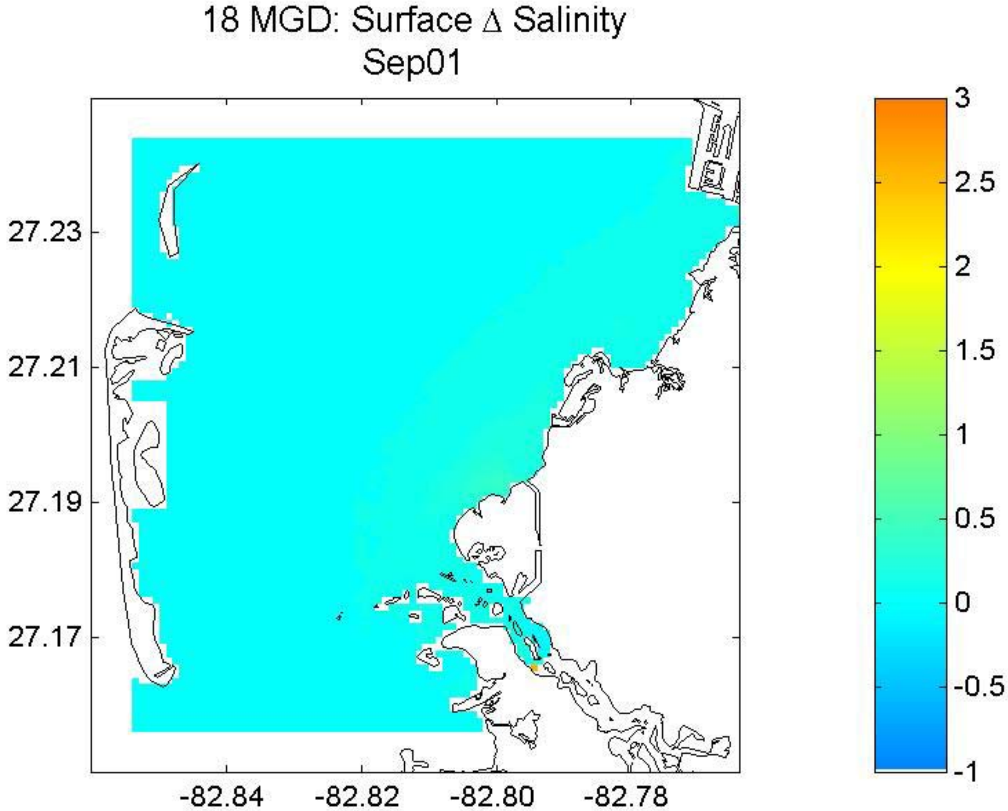

Figure 6.74. Predicted monthly mean surface salinity change, 18 MGD product water scenario, September 2001.

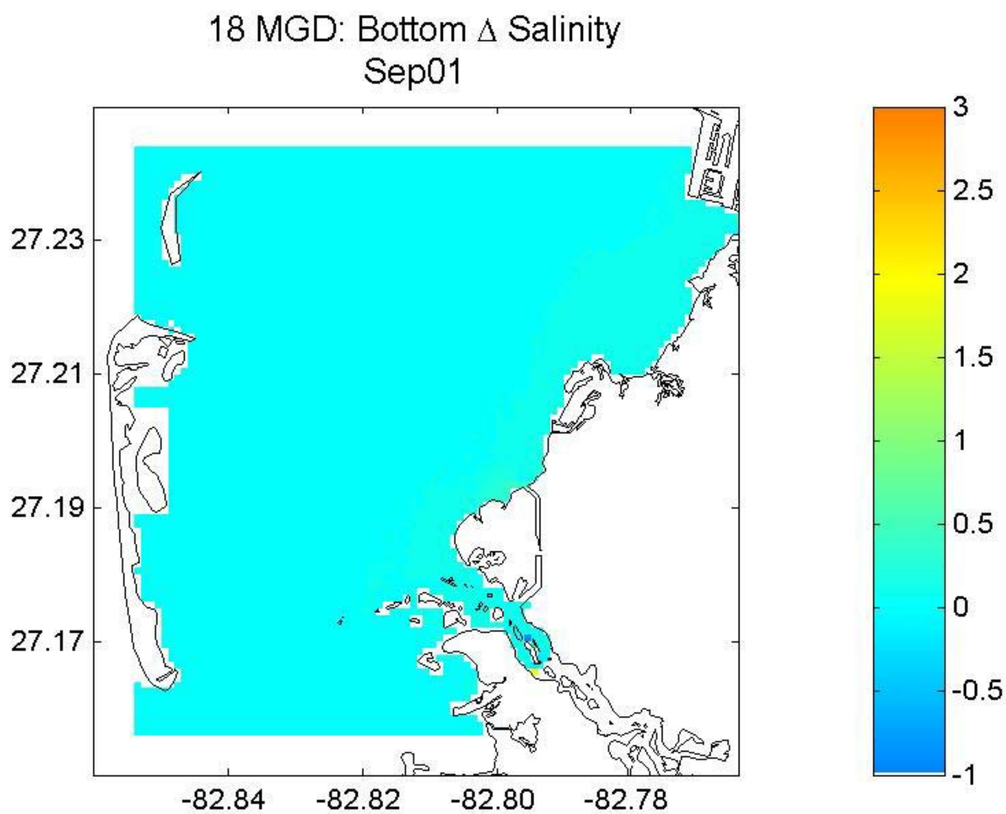

Figure 6.75. Predicted monthly mean bottom salinity change, 18 MGD product water scenario, September 2001.

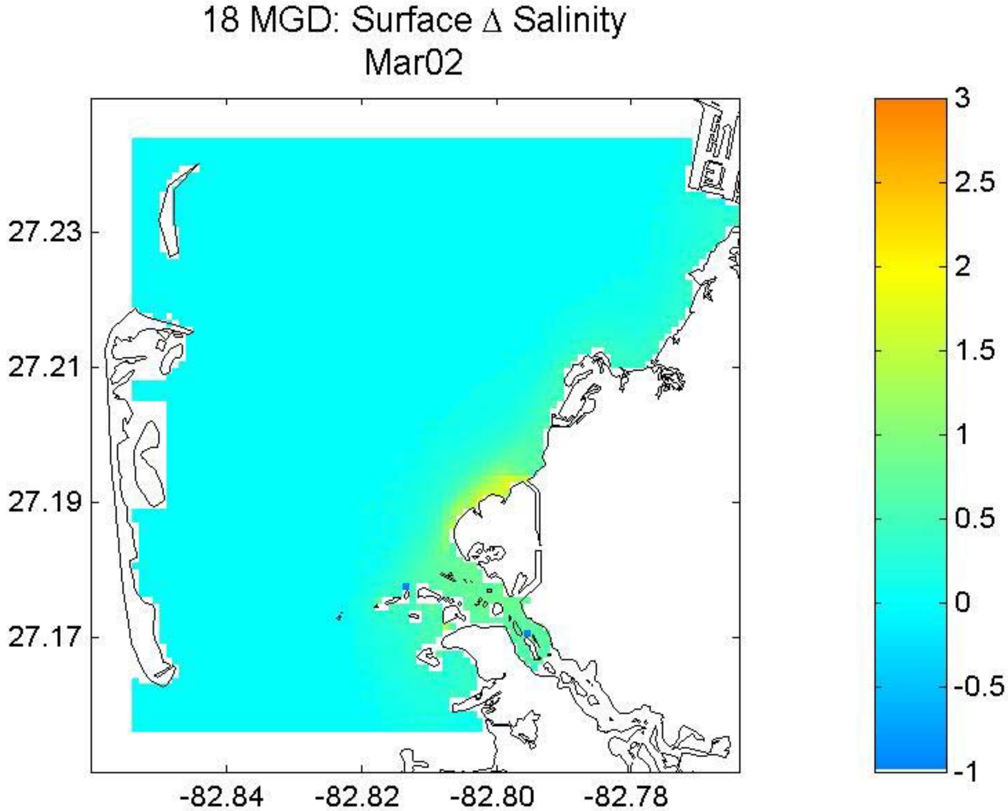

Figure 6.76. Predicted monthly mean surface salinity change, 18 MGD product water scenario, March 2002.

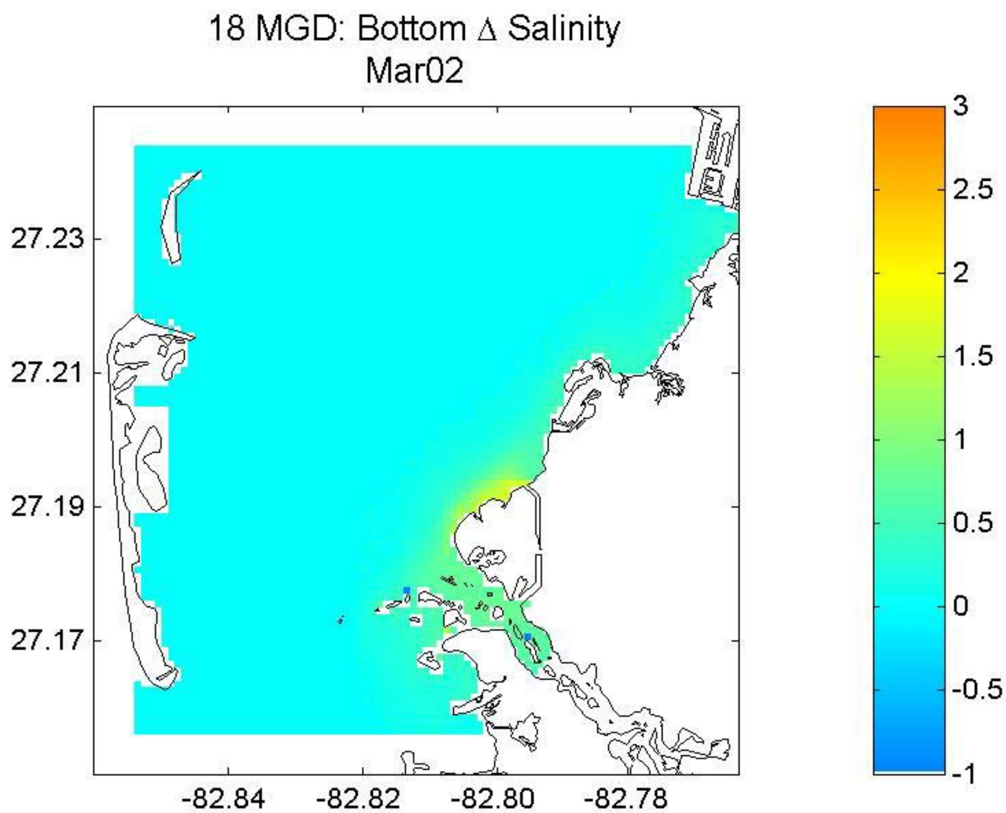

Figure 6.77. Predicted monthly mean bottom salinity change, 18 MGD product water scenario, March 2002.

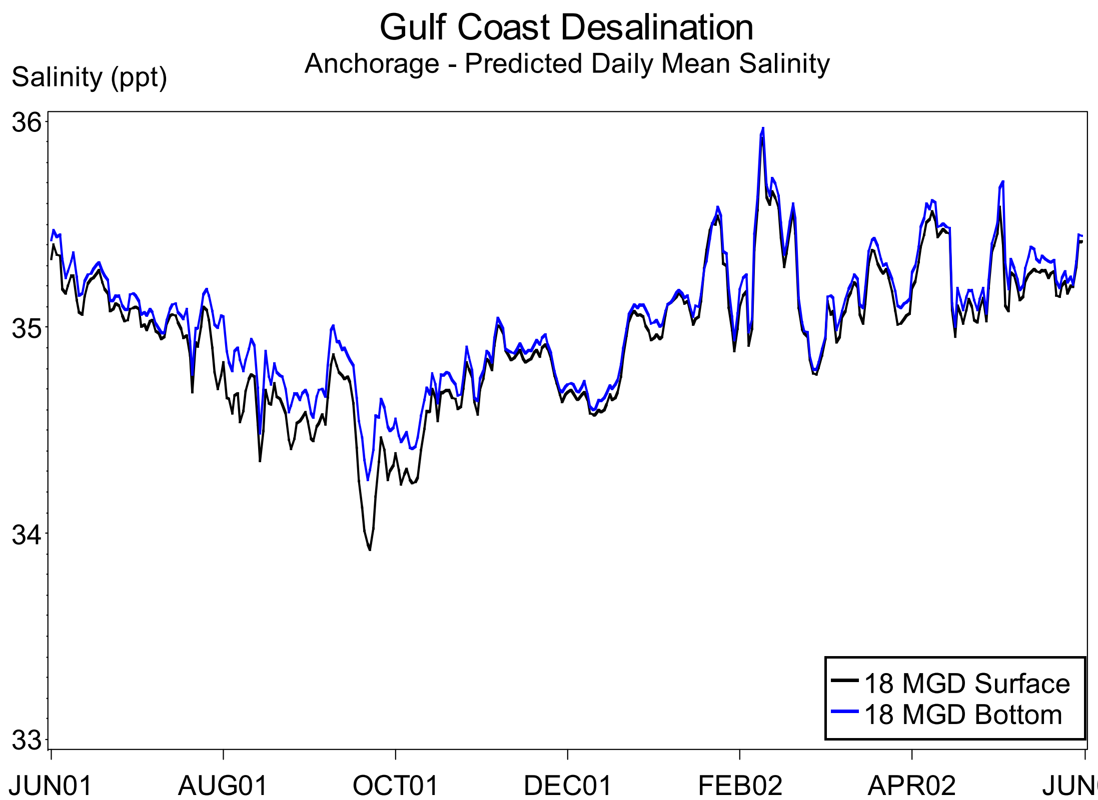

Figure 6.78. Time series of daily mean salinity for surface and bottom layers over the Anchorage, 18 MGD product water scenario, June 2001 to May 2002.

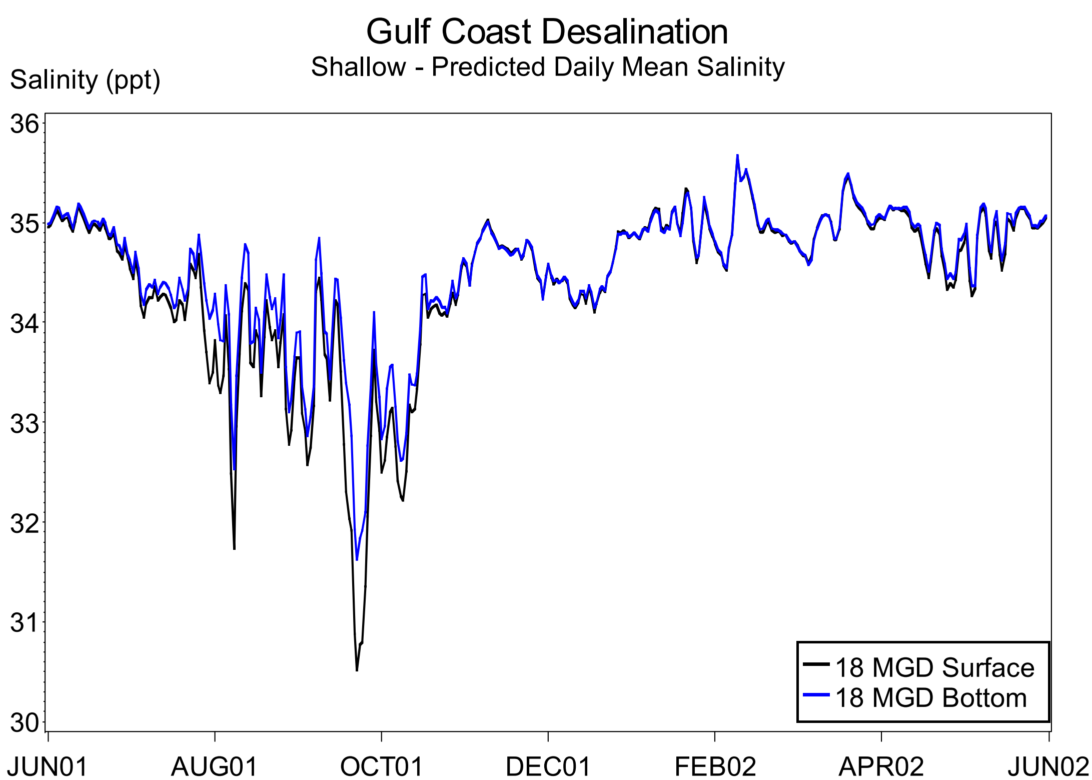

Figure 6.79. Time series of daily mean salinity, shallow area surface and bottom layers, 18 MGD product water scenario, June 2001 to May 2002.

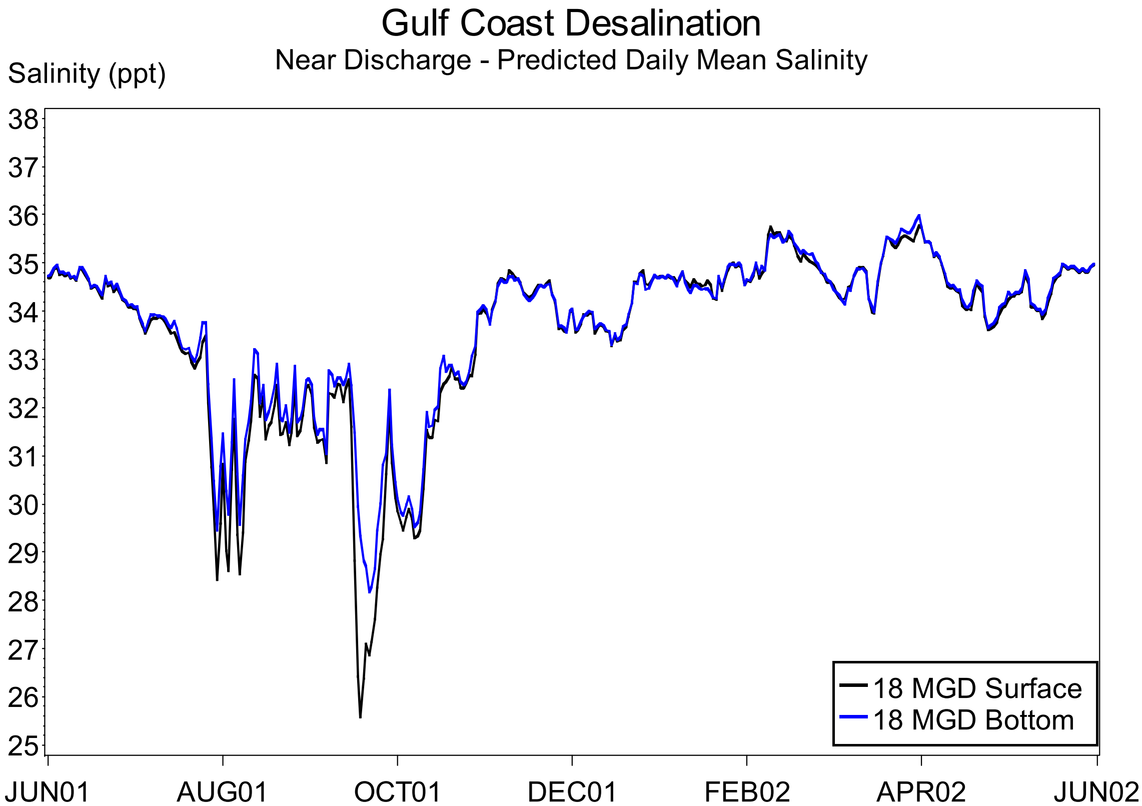

Figure 6.80. Time series of daily mean salinity, near discharge surface and bottom layers, 18 MGD product water scenario, June 2001 to May 2002.

6.1.5 Nearshore - 21 MGD Product Water Scenario

The nearshore 21 MGD product water scenario results in approximately 34 MGD of concentrate mixing with the cooling water release from the power station prior to entering the discharge canal. The resultant effects on salinity across the entire Anchorage are displayed as monthly mean values in maps below, with time series presentations of daily mean surface and bottom salinity predictions in three areas: near the discharge, in the shallow area near the eastern shore of the Anchorage, and in the Anchorage as a whole.

The statistics for the daily mean predicted salinity values for the nearshore 21 MGD product water scenario are summarized in Table 6.5. Changes in salinity (Δ salinity) are derived from the difference of the predicted salinity values for this scenario and those for the baseline. Maps of predicted changes in salinity for the month with the greatest change in salinity (March) and the month with the least change in salinity (September) for the surface and bottom layers are presented in Figures 6.81-6.84. Maps of predicted change in salinity for all months, surface and bottom, are presented in Appendix III. The mean of the daily values for the Anchorage over the entire year is 0.1 ppt greater than that for the baseline in the surface, and no different from the same statistic for the baseline scenario bottom layer (see Table 6.1).

Table 6.5. Statistics for the daily mean predicted salinity for the nearshore 21 MGD product water scenario.

Layer	N	Mean	Standard Deviation	Minimum	Maximum
Surface	365	34.9 ppt	0.3 ppt	33.9 ppt	35.9 ppt
Bottom	365	35.0 ppt	0.3 ppt	34.3 ppt	36.0 ppt

As for the previous product water scenarios, time series plots of the daily mean predicted salinity of the Anchorage, of the shallow area, and of the area near the discharge are provided in Figures 6.85, 6.86, and 6.87, respectively. A comparison of the predicted daily mean salinity of the baseline and 21 MGD product water scenarios for the shallow area reveals an increase in salinity of 0.2 ppt for the surface layer (34.2 to 34.4) and the bottom layer (34.3 to 34.5). These changes are the same as those for the 15 and 18 MGD product water scenarios. A comparison of the predicted daily mean salinity of the baseline and 21 MGD product water scenarios for the area near the discharge canal reveals an increase in salinity of 0.8 ppt for the surface layer (32.8 to 33.6) and the bottom layer (33.0 to 33.8).

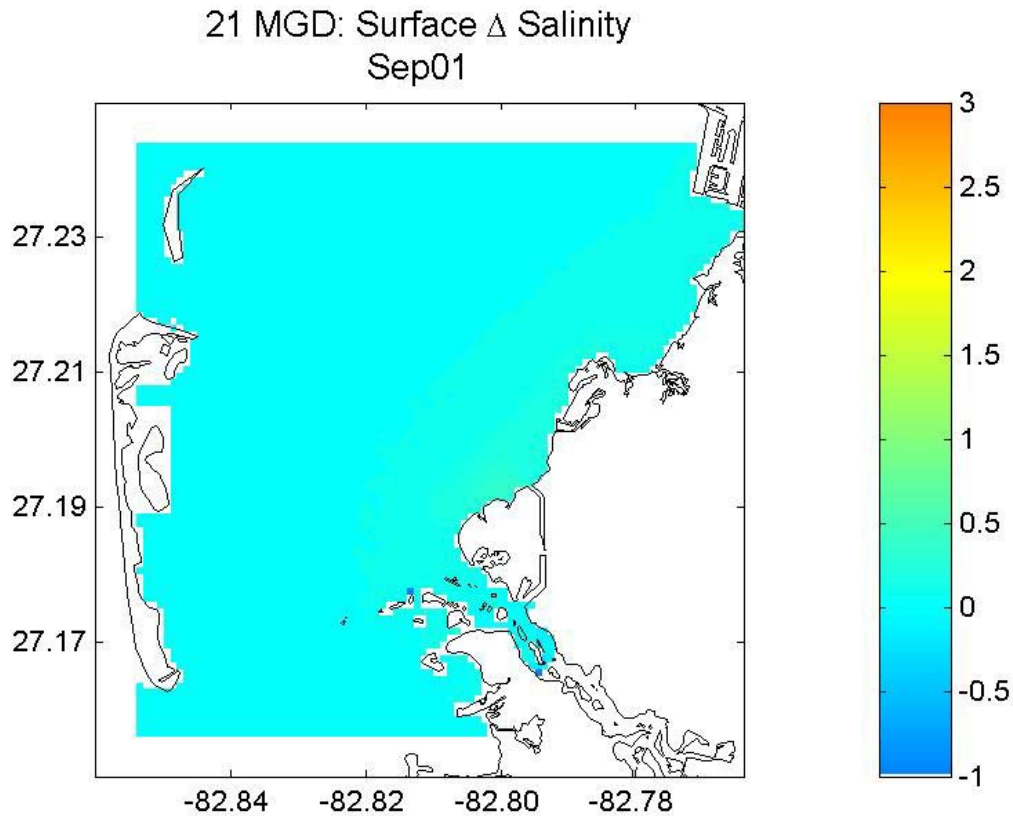

Figure 6.81. Predicted monthly mean surface salinity change, 21 MGD product water scenario, September 2001.

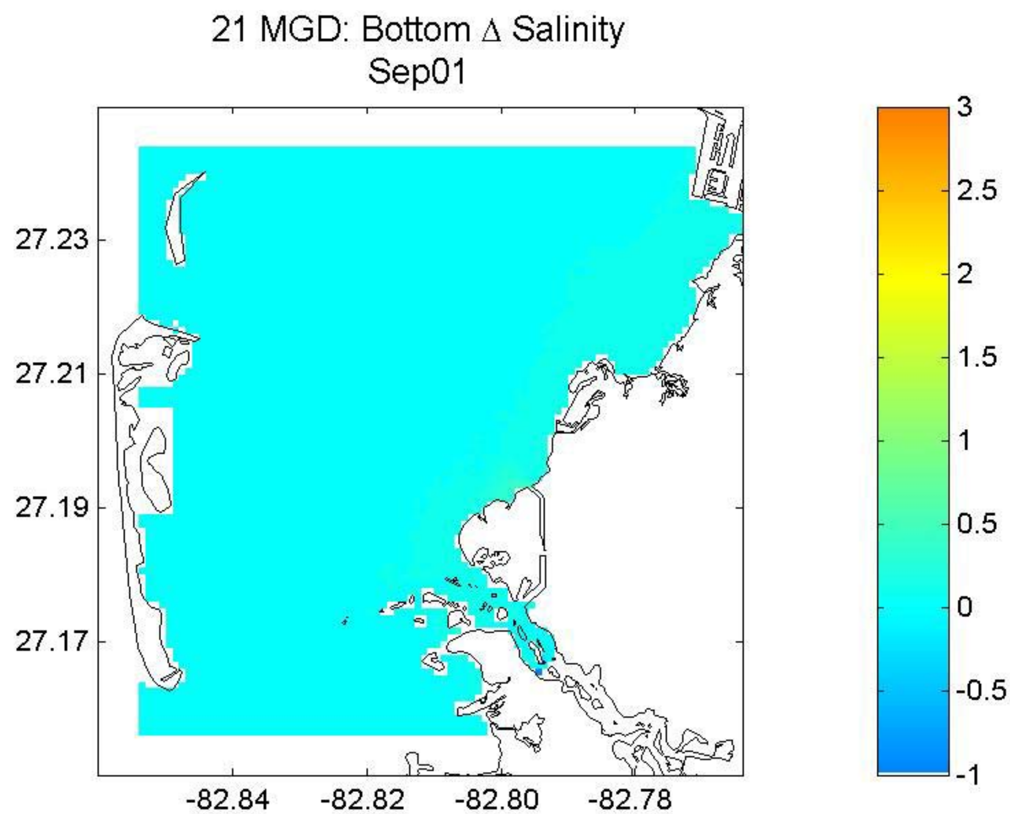

Figure 6.82. Predicted monthly mean bottom salinity change, 21 MGD product water scenario, September 2001.

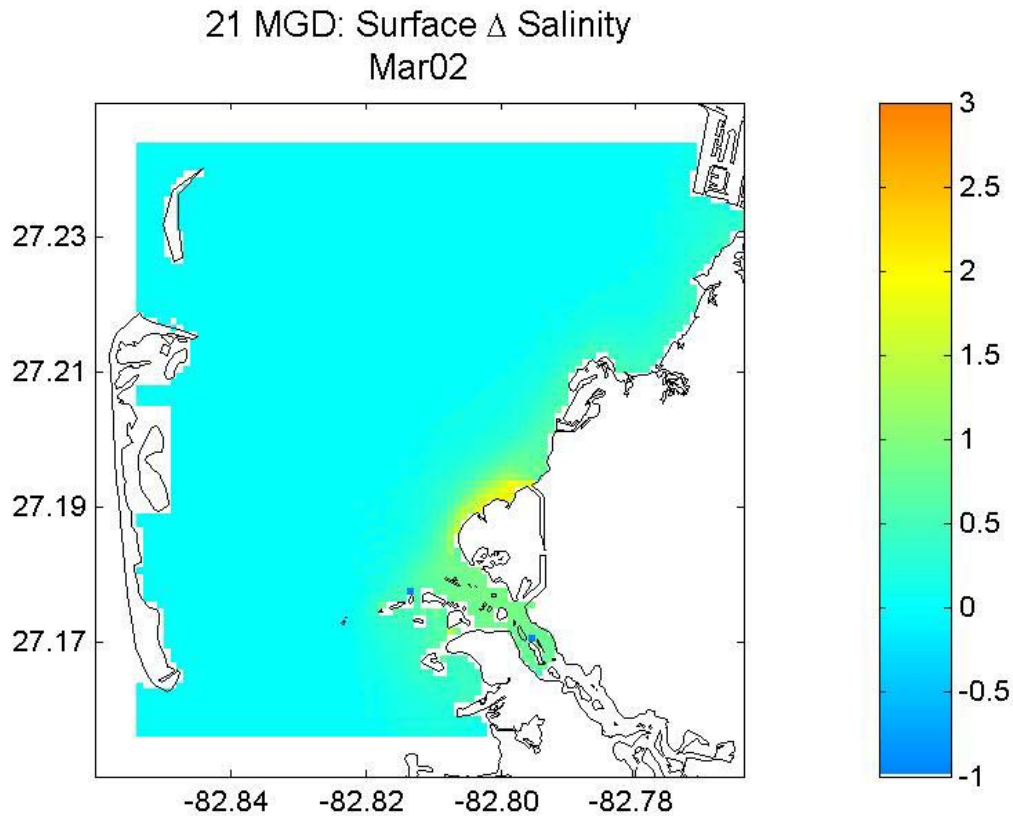

Figure 6.83. Predicted monthly mean surface salinity change, 21 MGD product water scenario, March 2002.

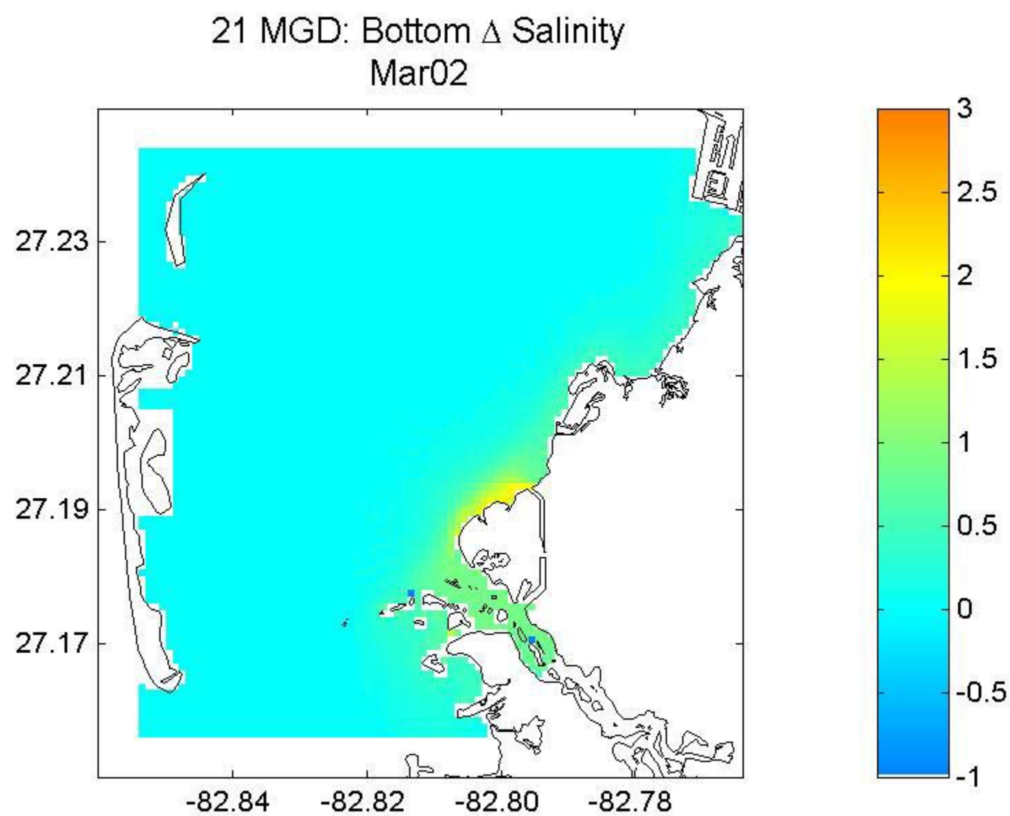

Figure 6.84. Predicted monthly mean bottom salinity change, 21 MGD product water scenario, March 2002.

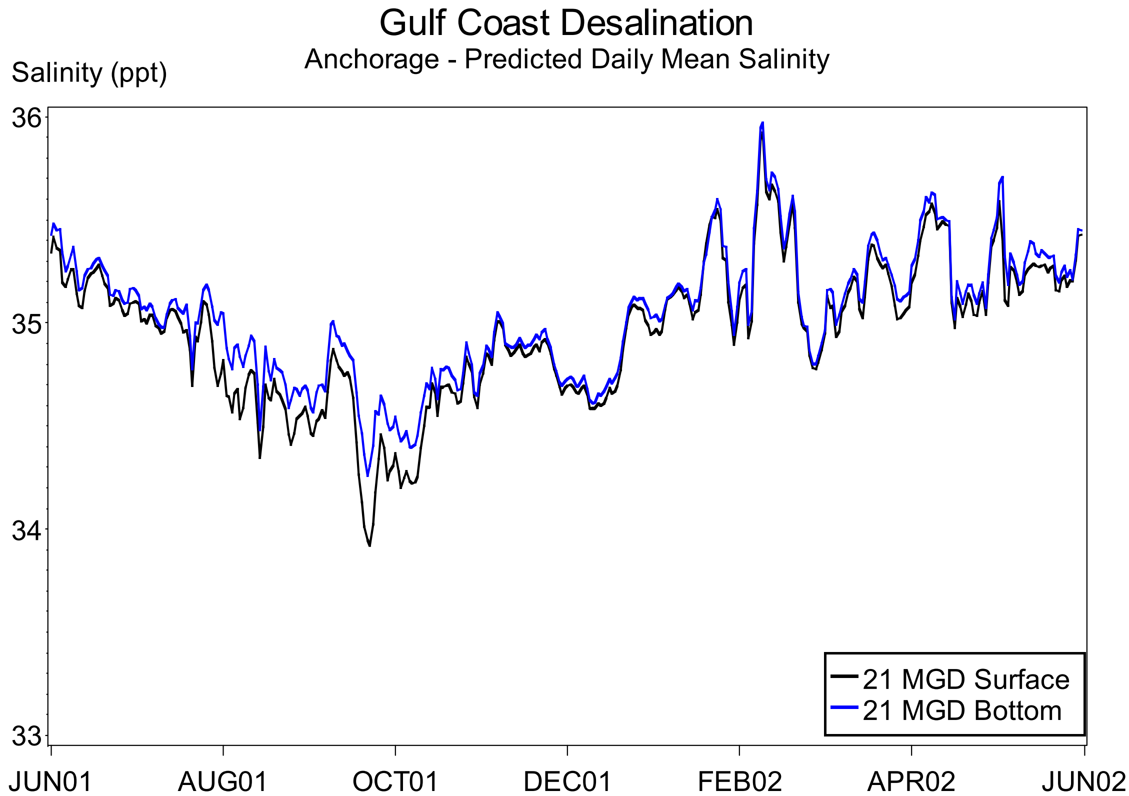

Figure 6.85. Time series of daily mean salinity for surface and bottom layers over the Anchorage, 21 MGD product water scenario, June 2001 to May 2002.

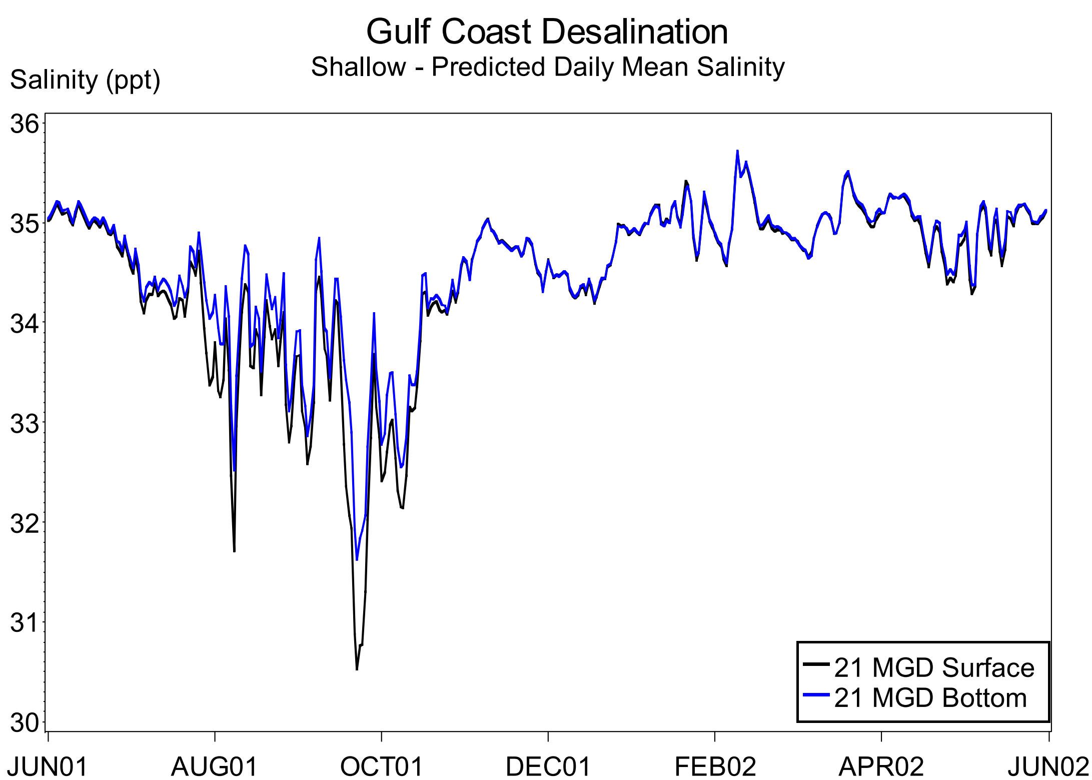

Figure 6.86. Time series of daily mean salinity, shallow area surface and bottom layers, 21 MGD product water scenario, June 2001 to May 2002.

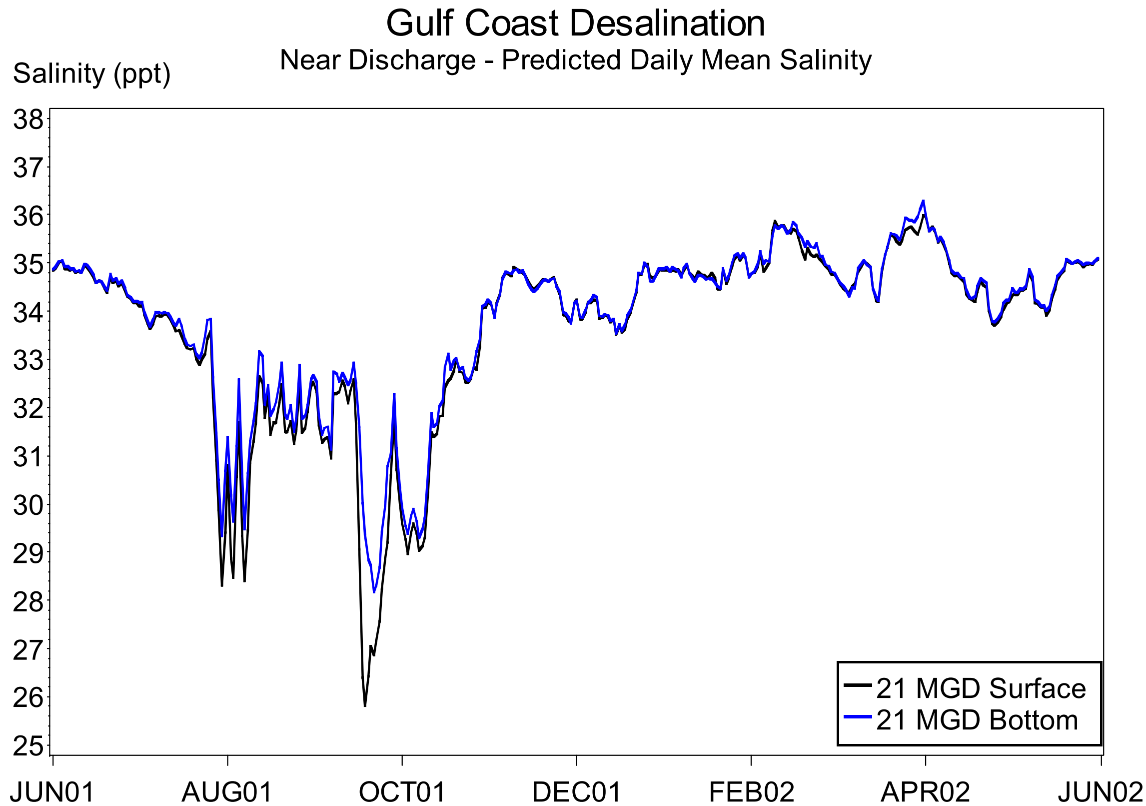

Figure 6.87. Time series of daily mean salinity, near discharge surface and bottom layers, 21 MGD product water scenario, June 2001 to May 2002.

6.1.6 Nearshore – 25 MGD Product Water Scenario

The nearshore 25 MGD product water scenario results in approximately 40 MGD of concentrate mixing with the cooling water release from the power station prior to entering the discharge canal. The resultant effects on salinity across the entire Anchorage are displayed as monthly mean values in maps below, with time series presentations of daily mean surface and bottom salinity predictions in three areas: near the discharge, in the shallow area near the eastern shore of the Anchorage, and in the Anchorage as a whole.

6.1.6.1 Nearshore – 25 MGD Product Water Scenario Salinity

The statistics for the daily mean predicted salinity values for the nearshore 25 MGD product water scenario are summarized in Table 6.6. Changes in salinity (Δ salinity) are derived from the difference of the predicted salinity values for this scenario and those for the baseline. Maps of predicted changes in salinity for the month with the greatest change in salinity (March) and the month with the least change in salinity (September) for the surface and bottom layers are presented in Figures 6.88-6.91. Maps of predicted change in salinity for all months, surface and bottom, are presented in Appendix IV. The mean of the daily values for the Anchorage over the entire year is 0.1 ppt greater than that for the baseline in the surface, and no different from the same statistic for the baseline scenario bottom layer (see Table 6.1).

Table 6.6. Statistics for the daily mean predicted salinity for the nearshore 25 MGD product water scenario.

Layer	N	Mean	Standard Deviation	Minimum	Maximum
Surface	365	35.0 ppt	0.3 ppt	33.9 ppt	35.9 ppt
Bottom	365	35.0 ppt	0.3 ppt	34.3 ppt	36.0 ppt

As for the previous product water scenarios, time series plots of the daily mean predicted salinity of the Anchorage, of the shallow area, and of the area near the discharge are provided in Figures 6.92, 6.93, and 6.94, respectively. A comparison of the predicted daily mean salinity of the baseline and 25 MGD product water scenarios for the shallow area reveals an increase in salinity of 0.3 ppt for the surface layer (34.2 to 34.5) and the bottom layer (34.3 to 34.6). A comparison of the predicted daily mean salinity of the baseline and 25 MGD product water scenarios for the area near the discharge canal reveals an increase in salinity of 1.0 ppt for the surface layer (32.8 to 33.8) and the bottom layer (33.0 to 34.0).

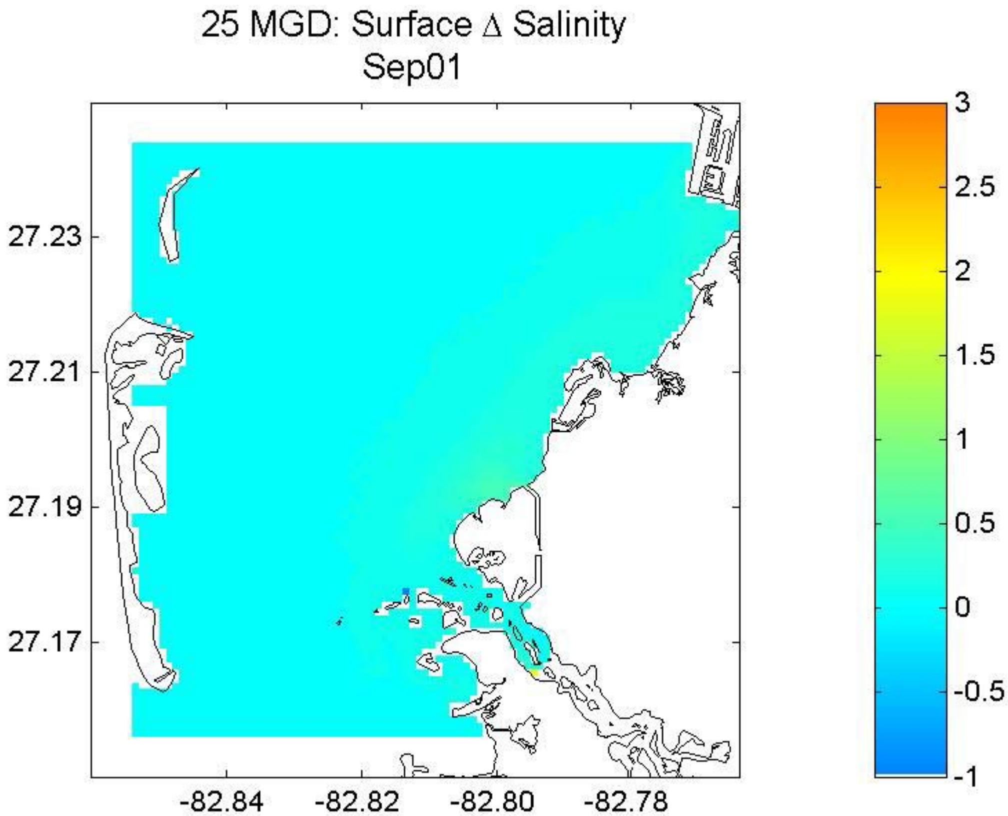

Figure 6.88. Predicted monthly mean surface salinity change, 25 MGD product water scenario, September 2001.

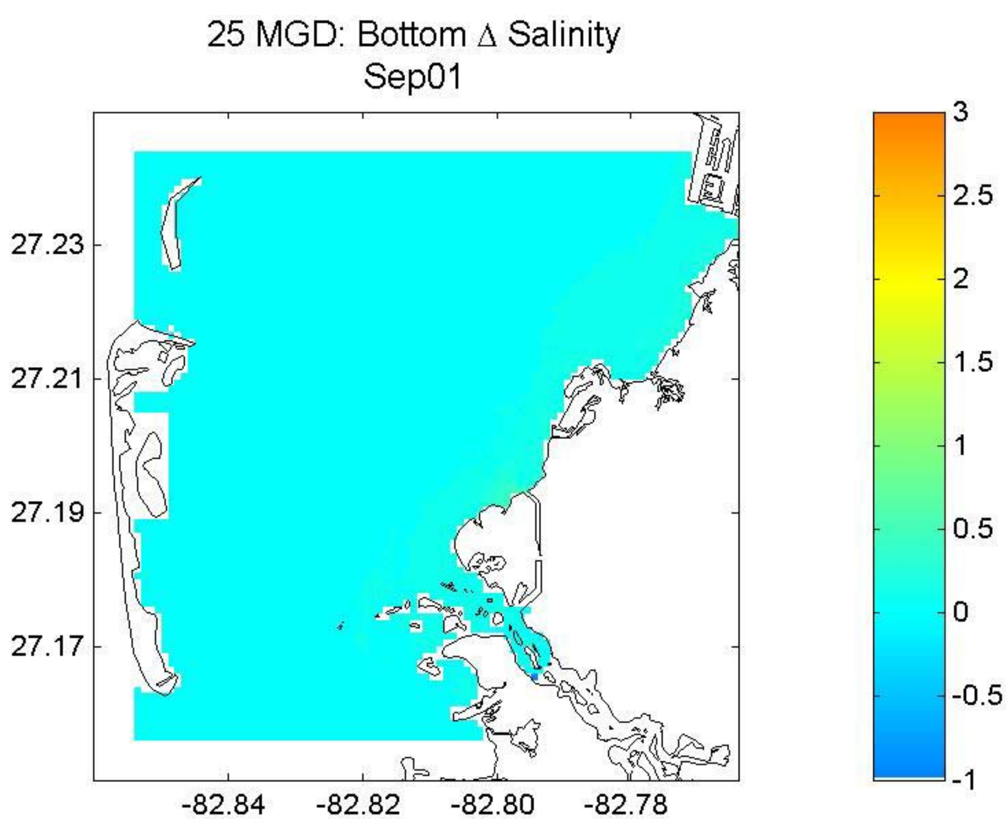

Figure 6.89. Predicted monthly mean bottom salinity change, 25 MGD product water scenario, September 2001.

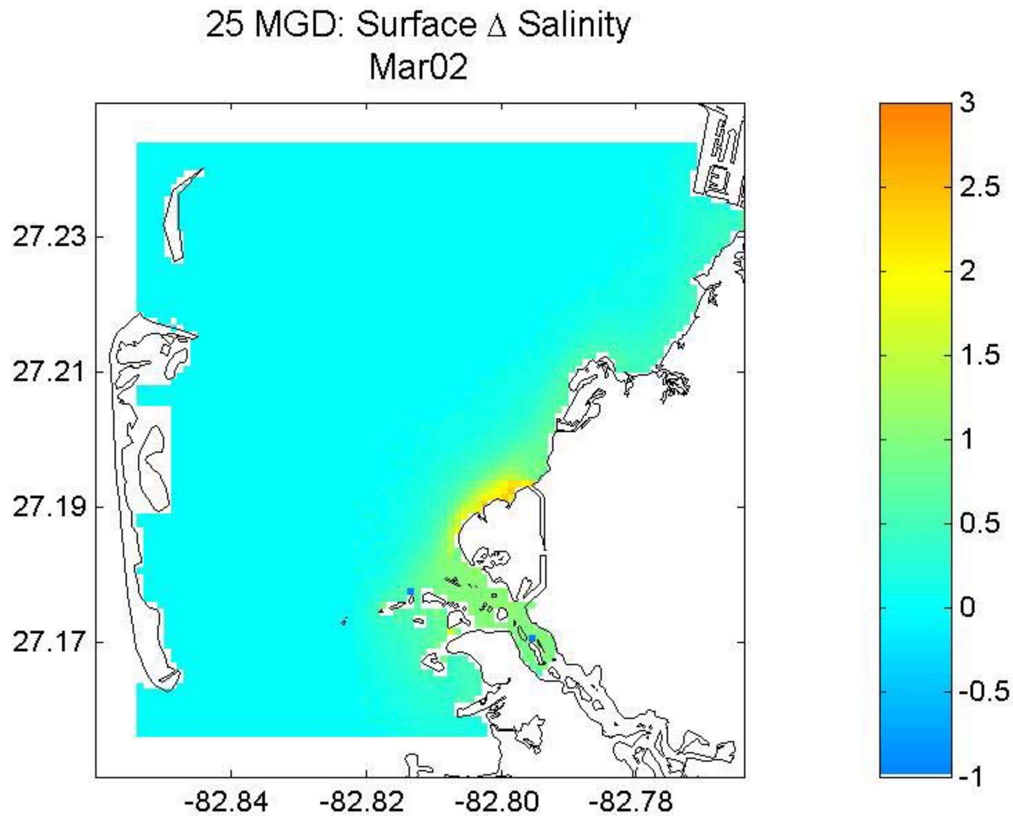

Figure 6.90. Predicted monthly mean surface salinity change, 25 MGD product water scenario, March 2002.

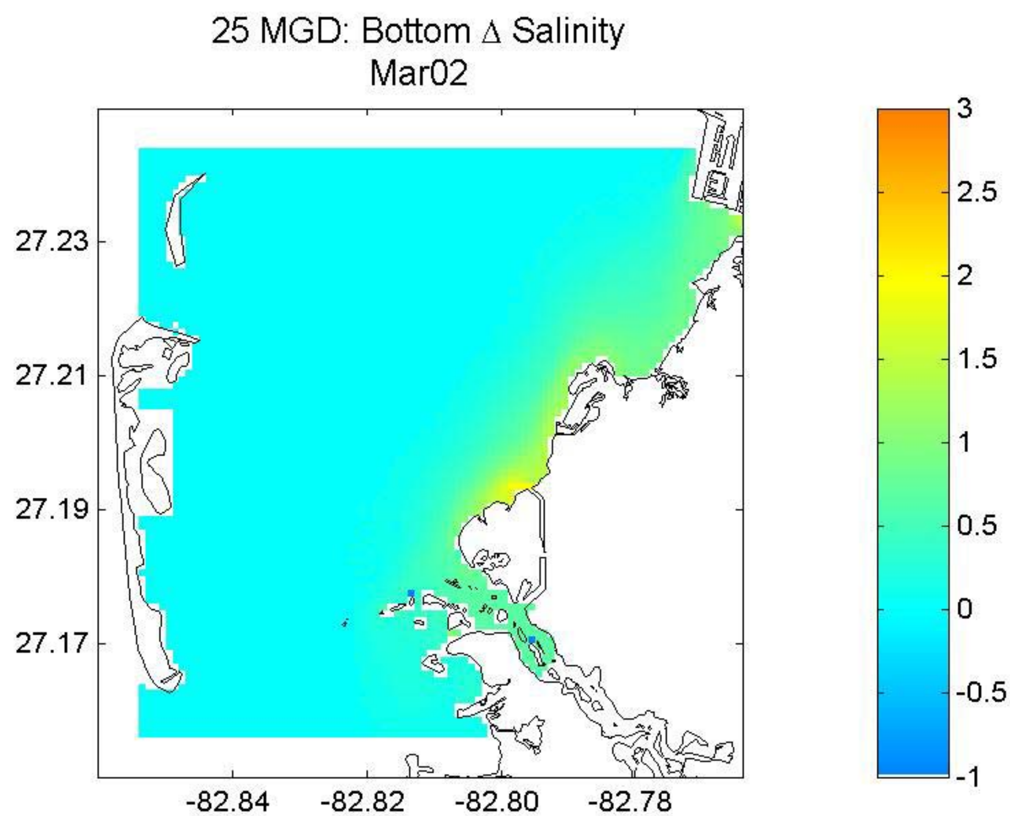

Figure 6.91. Predicted monthly mean bottom salinity change, 25 MGD product water scenario, March 2002.

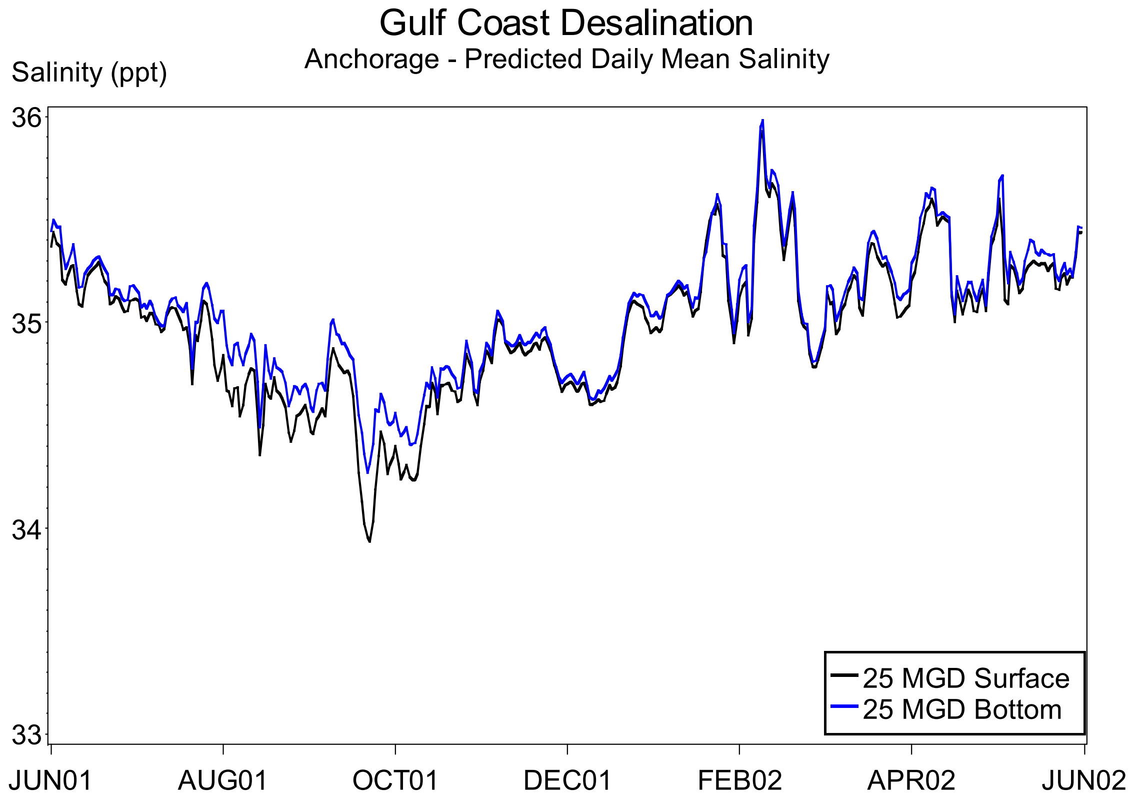

Figure 6.92. Time series of daily mean salinity for surface and bottom layers over the Anchorage, 25 MGD product water scenario, June 2001 to May 2002.

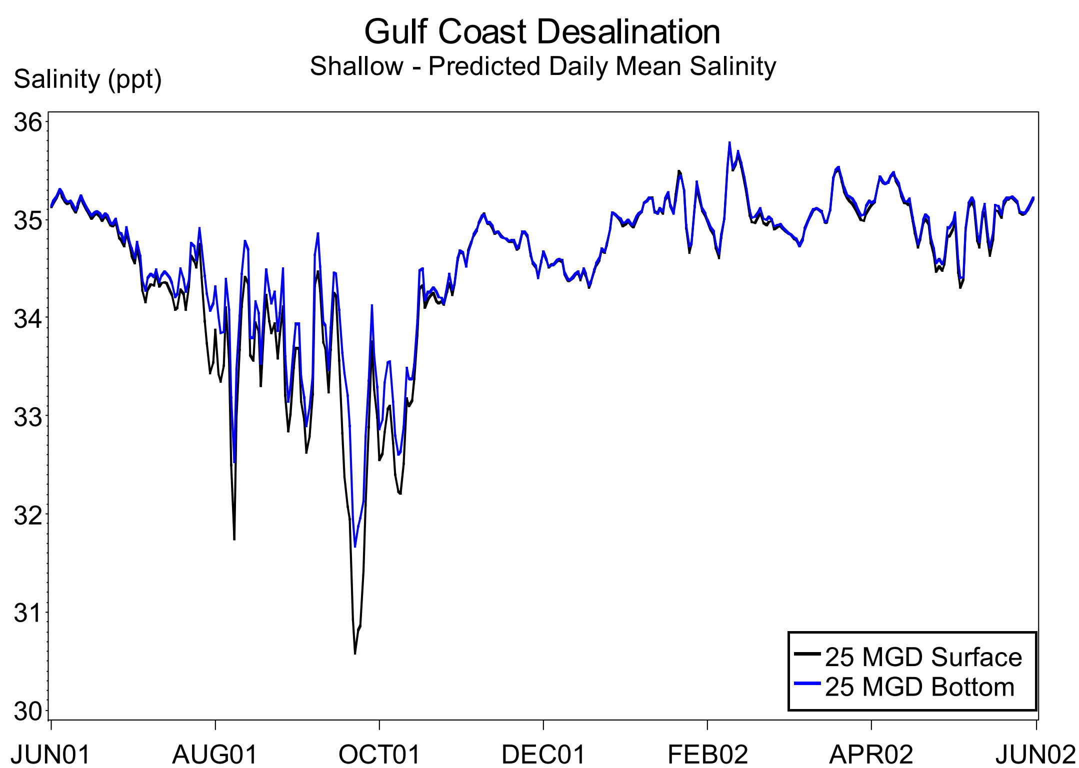

Figure 6.93. Time series of daily mean salinity, shallow area surface and bottom layers, 25 MGD product water scenario, June 2001 to May 2002.

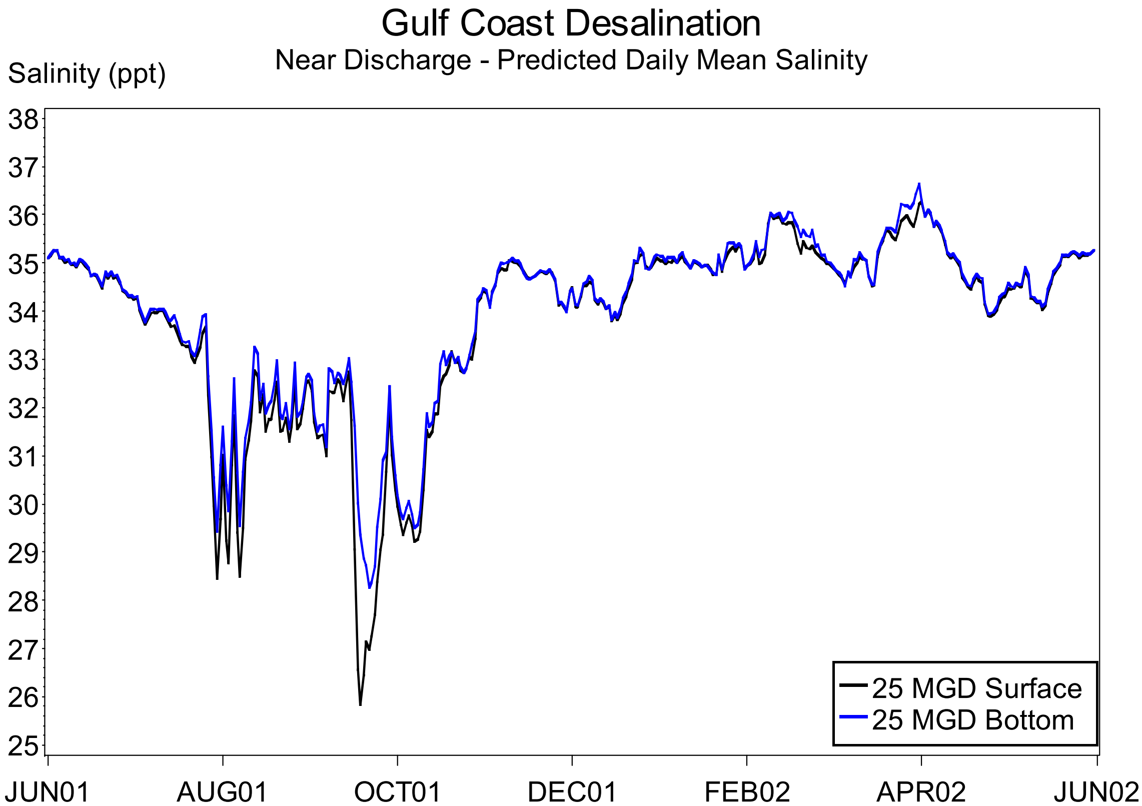

Figure 6.94. Time series of daily mean salinity, near discharge surface and bottom layers, 25 MGD product water scenario, June 2001 to May 2002.

6.1.7 Nearshore – 35 MGD Product Water Scenario

The nearshore 35 MGD product water scenario results in approximately 56 MGD of concentrate mixing with the cooling water release from the power station prior to entering the discharge canal. The resultant effects on salinity across the entire Anchorage are displayed as monthly mean values in maps below, with time series presentations of daily mean surface and bottom salinity predictions in three areas: near the discharge, in the shallow area near the eastern shore of the Anchorage, and in the Anchorage as a whole.

6.1.7.1 Nearshore – 35 MGD Product Water Scenario Salinity

The statistics for the daily mean predicted salinity values for the nearshore 35 MGD product water scenario are summarized in Table 6.7. Changes in salinity (Δ salinity) are derived from the difference of the predicted salinity values for this scenario and those for the baseline. Maps of predicted changes in salinity for the month with the greatest change in salinity (March) and the month with the least change in salinity (September) for the surface and bottom layers are presented in Figures 6.95-6.98. Maps of predicted change in salinity for all months, surface and bottom, are presented in Appendix V. The mean of the daily values for the Anchorage over the entire year is 0.1 ppt greater than that for the baseline in the surface, and no different from the same statistic for the baseline scenario bottom layer (see Table 6.1).

Table 6.7. Statistics for the daily mean predicted salinity for the nearshore 35 MGD product water scenario.

Layer	N	Mean	Standard Deviation	Minimum	Maximum
Surface	365	35.0 ppt	0.4 ppt	33.9 ppt	35.9 ppt
Bottom	365	35.1 ppt	0.3 ppt	34.3 ppt	36.0 ppt

As for the previous product water scenarios, time series plots of the daily mean predicted salinity of the Anchorage, of the shallow area, and of the area near the discharge are provided in Figures 6.99, 6.100, and 6.101, respectively. A comparison of the predicted daily mean salinity of the baseline and 35 MGD product water scenarios for the shallow area reveals an increase in salinity of 0.4 ppt for the surface layer (34.2 to 34.6) and an increase of 0.5 ppt for the bottom layer (34.3 to 34.8). A comparison of the predicted daily mean salinity of the baseline and 35 MGD product water scenarios for the area near the discharge canal reveals an increase in salinity of 1.4 ppt for the surface layer (32.8 to 34.2) and the bottom layer (33.0 to 34.4).

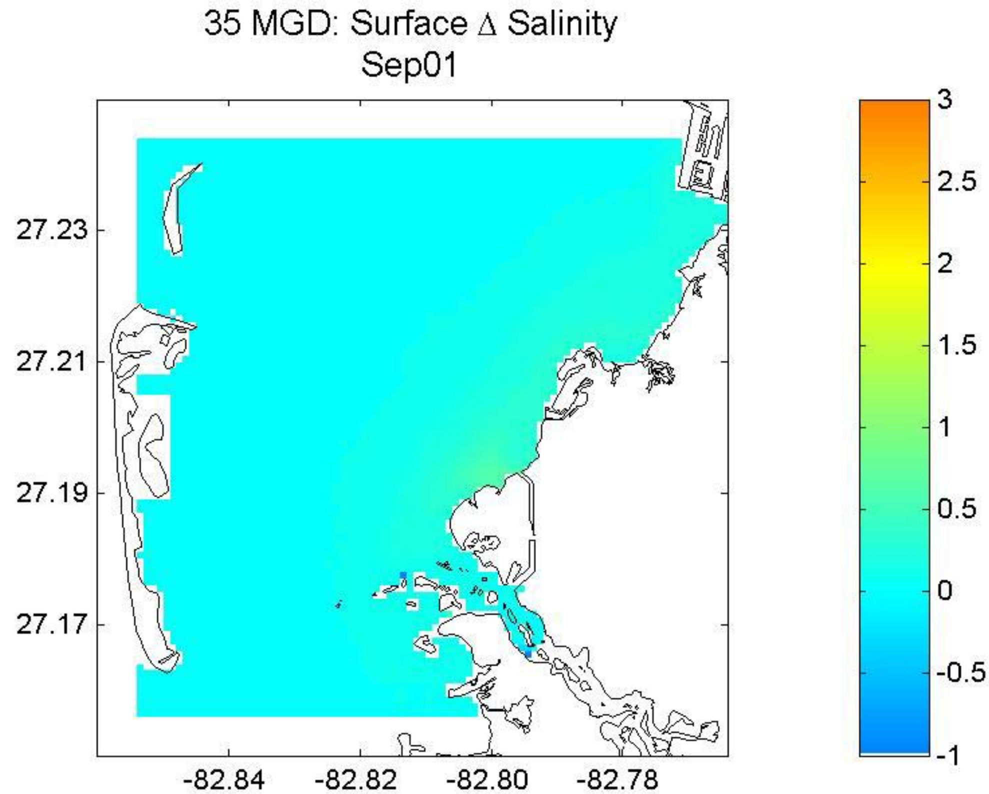

Figure 6.95. Predicted monthly mean surface salinity change, 35 MGD product water scenario, September 2001.

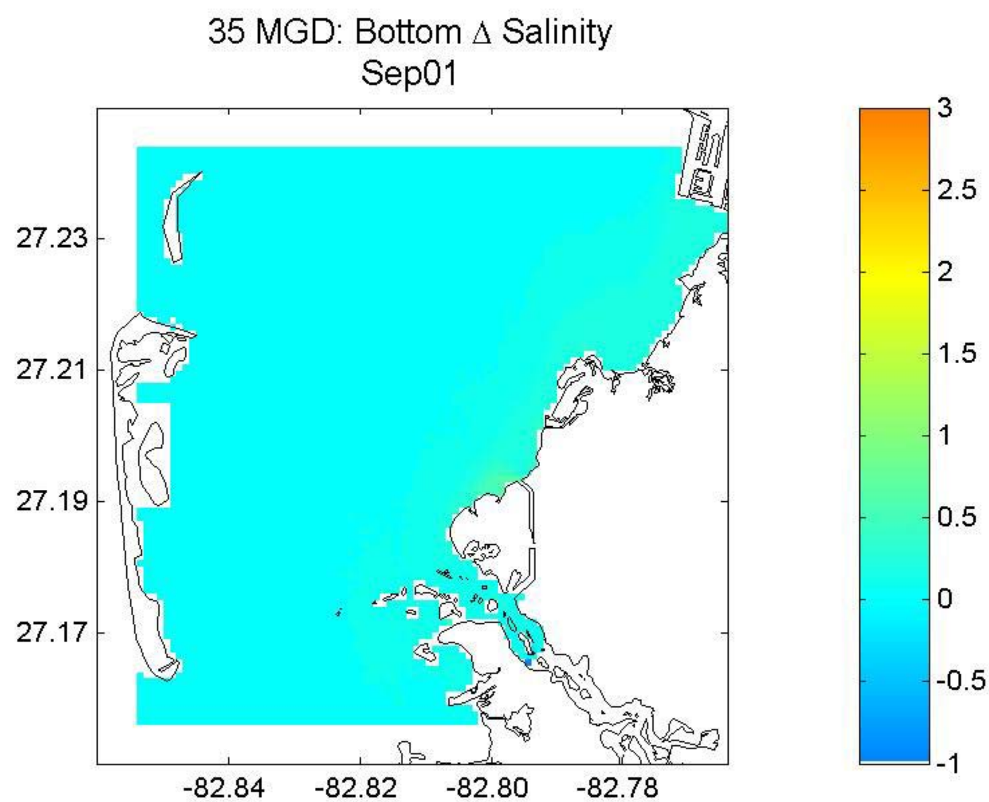

Figure 6.96. Predicted monthly mean bottom salinity change, 35 MGD product water scenario, September 2001.

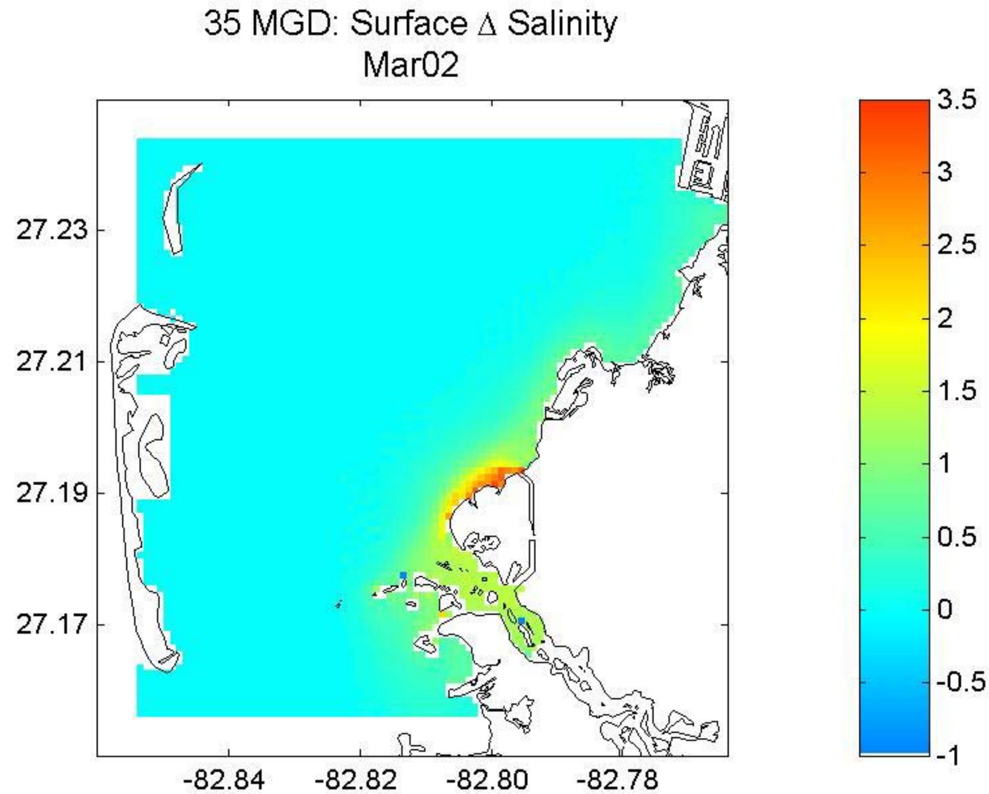

Figure 6.97. Predicted monthly mean surface salinity change, 35 MGD product water scenario, March 2002.

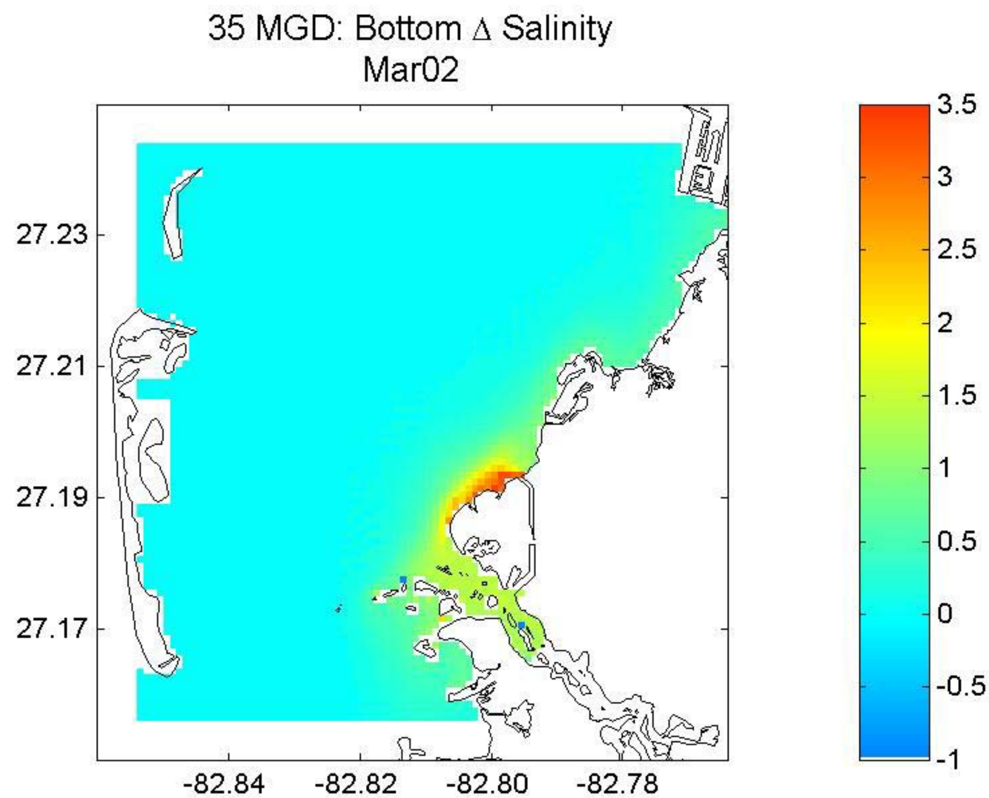

Figure 6.98. Predicted monthly mean bottom salinity change, 35 MGD product water scenario, March 2002.

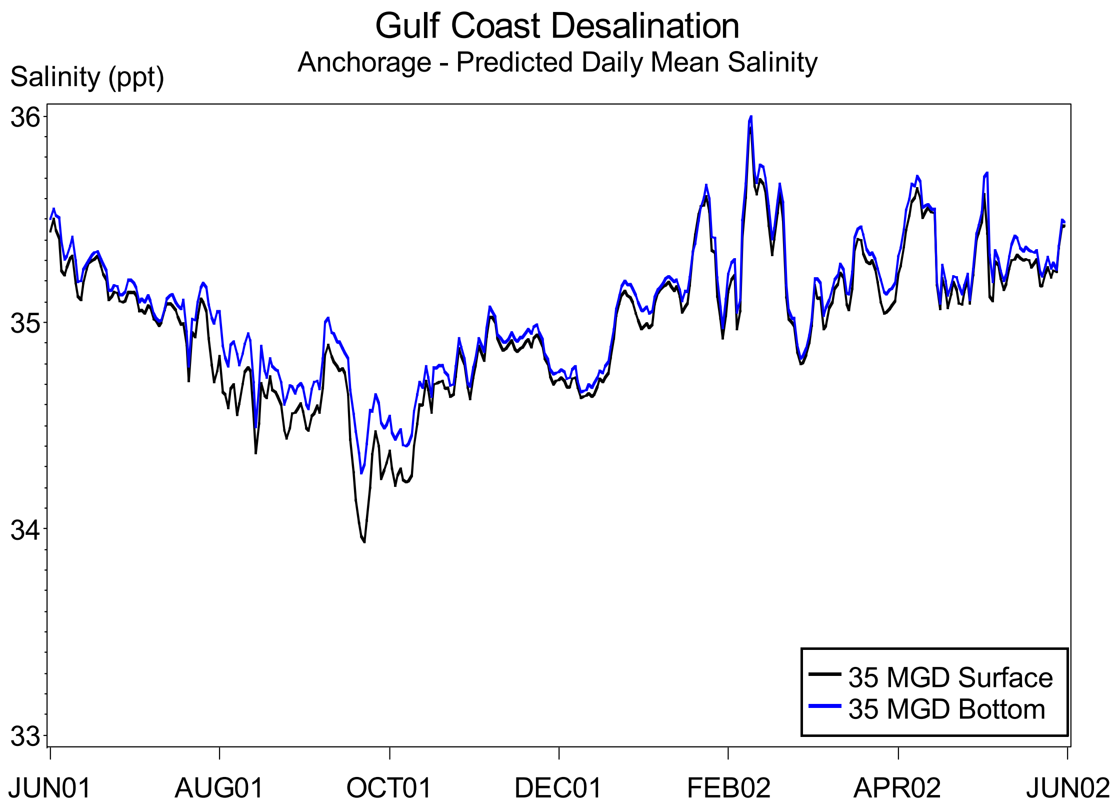

Figure 6.99. Time series of daily mean salinity for surface and bottom layers over the Anchorage, 35 MGD product water scenario, June 2001 to May 2002.

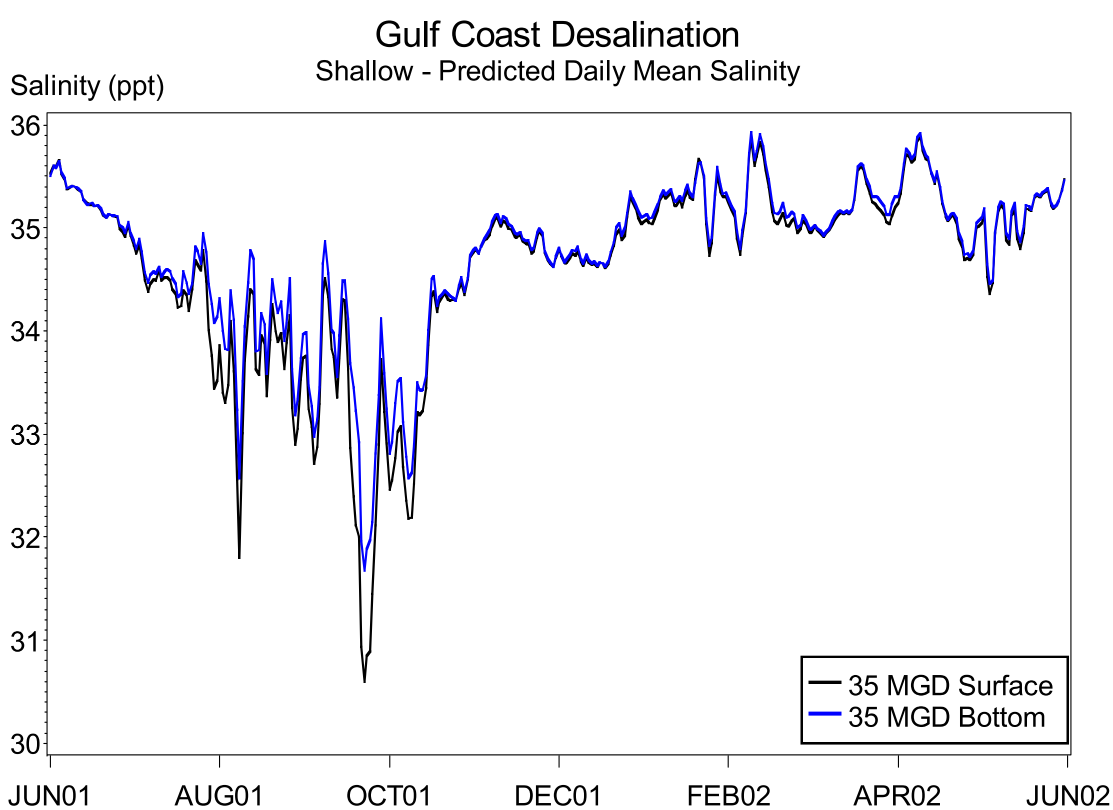

Figure 6.100. Time series of daily mean salinity, shallow area surface and bottom layers, 35 MGD product water scenario, June 2001 to May 2002.

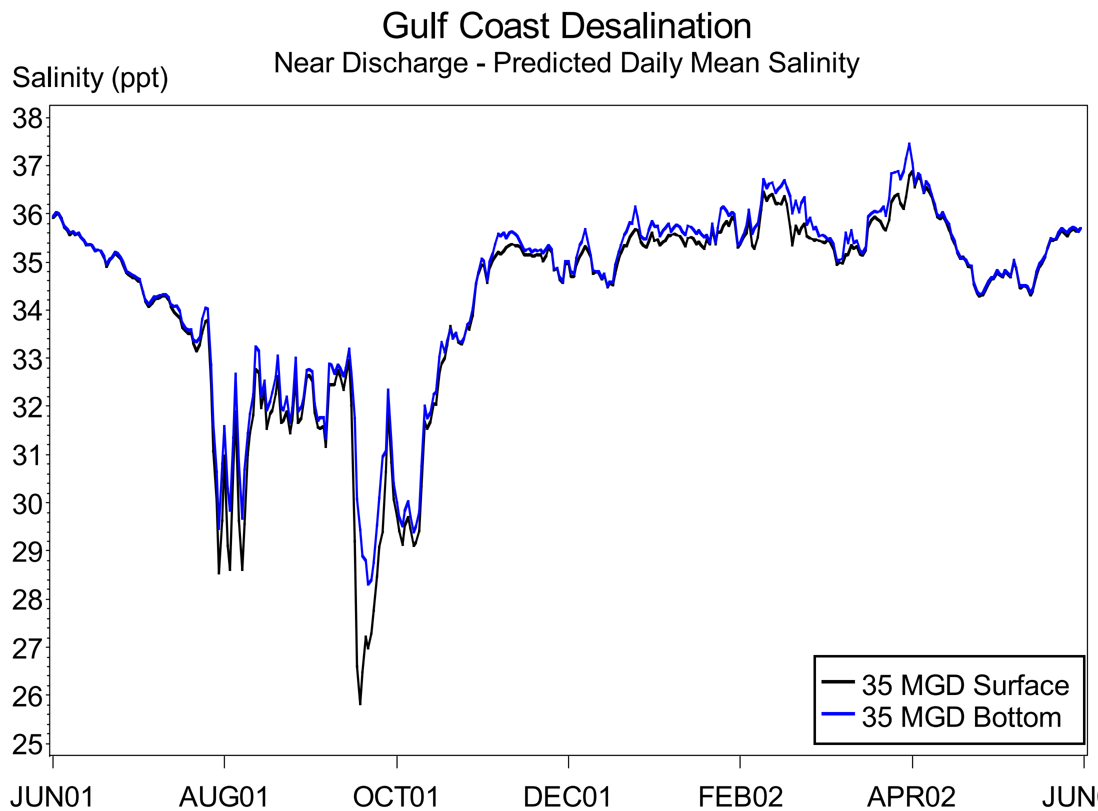

Figure 6.101. Time series of daily mean salinity, near discharge surface and bottom layers, 35 MGD product water scenario, June 2001 to May 2002.

6.1.7.2 Nearshore – 35 MGD Product Water Scenario Circulation

Monthly mean predicted circulation maps are presented in Figures 6.102-6.113. As for the baseline scenario maps, the length of the longest vector, in the northeastern corner of the Anchorage in September, represents a speed of 0.067 m/s. Again, the velocities have been averaged over an area of 10 cells by 10 cells. At this resolution, there are no differences in current speeds to the nearest one hundredth of a meter per second. To place these changes in perspective, current meter measurements are typically accurate to the order of 0.01 m/s. Additional analyses reveal that the maximum difference in monthly mean current speed for any one cell, between the baseline scenario and the 35 MGD product water scenario, is found at the mouth of the discharge canal. This is as expected, given the change in discharge volume of 35 MGD between the two scenarios. The maximum monthly mean difference in speed at the mouth of the discharge canal is 0.008 m/s, found in April 2002, representing a relative change of 2.0%. The maximum relative change of 3.8% in current speed is found in February 2002. For the year, the relative change in current speed at the mouth of the discharge averaged 2.0%.

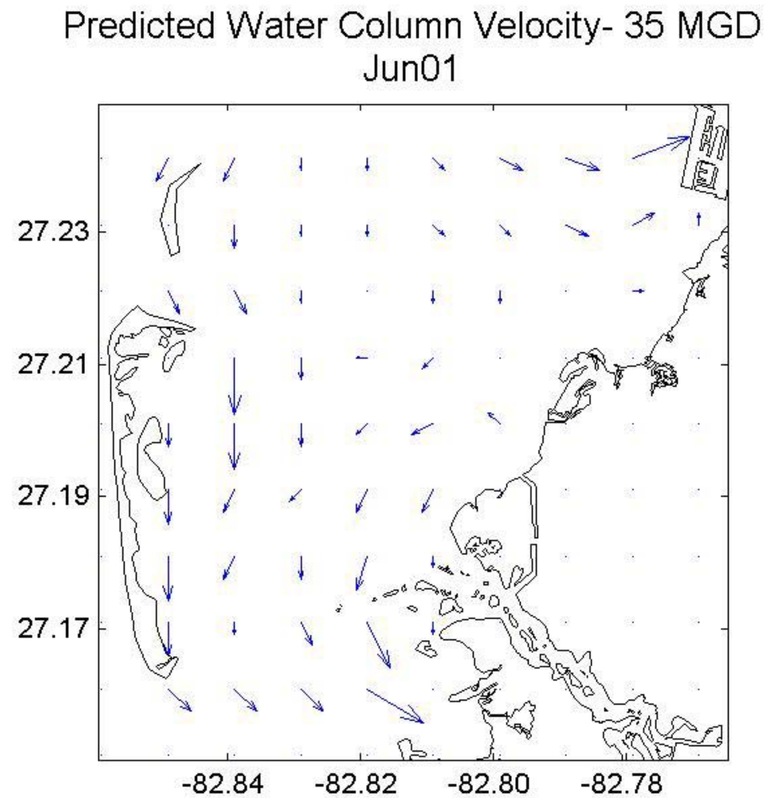

Figure 6.102. Water column monthly mean circulation, 35 MGD product water scenario, June 2001.

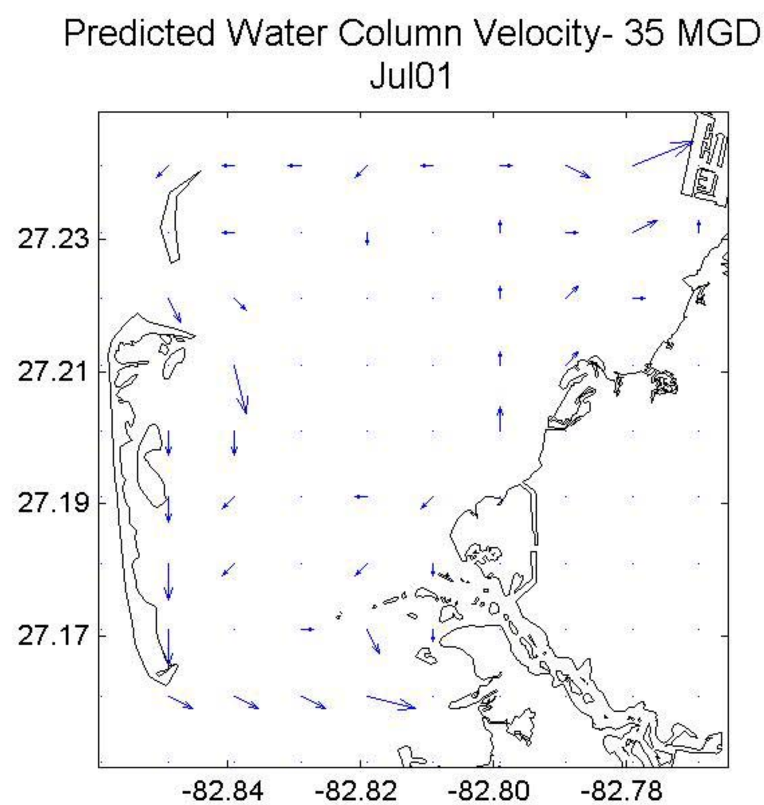

Figure 6.103. Water column monthly mean circulation, 35 MGD product water scenario, July 2001.

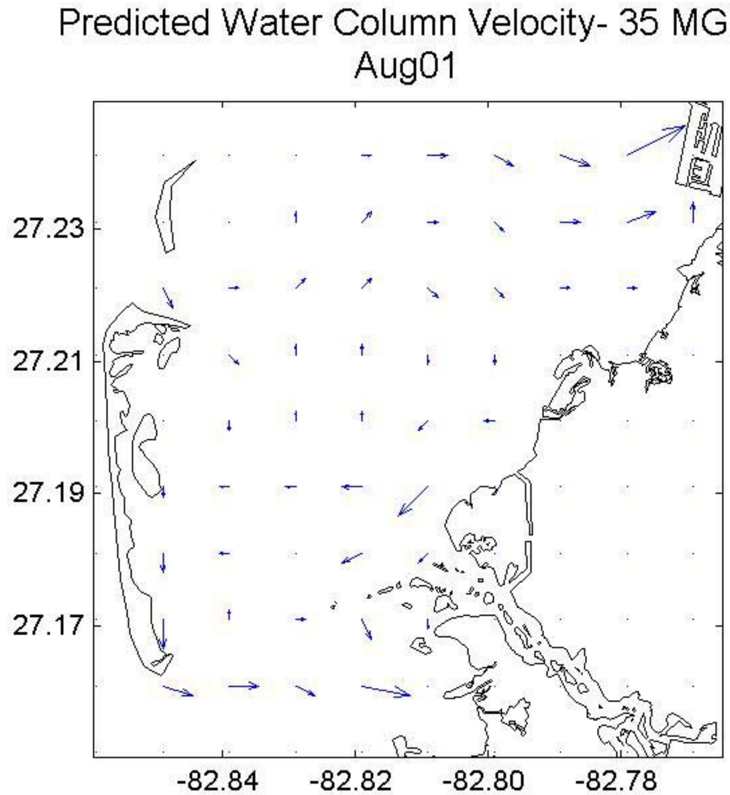

Figure 6.104. Water column monthly mean circulation, 35 MGD product water scenario, August 2001.

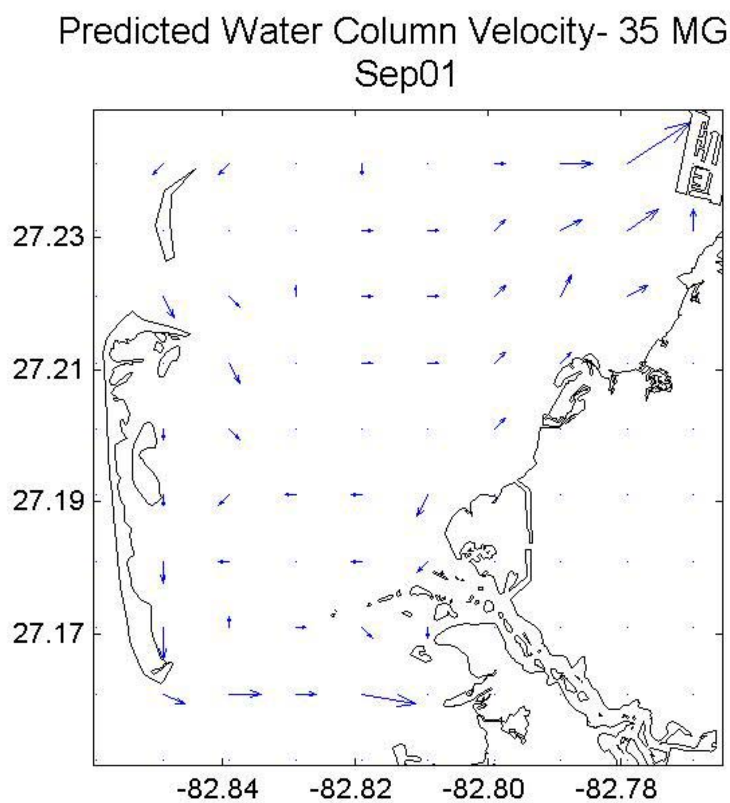

Figure 6.105. Water column monthly mean circulation, 35 MGD product water scenario, September 2001.

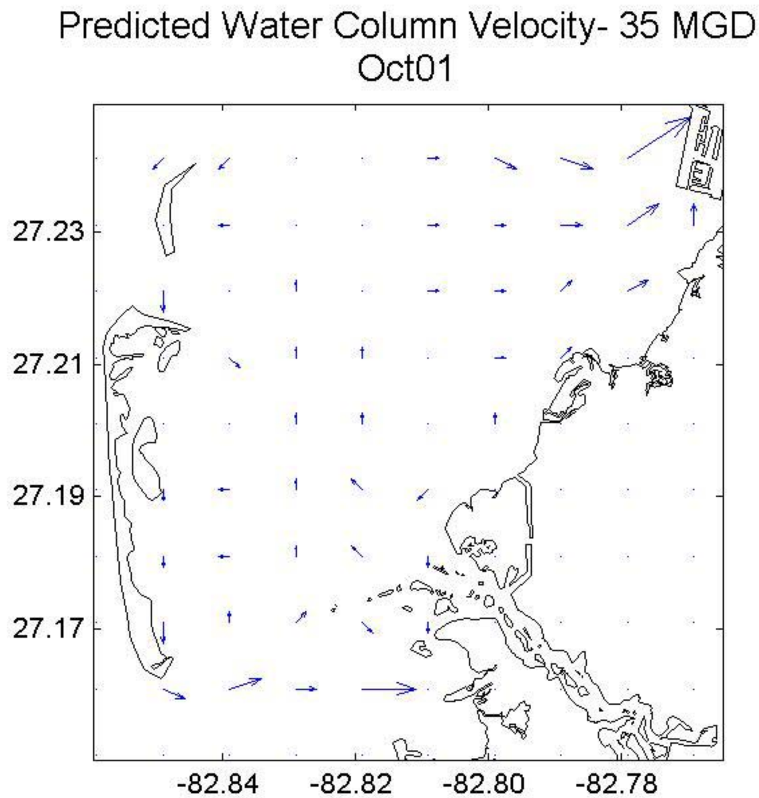

Figure 6.106. Water column monthly mean circulation, 35 MGD product water scenario, October 2001.

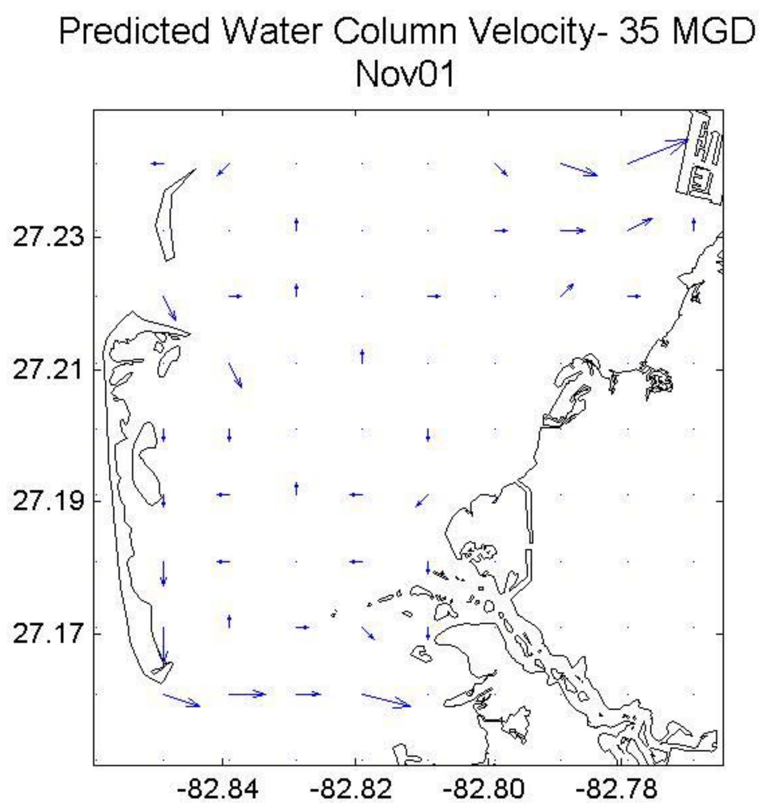

Figure 6.107. Water column monthly mean circulation, 35 MGD product water scenario, November 2001.

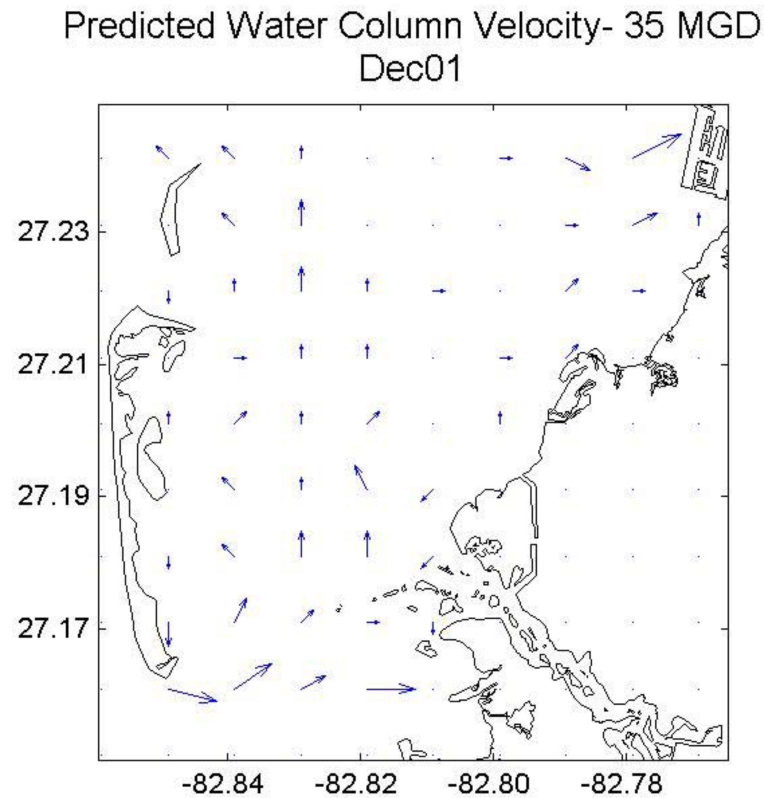

Figure 6.108. Water column monthly mean circulation, 35 MGD product water scenario, December 2001.

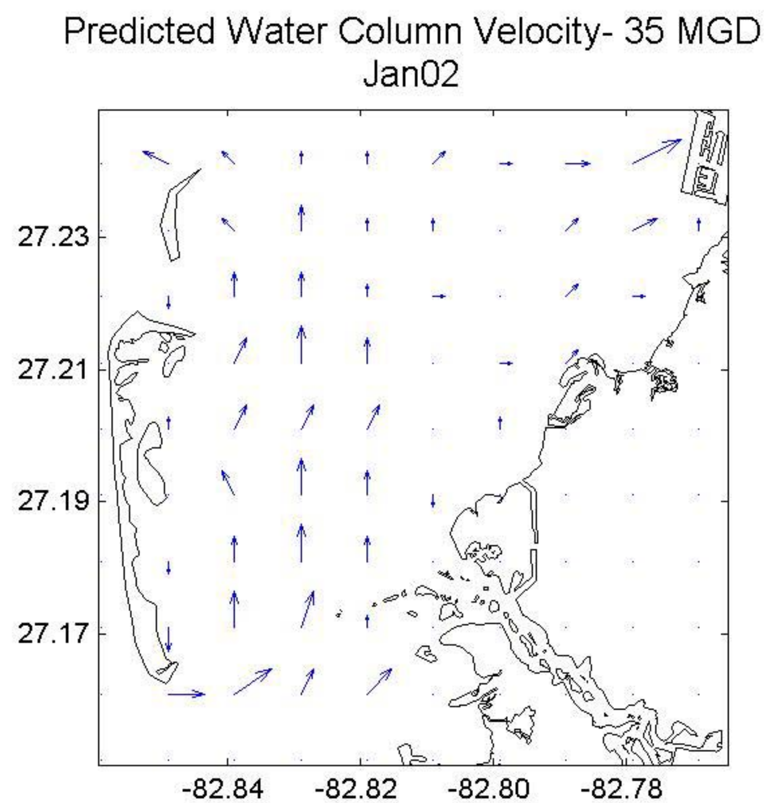

Figure 6.109. Water column monthly mean circulation, 35 MGD product water scenario, January 2002.

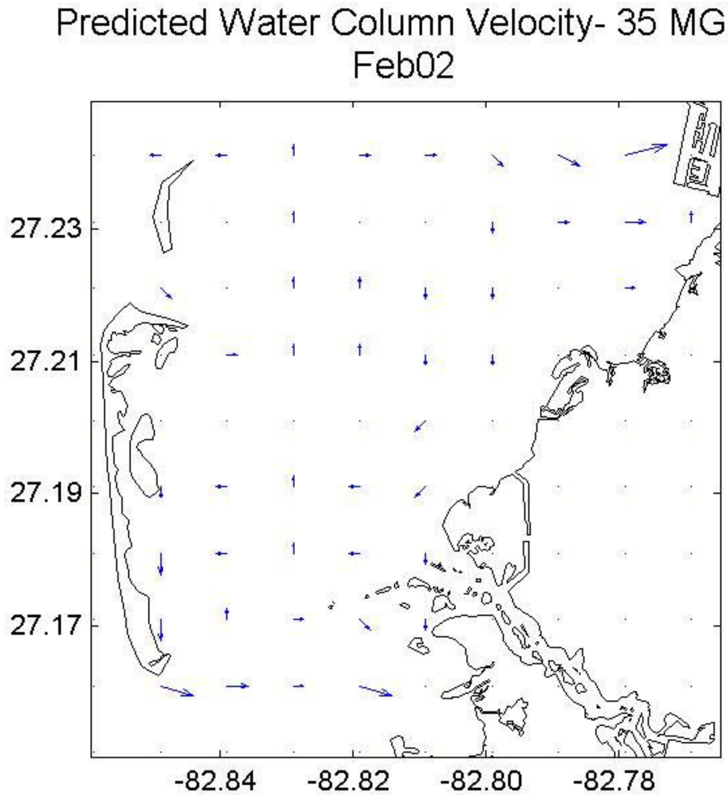

Figure 6.110. Water column monthly mean circulation, 35 MGD product water scenario, February 2002.

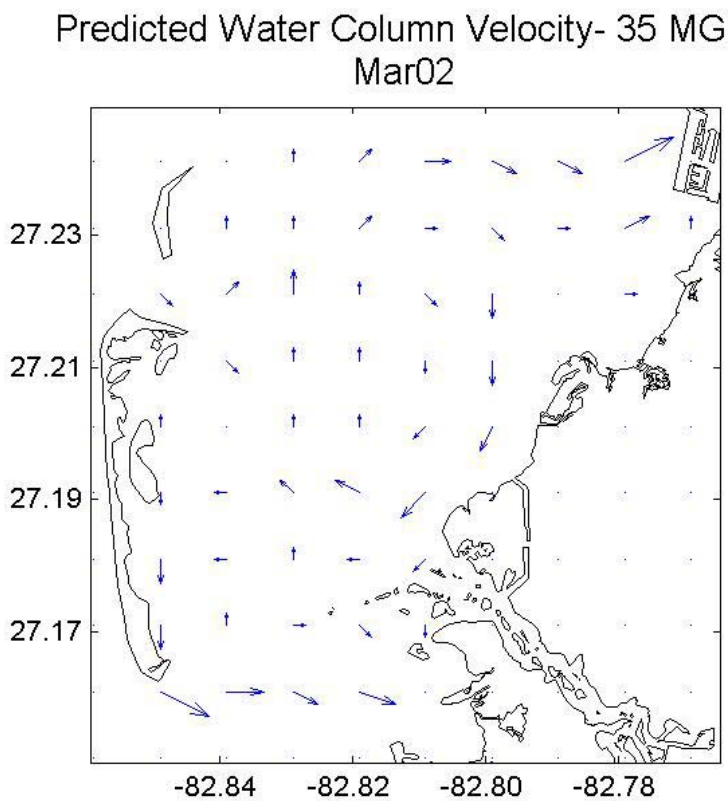

Figure 6.111. Water column monthly mean circulation, 35 MGD product water scenario, March 2002.

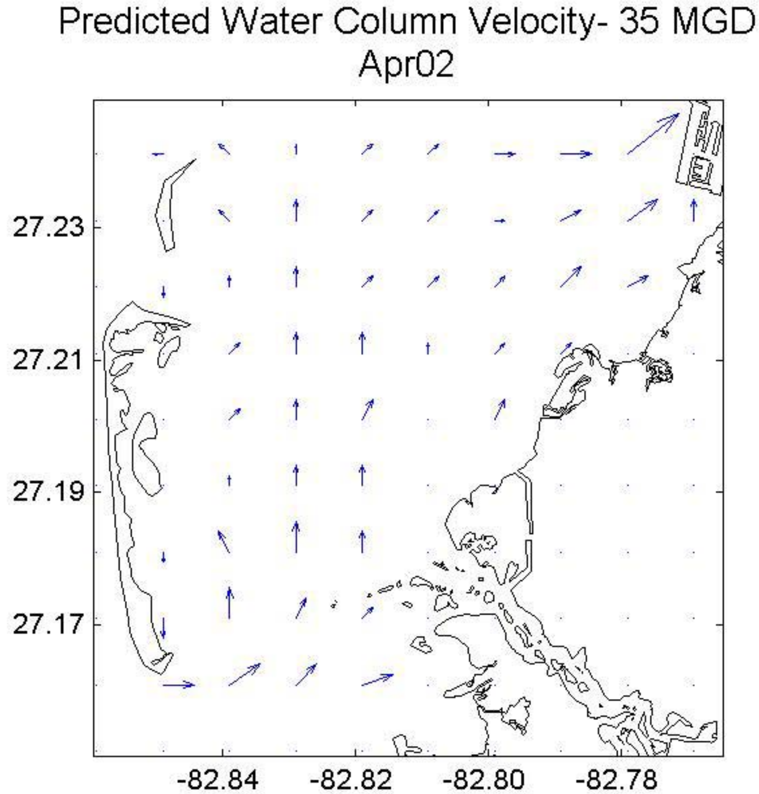

Figure 6.112. Water column monthly mean circulation, 35 MGD product water scenario, April 2002.

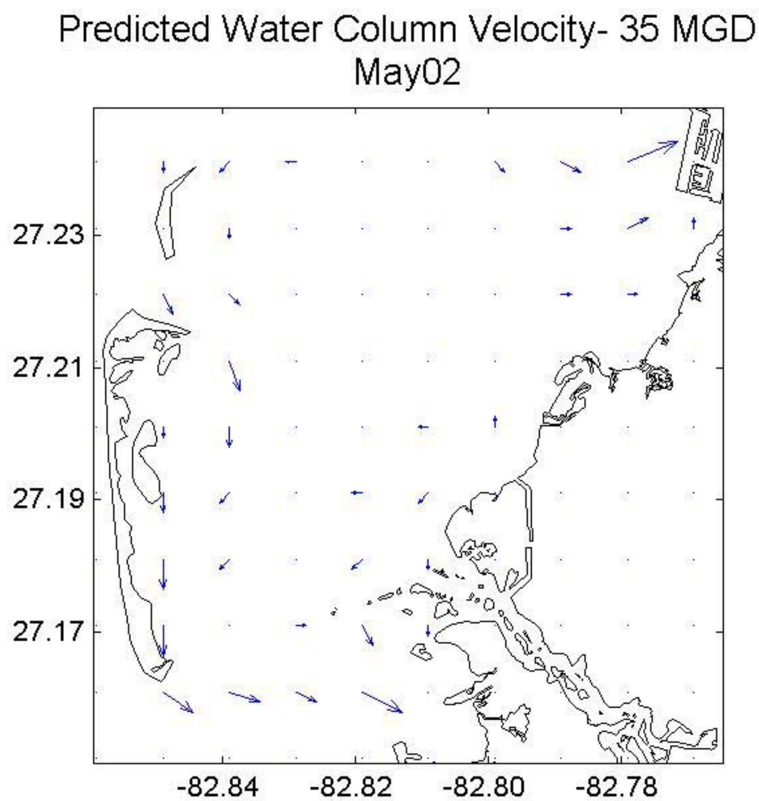

Figure 6.113. Water column monthly mean circulation, 35 MGD product water scenario, May 2002.

6.1.8 Nearshore – Five Year 25 MGD Product Water Scenario

To evaluate the potential longer term effects on salinity resulting from desalination operations and discharge to the Anchorage, a five-year run of the 25 MGD product water scenario was completed. Boundary conditions, including boundary velocities, temperature, and salinity values, and freshwater inflows and wind forcing, were set to repeat each year. The model output data were examined for any inter-annual predicted changes in salinity distribution. Figure 6.114 displays the time series of the predicted daily mean surface and bottom salinity in the area near the discharge canal, where any increases in salinity would be most likely to occur. As seen in the figure, there were no increases in salinity from year to year within the Anchorage, with salinity distributions repeating in an annual cycle.

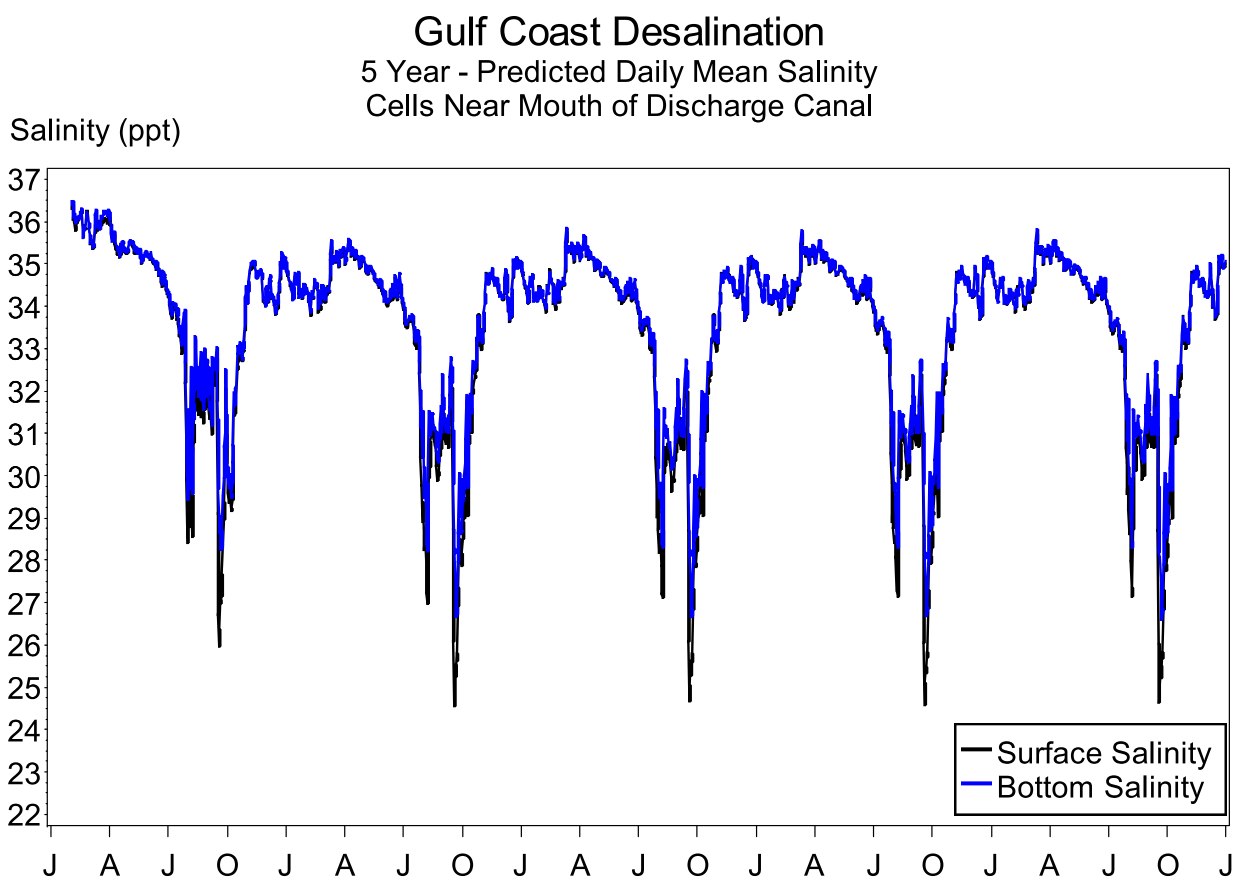

Figure 6.114. Time series of daily mean salinity, near discharge surface and bottom layers, 25 MGD product water scenario for five years.

6.2 Offshore

For the offshore discharge alternative, concentrate from the desalination facility will be discharged through a pipeline to a point offshore without being mixed with any cooling water from the power station. This provides for no dilution of the concentrate before it is discharged offshore. For the offshore alternative, models runs were executed for the baseline condition scenario, and for 10 MGD and 25 MGD product water scenarios.

As in the nearshore discharge alternative, each of the product water scenarios utilizes an efficiency factor of 0.385 for conversion of saltwater to freshwater. This results in the concentrate having a salinity of 1.625 times the intake water salinity. For example, if the intake salinity is 33 ppt, the resultant salinity in the concentrate would be approximately 53.6 ppt. Since no mixing with other waters occurs, this is the salinity of the concentrate discharged offshore. Per design drawings for the potential offshore discharge pipeline, discharge is to the bottom two layers of the water column. The offshore small grid location in reference to the Anchorage was previously shown in Figure 4.3. The discharge site is approximately 3.3 km south of the northern extent of the offshore small grid system, near the middle of the east-west extent of the grid (Figure 6.115), where the water column has a depth of approximately 8.7 m MLLW.

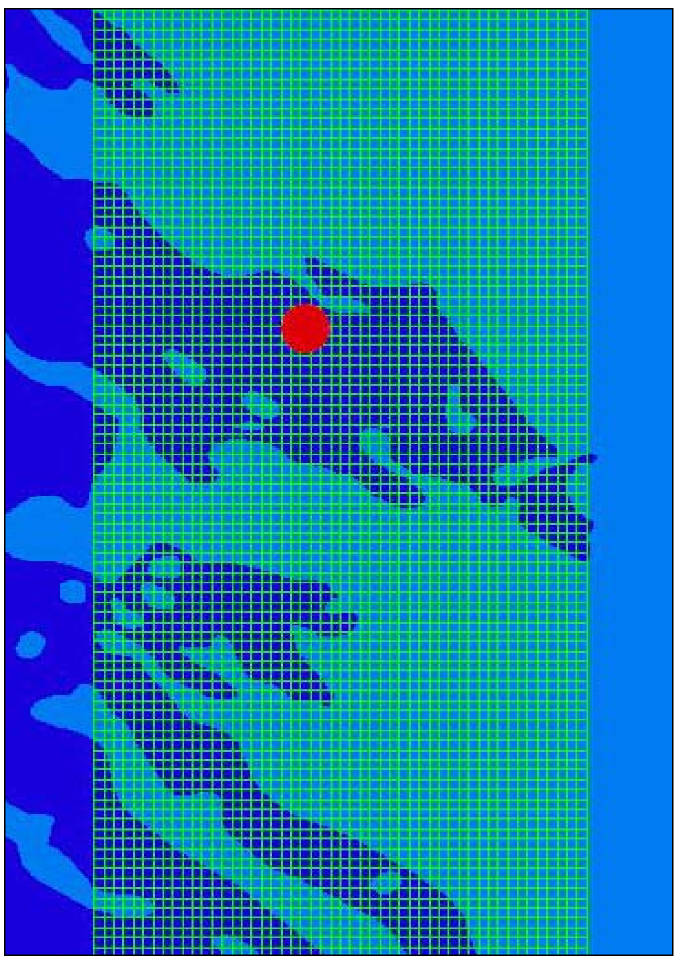

Figure 6.115. Offshore small grid system with location of discharge.

6.2.1 Offshore – Baseline Scenario

The offshore baseline scenario has no input of concentrate from the desalination facility, and is representative of conditions in the offshore small grid system during the June 2001 through May 2002 period. This scenario was run in order to compare results of the product water scenarios to a set of baseline conditions.

6.2.1.1 Offshore – Baseline Salinity

The statistics for the daily mean predicted salinity values over the offshore small grid system are summarized in Table 6.8. Mean values are estimated as volume-weighted means. The mean, extrema, and standard deviation of the predicted daily salinity values for the surface and bottom layers show that the surface is slightly fresher than the bottom, as expected given the depth of the water column. Predicted monthly mean salinity maps for all months, for both the surface and bottom layers, are presented in Figures 6.116-6.139. Examination of these maps reveals that very little variation in salinity is predicted over monthly time frames in both the surface and bottom.

Table 6.8. Statistics for the daily mean predicted salinity for the offshore baseline scenario.

Layer	N	Mean	Standard Deviation	Minimum	Maximum
Surface	365	35.1 ppt	0.3 ppt	34.5 ppt	35.7 ppt
Bottom	365	35.3 ppt	0.3 ppt	34.8 ppt	35.8 ppt

Examination of the baseline salinity maps show that predicted salinity values are typically 35 ppt across most of the offshore grid, with the surface slightly less saline than the bottom. Predicted salinity values show little variation throughout the year.

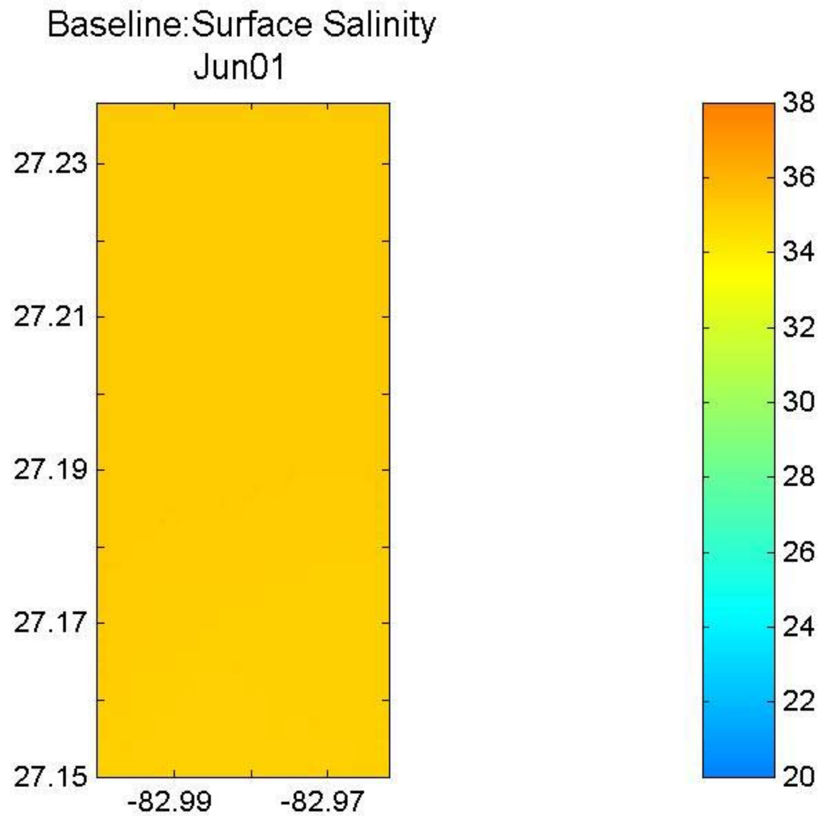

Figure 6.116. Predicted monthly mean surface salinity, baseline scenario, June 2001.

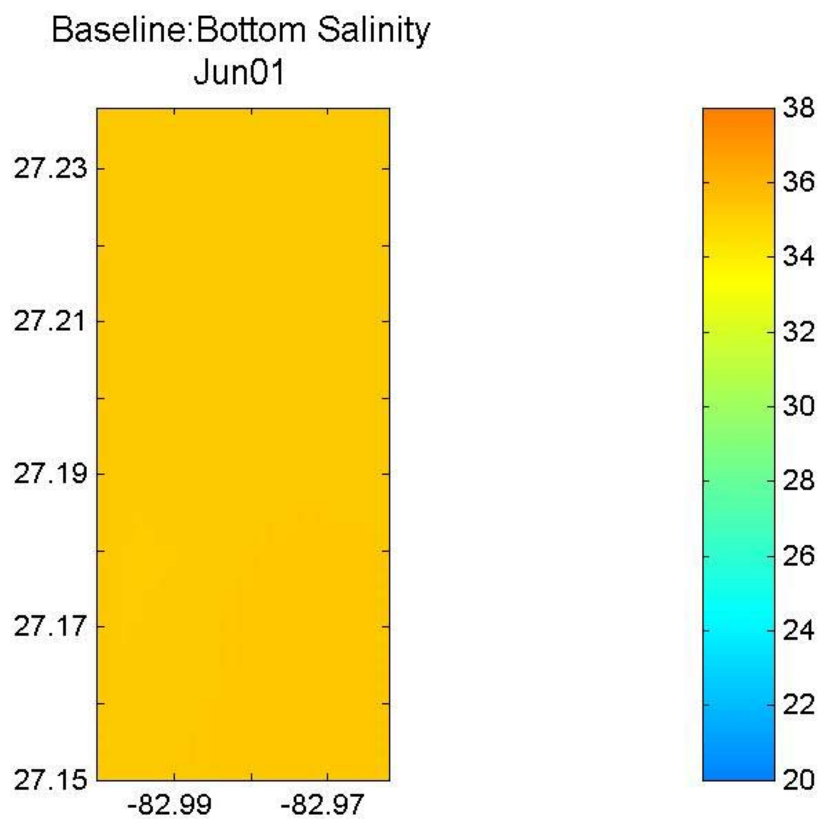

Figure 6.117. Predicted monthly mean bottom salinity, baseline scenario, June 2001.

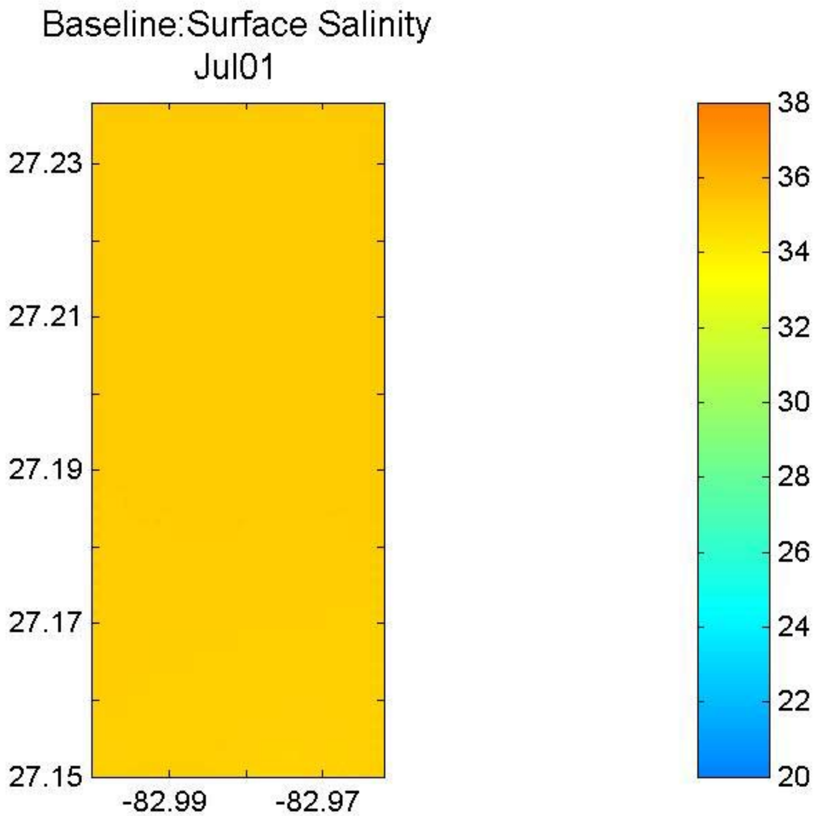

Figure 6.118. Predicted monthly mean surface salinity, baseline scenario, July 2001.

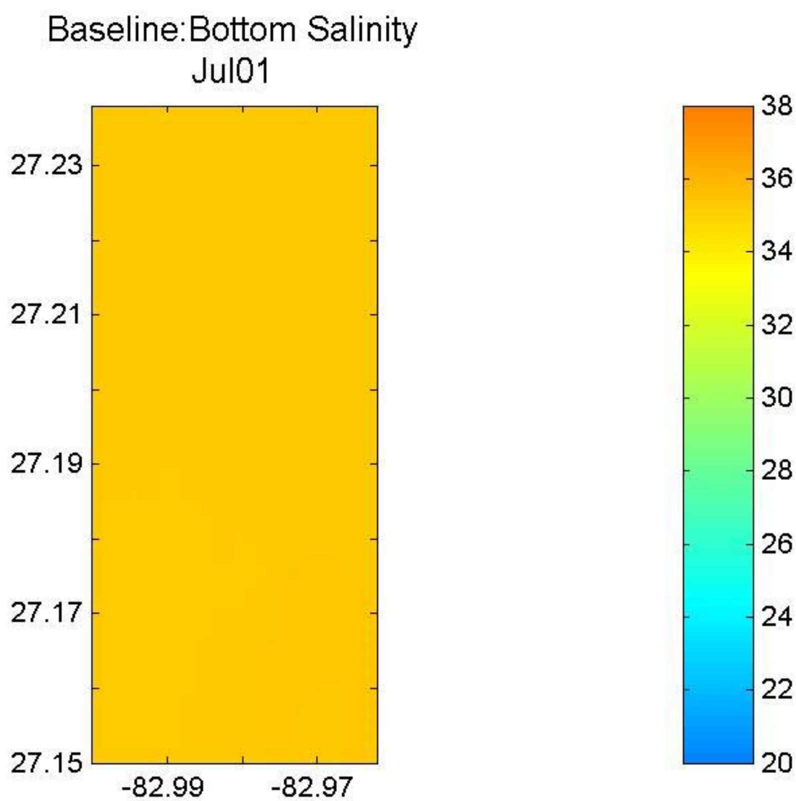

Figure 6.119. Predicted monthly mean bottom salinity, baseline scenario, July 2001.

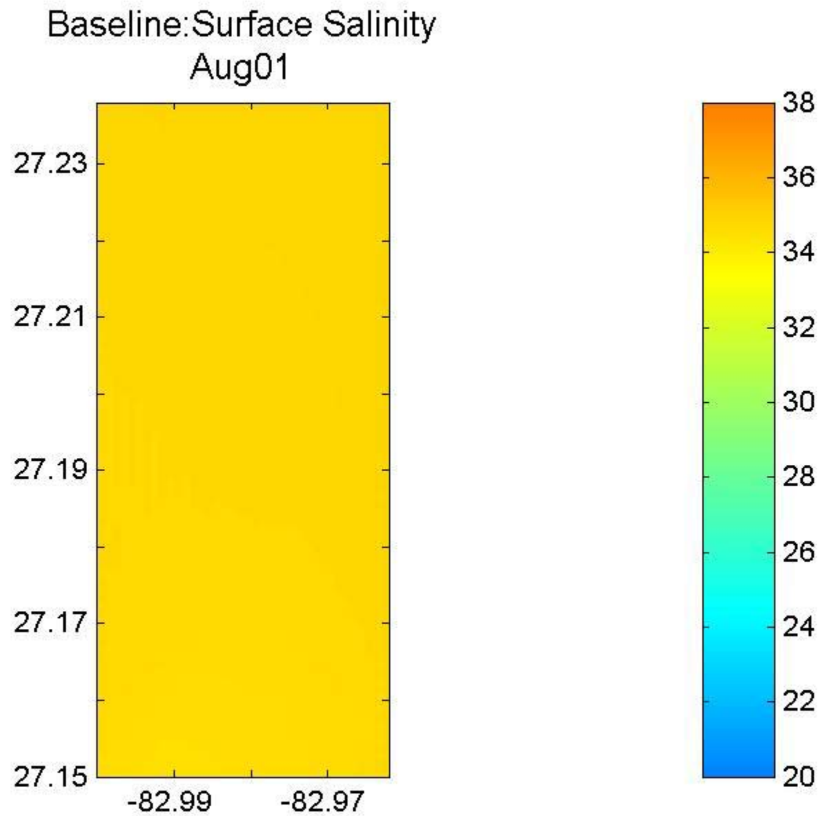

Figure 6.120. Predicted monthly mean surface salinity, baseline scenario, August 2001.

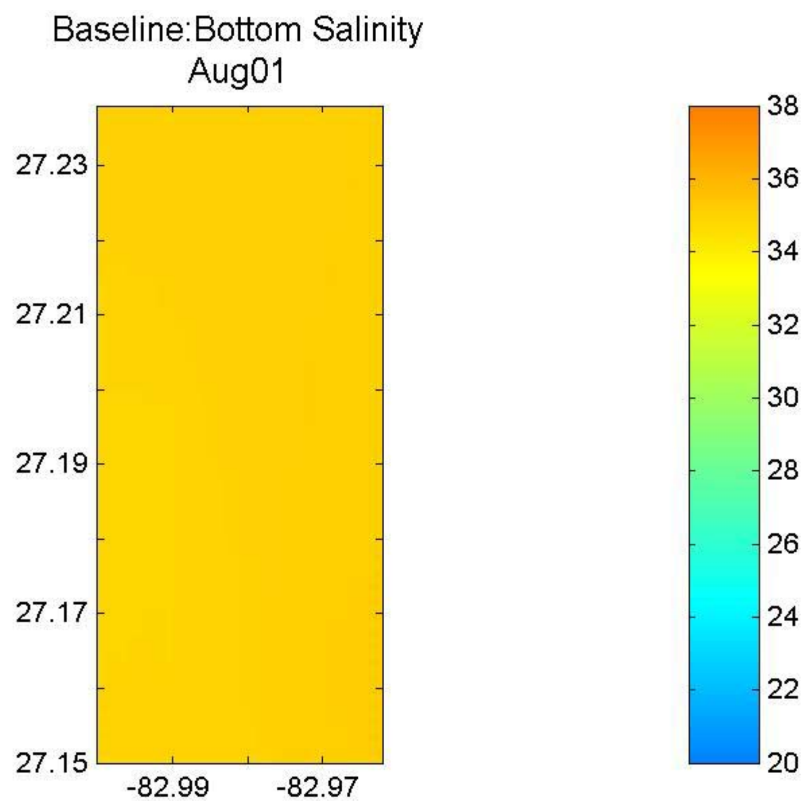

Figure 6.121. Predicted monthly mean bottom salinity, baseline scenario, August 2001.

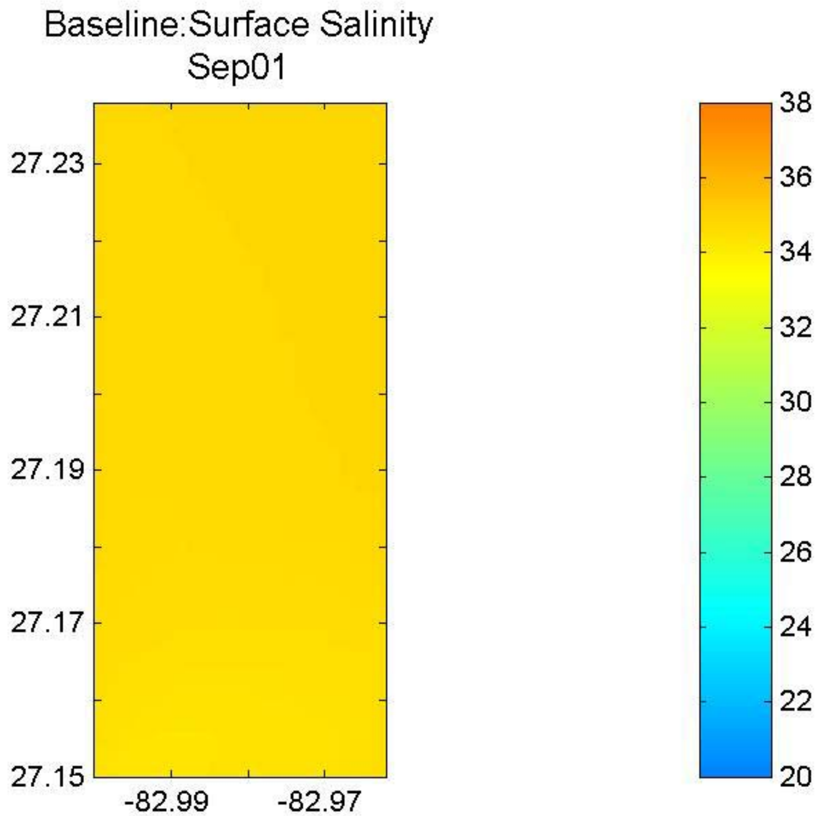

Figure 6.122. Predicted monthly mean surface salinity, baseline scenario, September 2001.

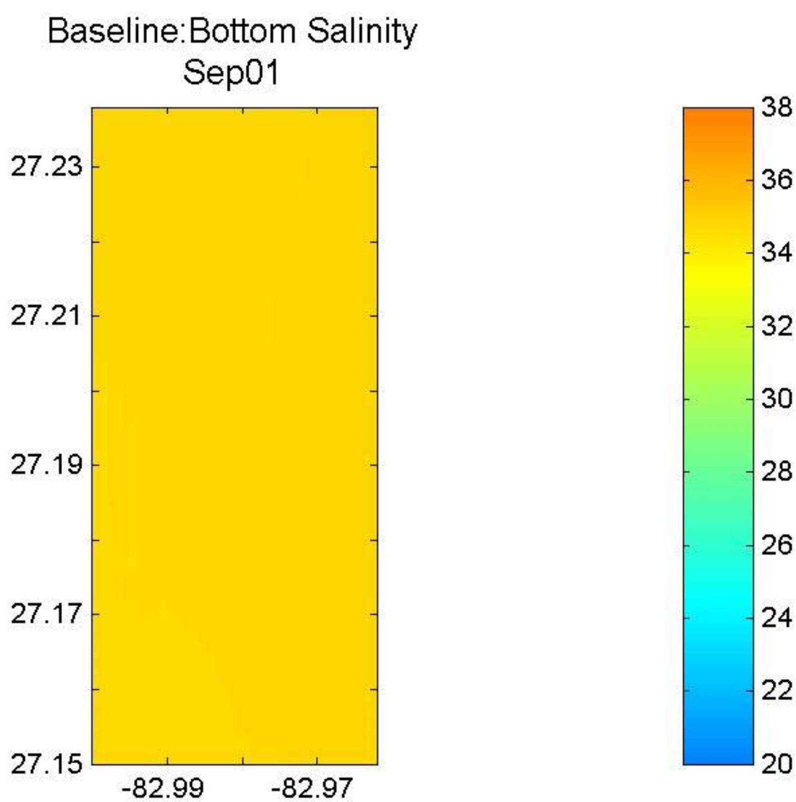

Figure 6.123. Predicted monthly mean bottom salinity, baseline scenario, September 2001.

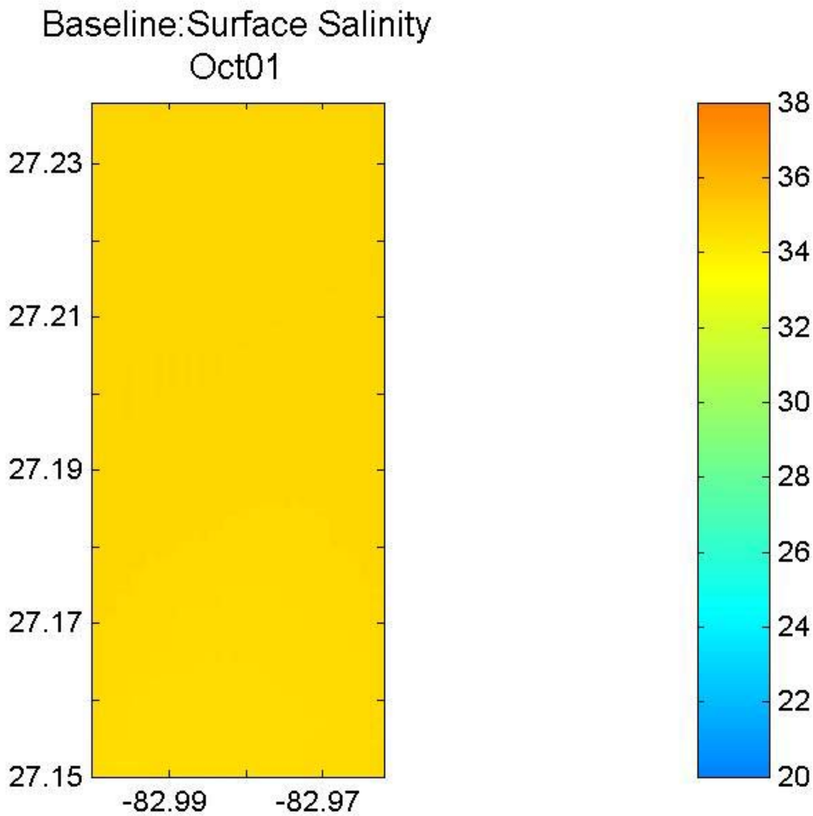

Figure 6.124. Predicted monthly mean surface salinity, baseline scenario, October 2001.

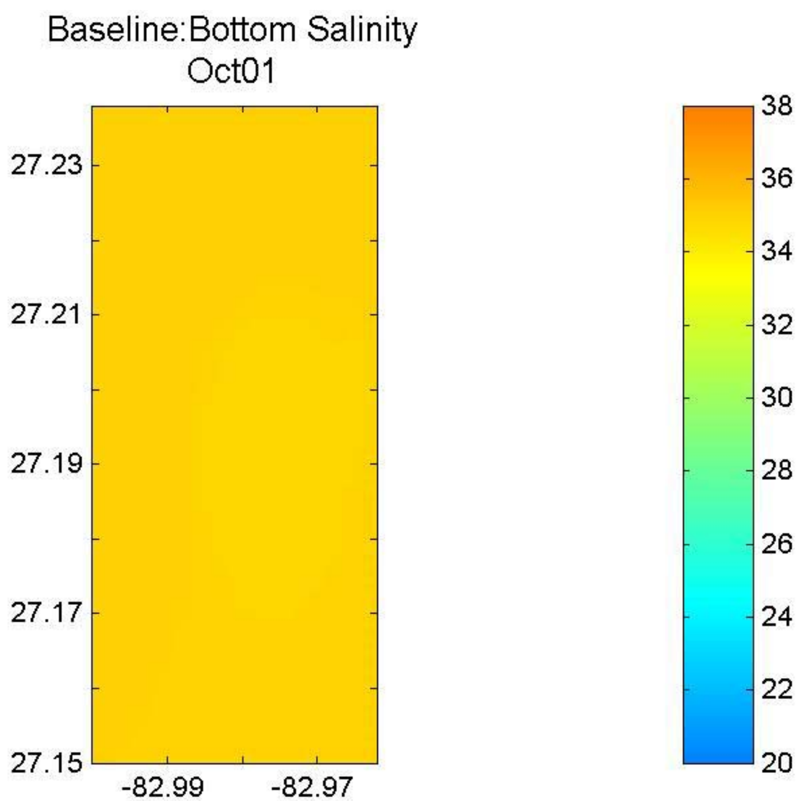

Figure 6.125. Predicted monthly mean bottom salinity, baseline scenario, October 2001.

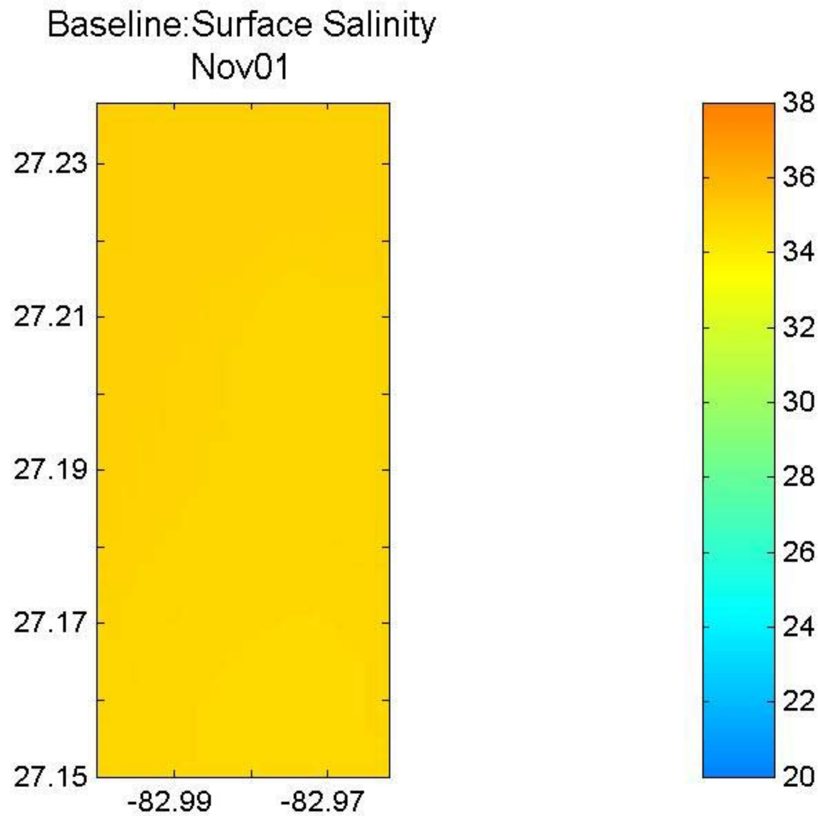

Figure 6.126. Predicted monthly mean surface salinity, baseline scenario, November 2001.

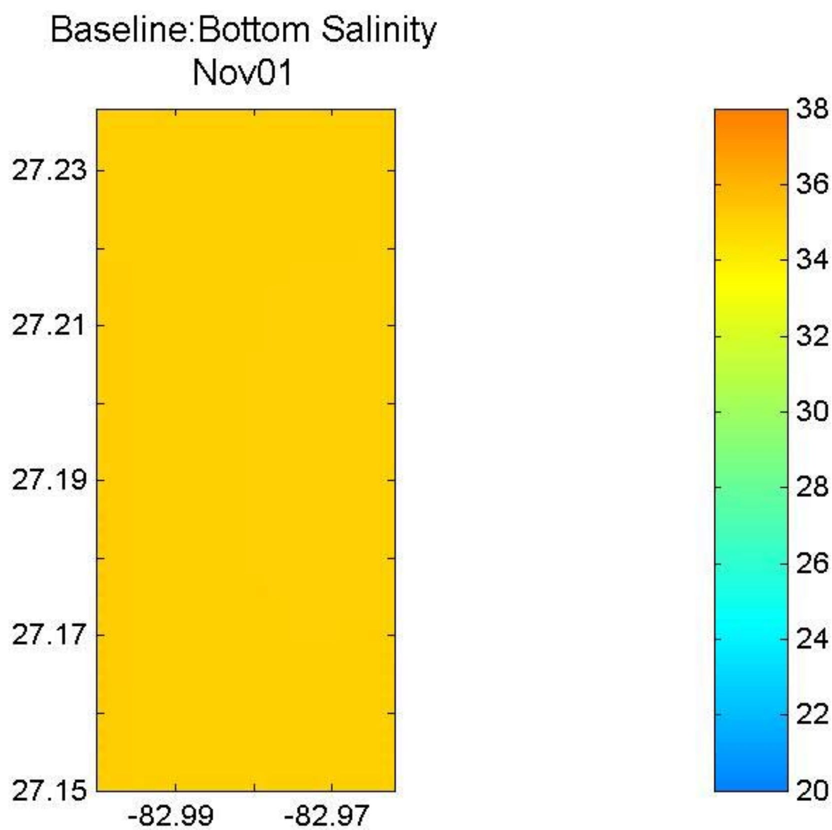

Figure 6.127. Predicted monthly mean bottom salinity, baseline scenario, November 2001.

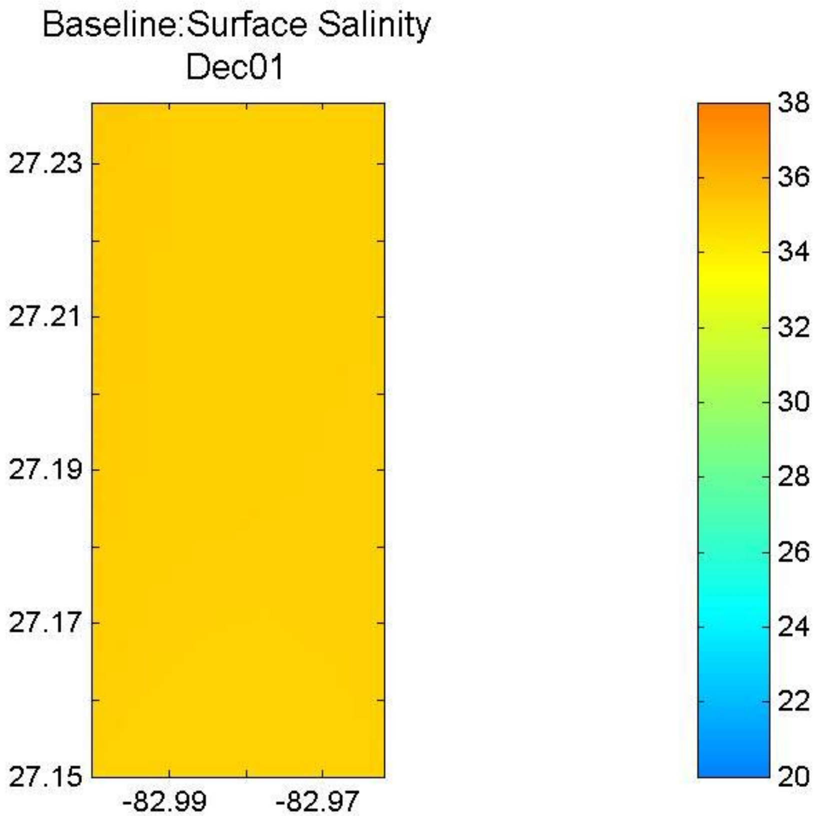

Figure 6.128. Predicted monthly mean surface salinity, baseline scenario, December 2001.

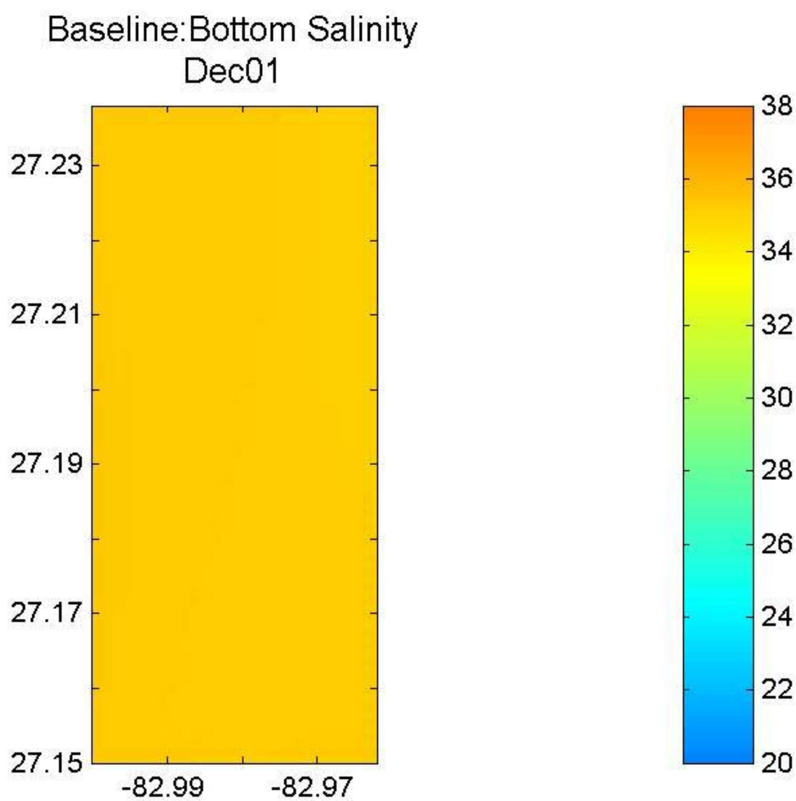

Figure 6.129. Predicted monthly mean bottom salinity, baseline scenario, December 2001.

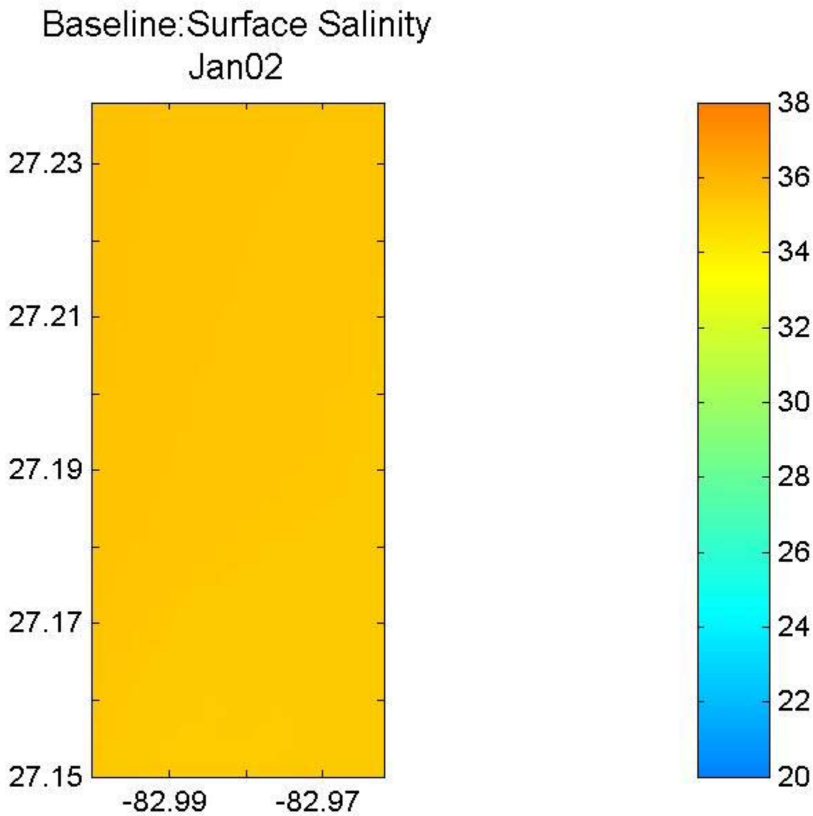

Figure 6.130. Predicted monthly mean surface salinity, baseline scenario, January 2002.

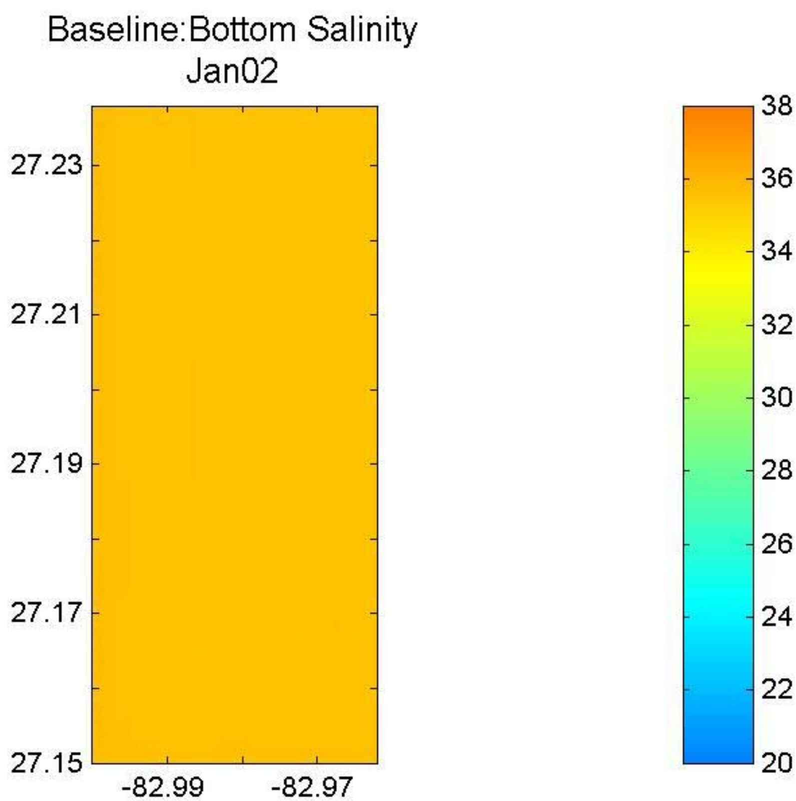

Figure 6.131. Predicted monthly mean bottom salinity, baseline scenario, January 2002.

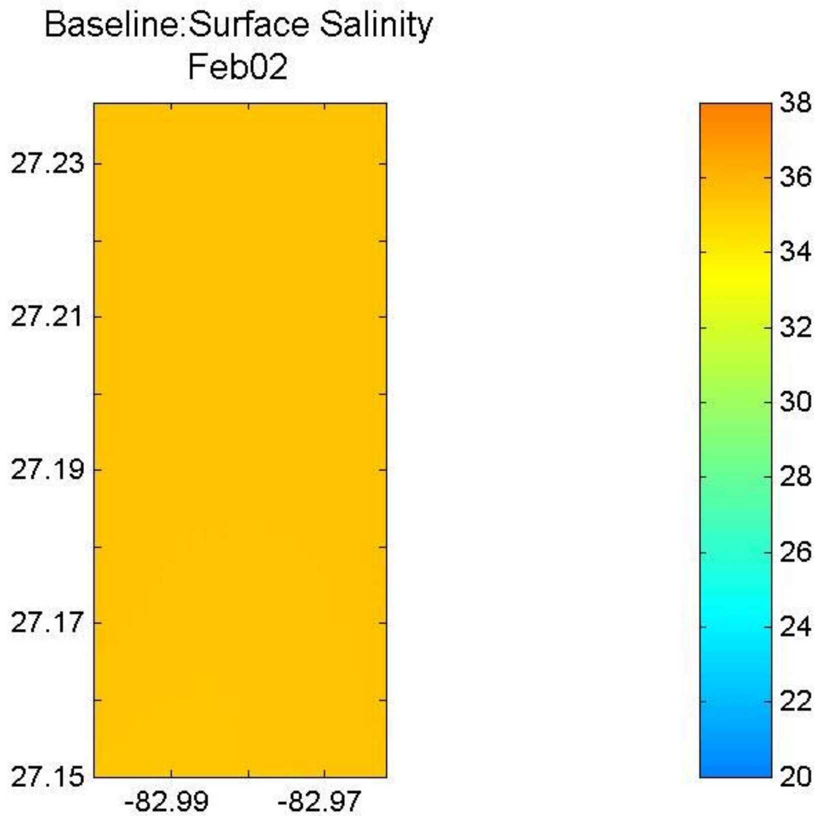

Figure 6.132. Predicted monthly mean surface salinity, baseline scenario, February 2002.

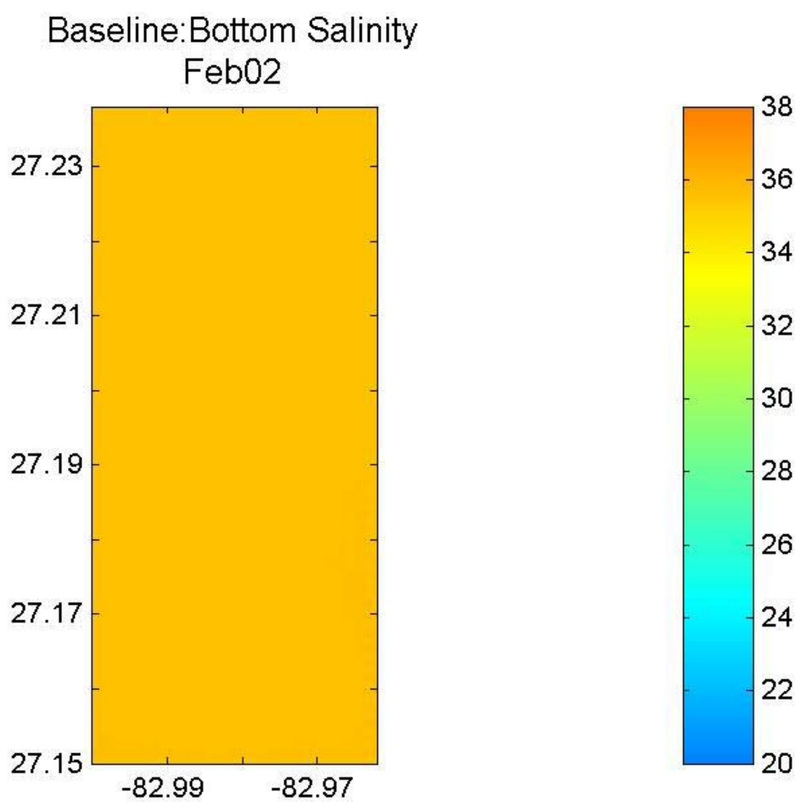

Figure 6.133. Predicted monthly mean bottom salinity, baseline scenario, February 2002.

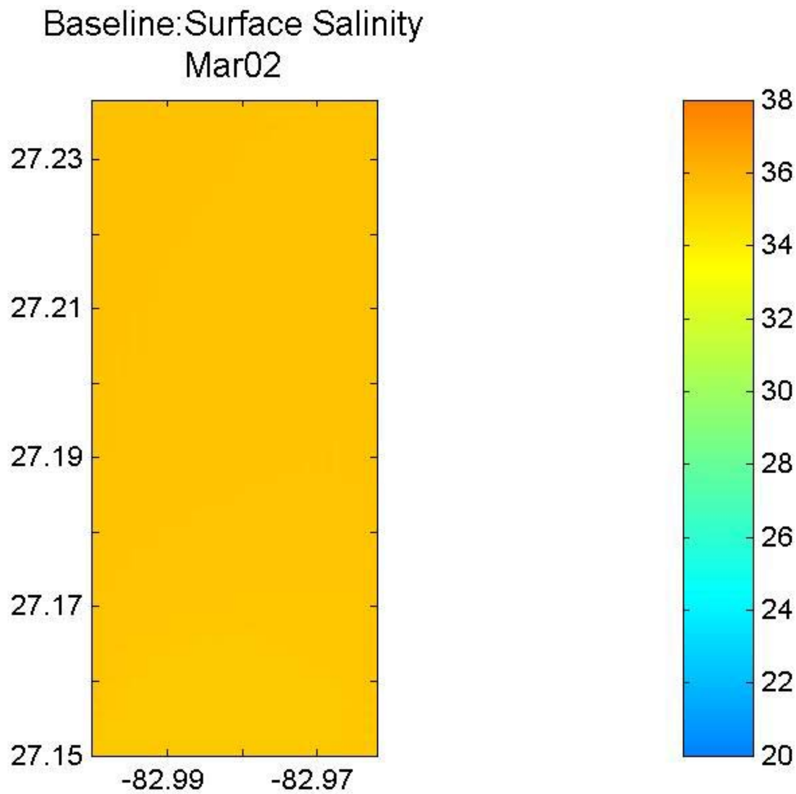

Figure 6.134. Predicted monthly mean surface salinity, baseline scenario, March 2002.

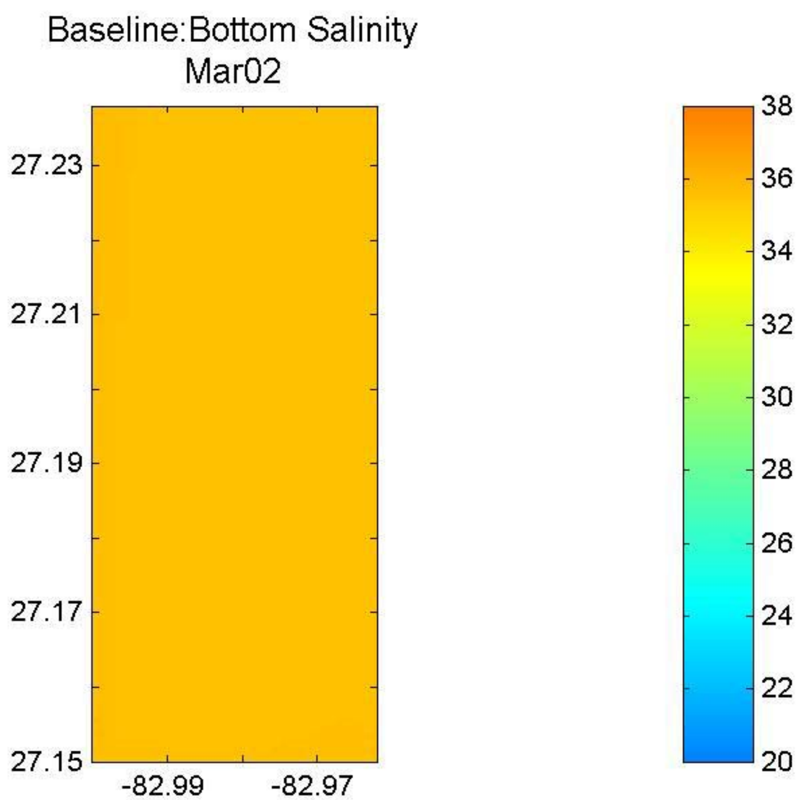

Figure 6.135. Predicted monthly mean bottom salinity, baseline scenario, March 2002.

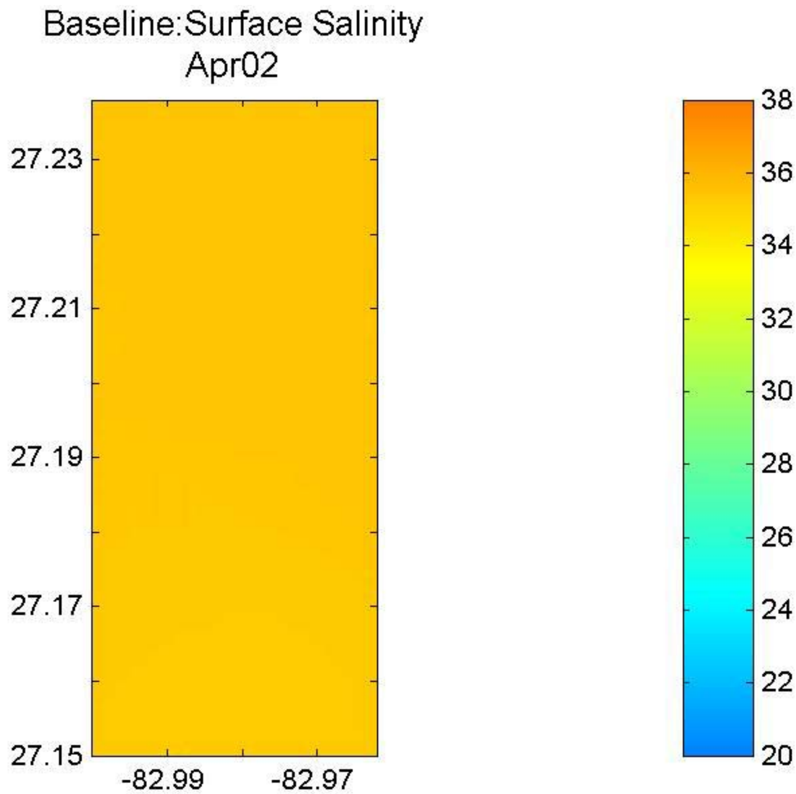

Figure 6.136. Predicted monthly mean surface salinity, baseline scenario, April 2002.

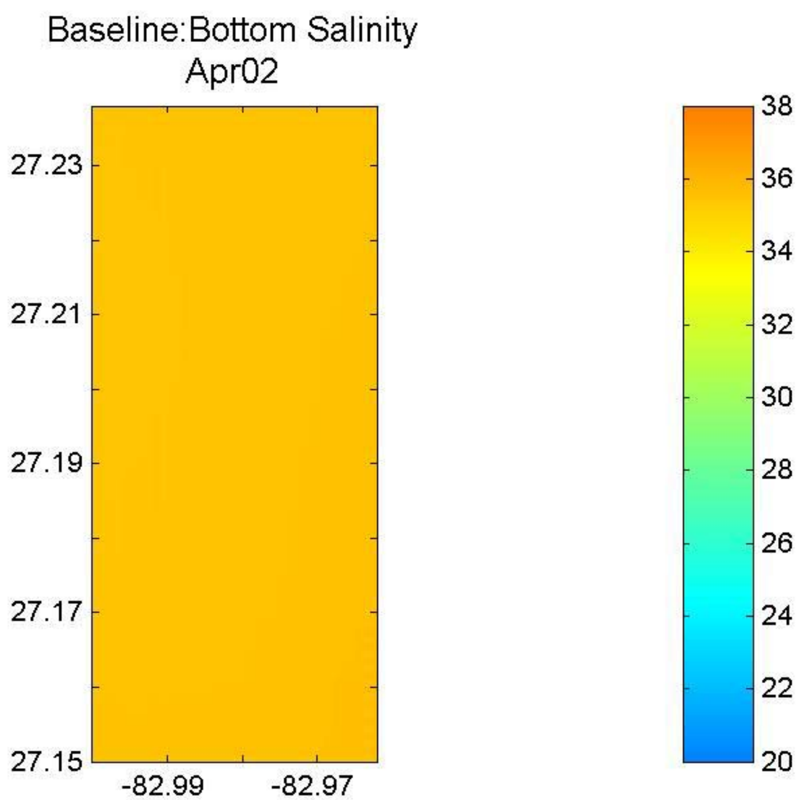

Figure 6.137. Predicted monthly mean bottom salinity, baseline scenario, April 2002.

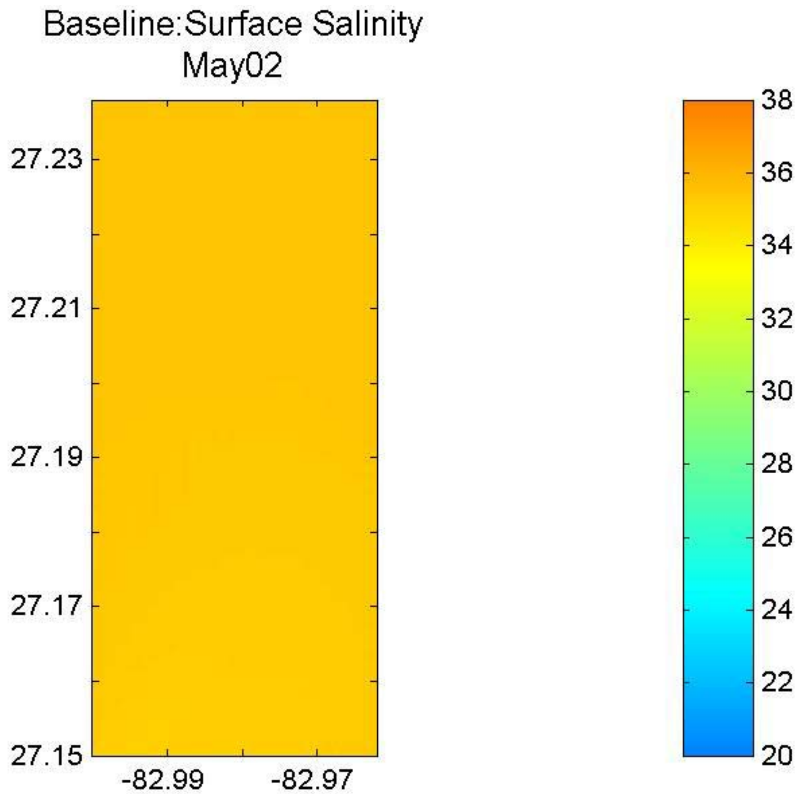

Figure 6.138. Predicted monthly mean surface salinity, baseline scenario, May 2002.

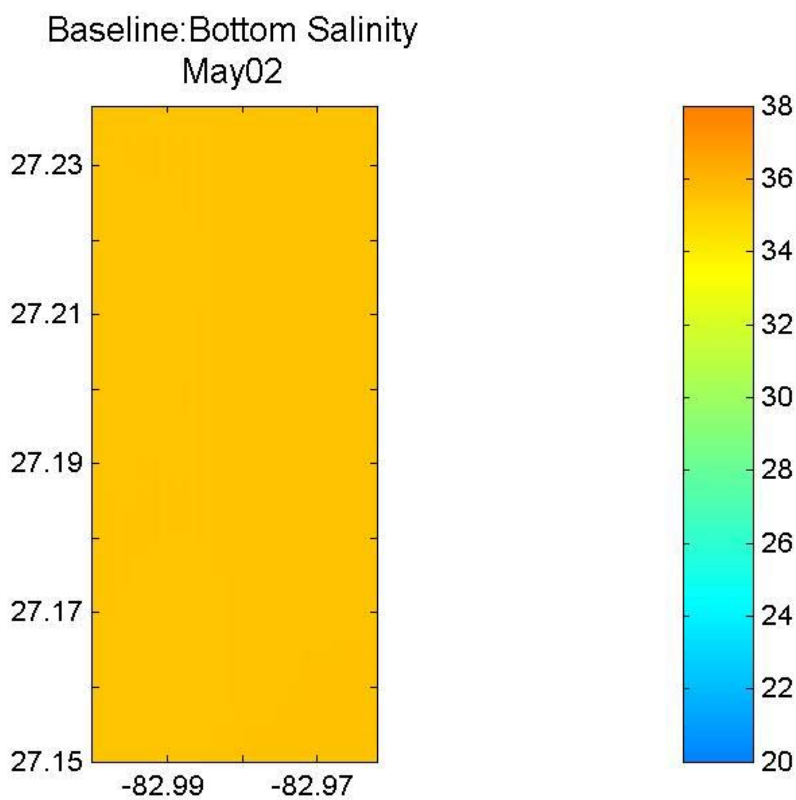

Figure 6.139. Predicted monthly mean bottom salinity, baseline scenario, May 2002.

A time series plot of the daily mean predicted salinity for the baseline scenario is presented in Figure 6.140. Predicted salinity in the rainy season (July-October) is lower than in the dry season (November-June). The vertical salinity difference, although small, is present throughout most of the year, as the deeper water column is not as likely to be vertically well-mixed here as it is in the nearshore environment (see Figure 6.26). The range of daily mean salinity is not as great as it is in the nearshore region, as the effects of freshwater input to the offshore small grid are decreased because of the distance from shore.

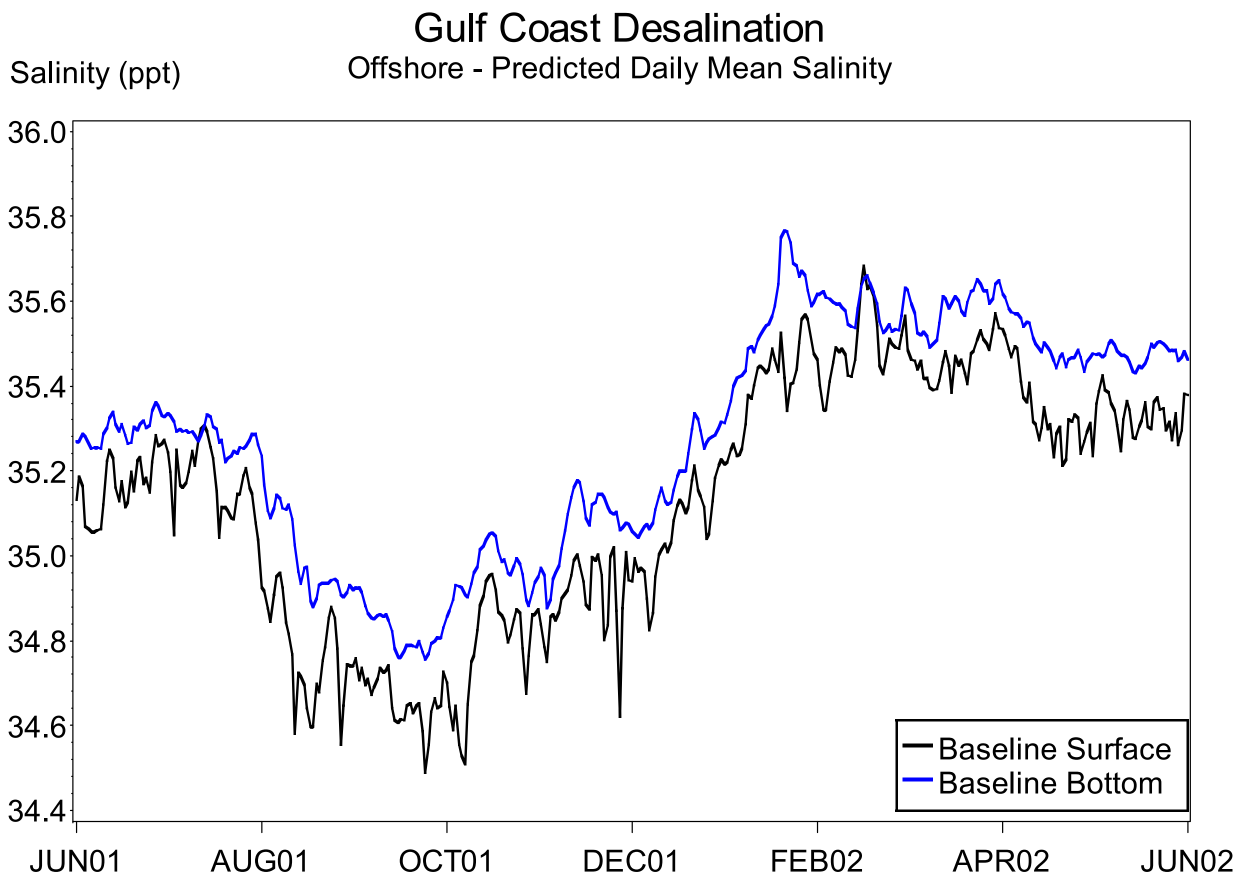

Figure 6.140. Time series of daily mean salinity for surface and bottom layers, baseline, June 2001 to May 2002.

6.2.1.2 Offshore – Baseline Circulation

Monthly mean predicted circulation maps are presented in Figures 6.141-6.152. The velocity vectors in the figures were derived from the values over a 10 cell by 10 cell area. The length of the longest vector, in the northwestern corner of the offshore small grid in December, represents a speed of 0.025 m/s. The model results suggest that the mean velocities flow to the north in October through March, while the remaining months do not show a consistent pattern of transport.

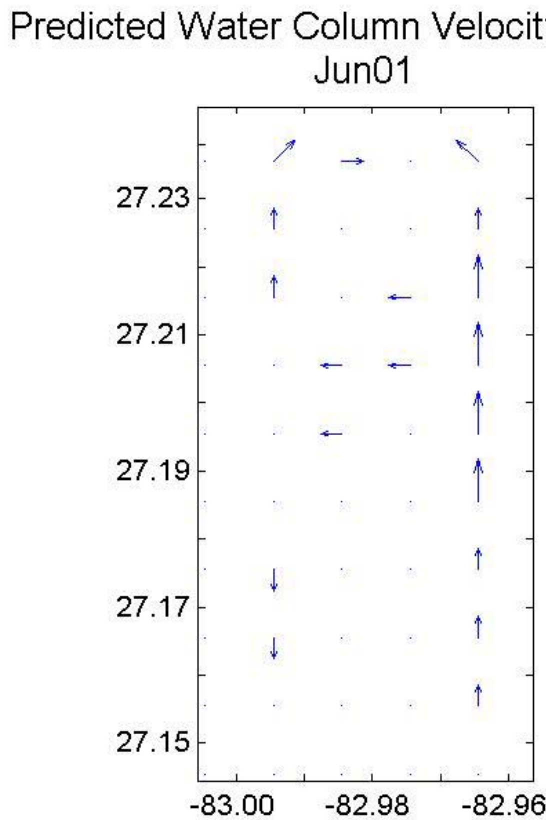

Figure 6.141. Water column monthly mean circulation, baseline scenario, June 2001.

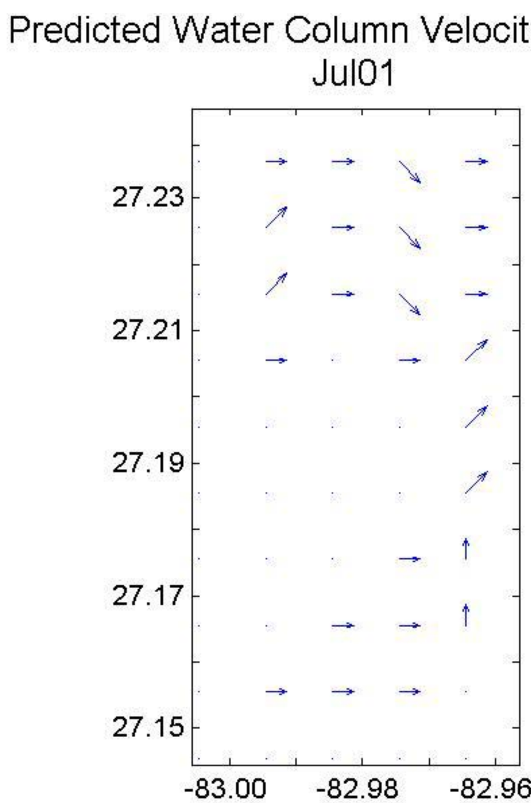

Figure 6.142. Water column monthly mean circulation, baseline scenario, July 2001.

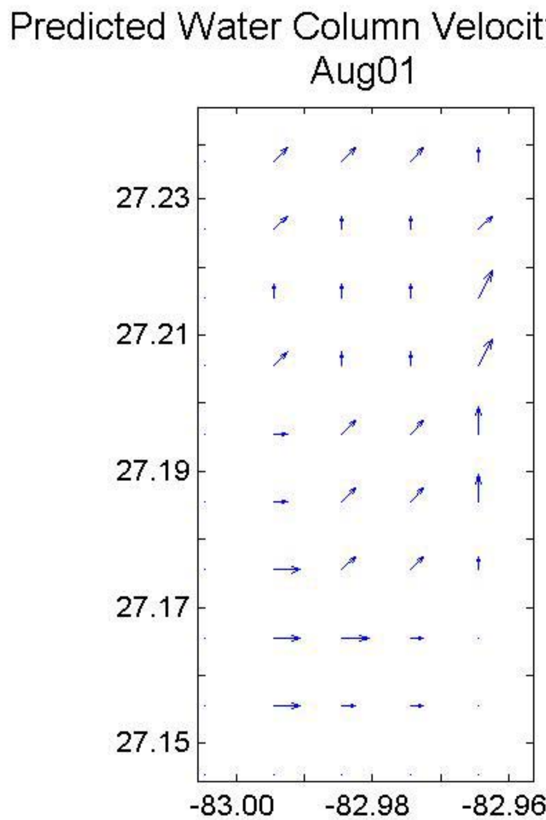

Figure 6.143. Water column monthly mean circulation, baseline scenario, August 2001.

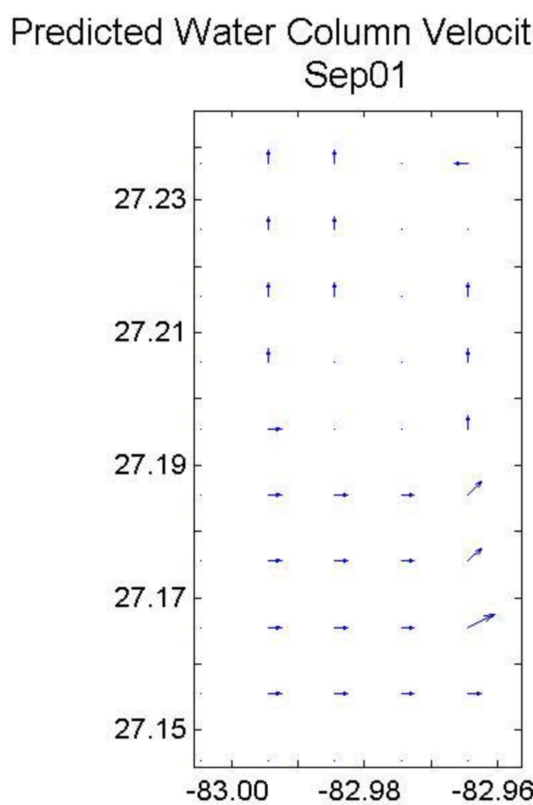

Figure 6.144. Water column monthly mean circulation, baseline scenario, September 2001.

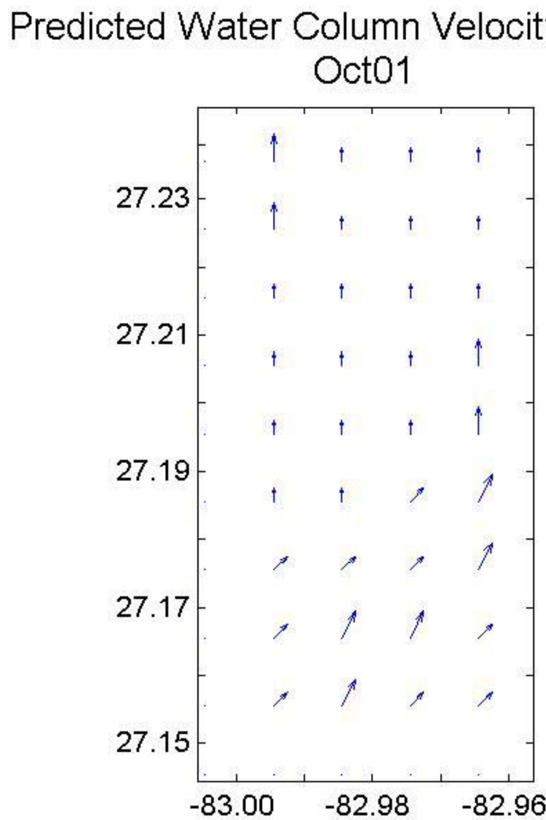

Figure 6.145. Water column monthly mean circulation, baseline scenario, October 2001.

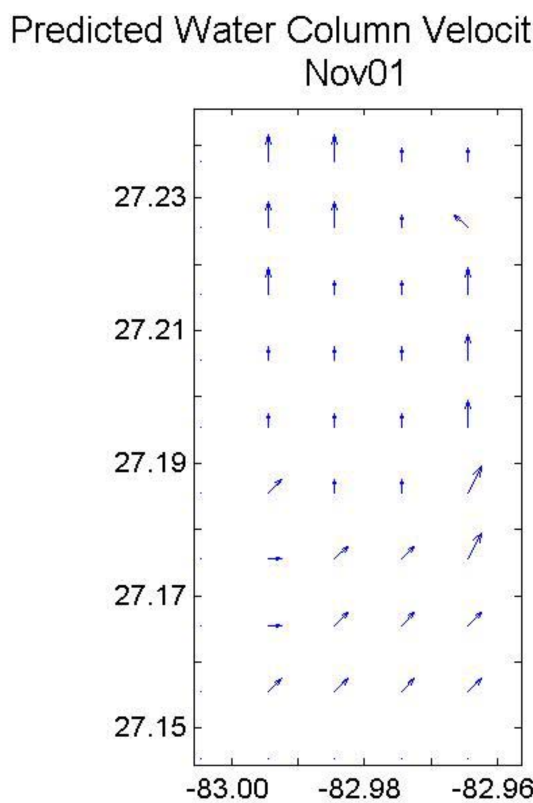

Figure 6.146. Water column monthly mean circulation, baseline scenario, November 2001.

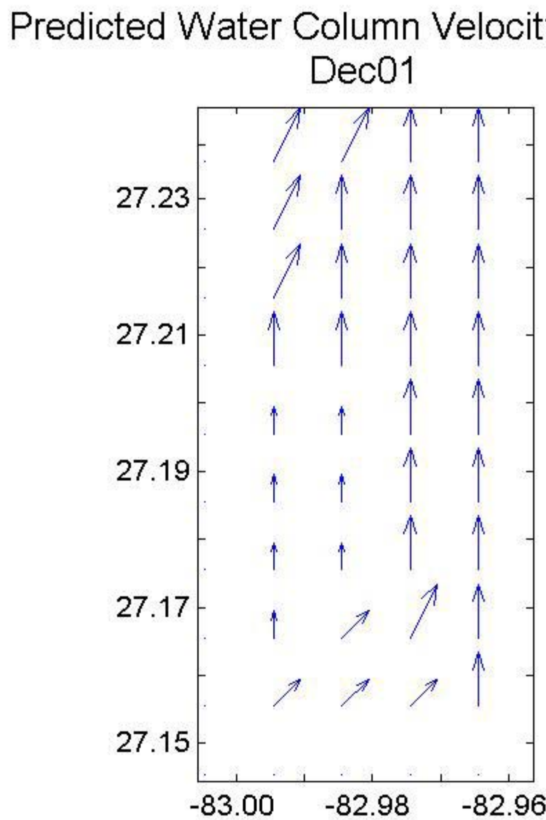

Figure 6.147. Water column monthly mean circulation, baseline scenario, December 2001.

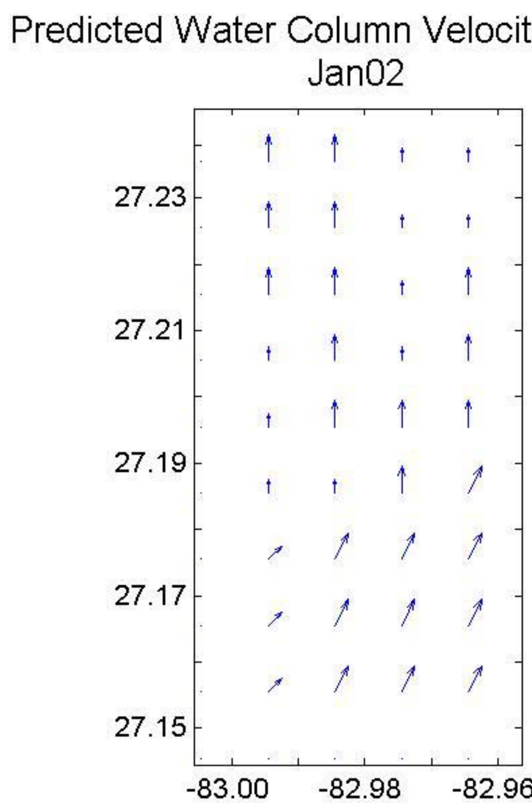

Figure 6.148. Water column monthly mean circulation, baseline scenario, January 2002.

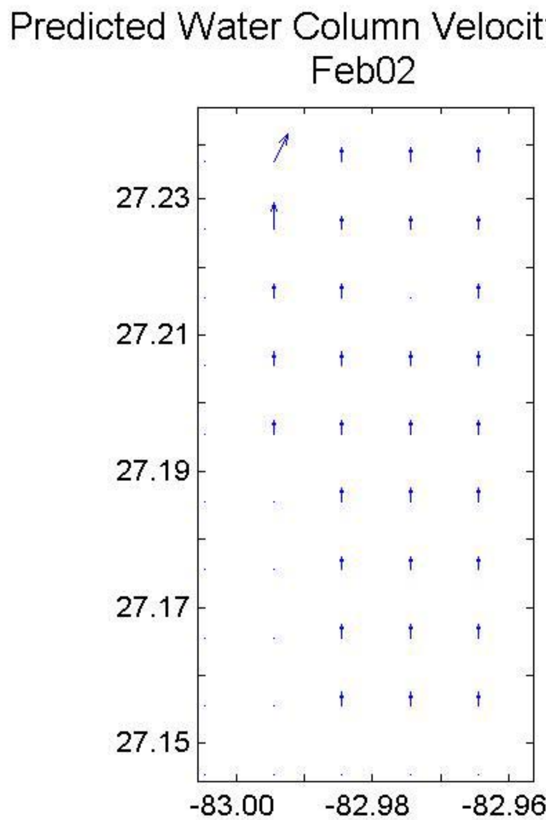

Figure 6.149. Water column monthly mean circulation, baseline scenario, February 2002.

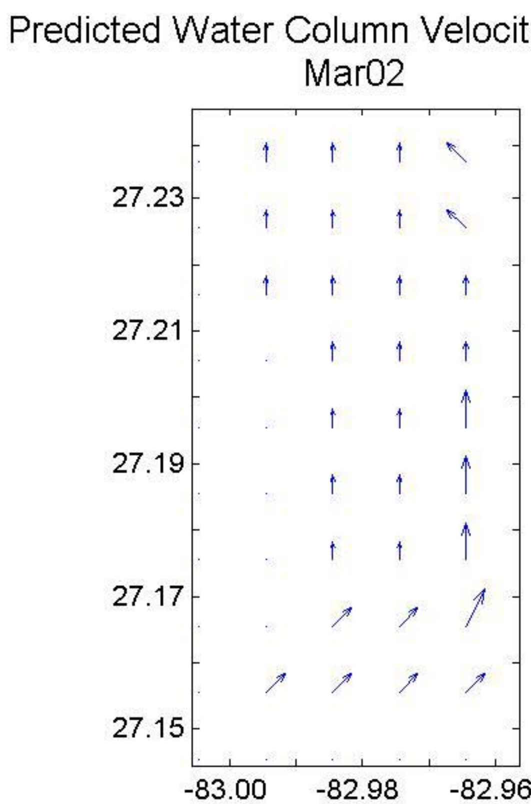

Figure 6.150. Water column monthly mean circulation, baseline scenario, March 2002.

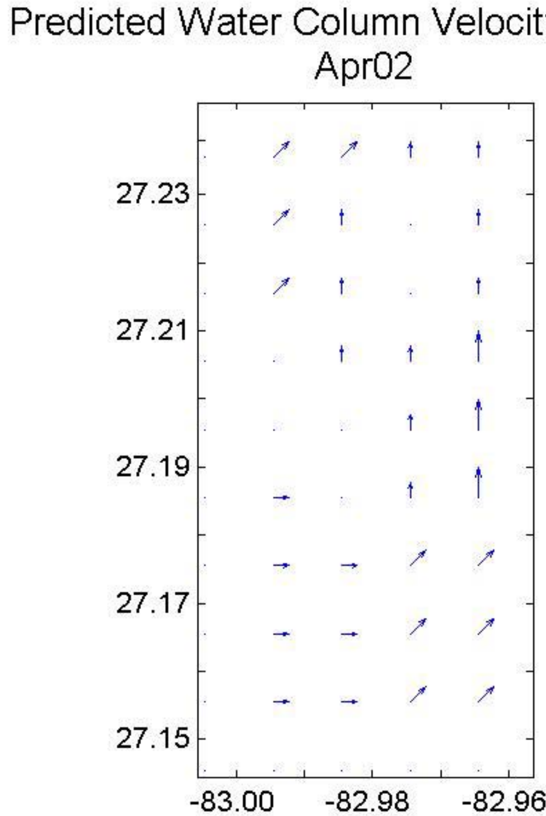

Figure 6.151. Water column monthly mean circulation, baseline scenario, April 2002.

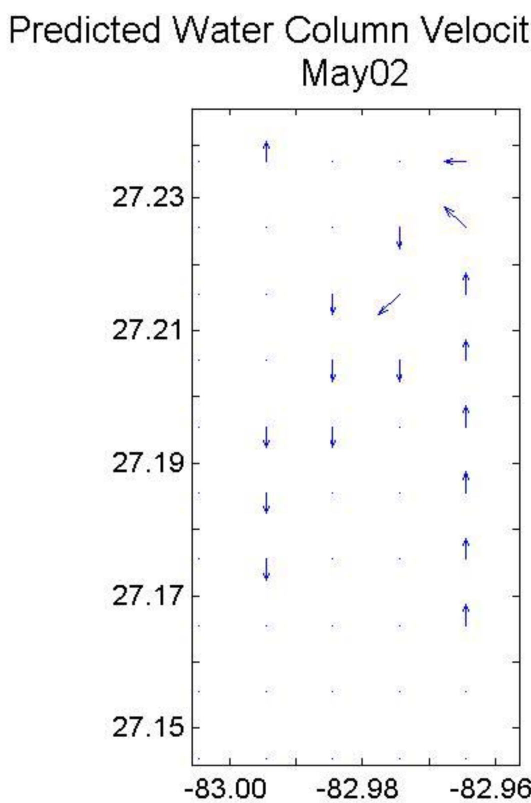

Figure 6.152. Water column monthly mean circulation, baseline scenario, May 2002

6.2.2 Offshore - 10 MGD Product Water Scenario

The offshore 10 MGD product water scenario results in approximately 16 MGD of concentrate discharging to the offshore small grid. For modeling purposes, the discharge occurs in a 100m x 100m cell near the bottom of the water column. Discharge is via two ports, one facing north and one facing south, with equal amounts of concentrate discharging through both ports. The resultant effects on salinity across the entire small grid system are displayed as monthly mean values in maps below, with time series presentations of daily mean surface and bottom salinity predictions in the offshore small grid as a whole.

The statistics for the daily mean predicted salinity values for the offshore 10 MGD product water scenario are summarized in Table 6.9. Changes in salinity (Δ salinity) are derived from the difference of the predicted salinity values for this scenario and those for the baseline. The 10 MGD product water scenario results in no change in the predicted mean salinity over the offshore grid system. Maps of predicted changes in salinity for all months for the surface and bottom layers are presented in Figures 6.153-6.176. Elevated predicted salinity values in comparison to baseline conditions can be detected in the shallow area near the discharge canal from November to April (the dry season), although the change in salinity is less than 0.5 ppt near the discharge. Greatest increases in salinity values are in March in comparison to the baseline condition, with the least change occurring in September. The mean of the daily values for the Anchorage over the entire year is no different from the same statistic for the offshore baseline scenario (see Table 6.8).

The salinity change maps in Figures 6.153-6.176 suggest that the effects on salinity of the 10 MGD product water scenario are confined to the bottom of the water column in a north-south transect centered on the discharge port. There is very little variation in the increased salinity signal over the year, as the seasonal effects of freshwater inflow and power station cooling water usage do not affect this discharge.

Table 6.9. Statistics for the daily mean predicted salinity for the offshore 10 MGD product water scenario.

Layer	N	Mean	Standard Deviation	Minimum	Maximum
Surface	365	35.1 ppt	0.3 ppt	34.5 ppt	35.7 ppt
Bottom	365	35.3 ppt	0.3 ppt	34.8 ppt	35.8 ppt

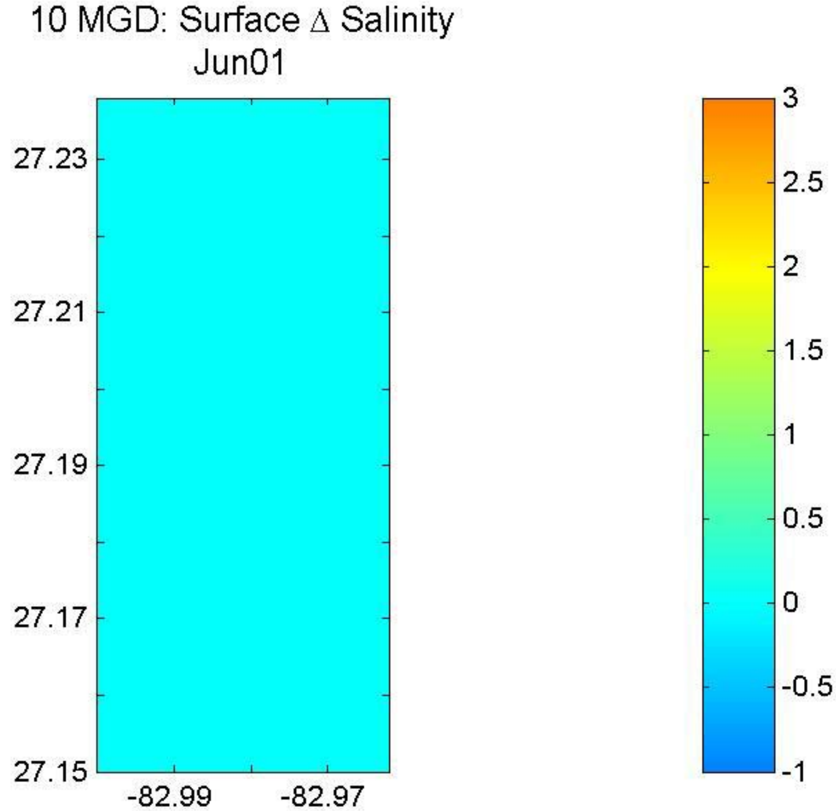

Figure 6.153. Predicted monthly mean surface salinity change, 10 MGD product water scenario, June 2001.

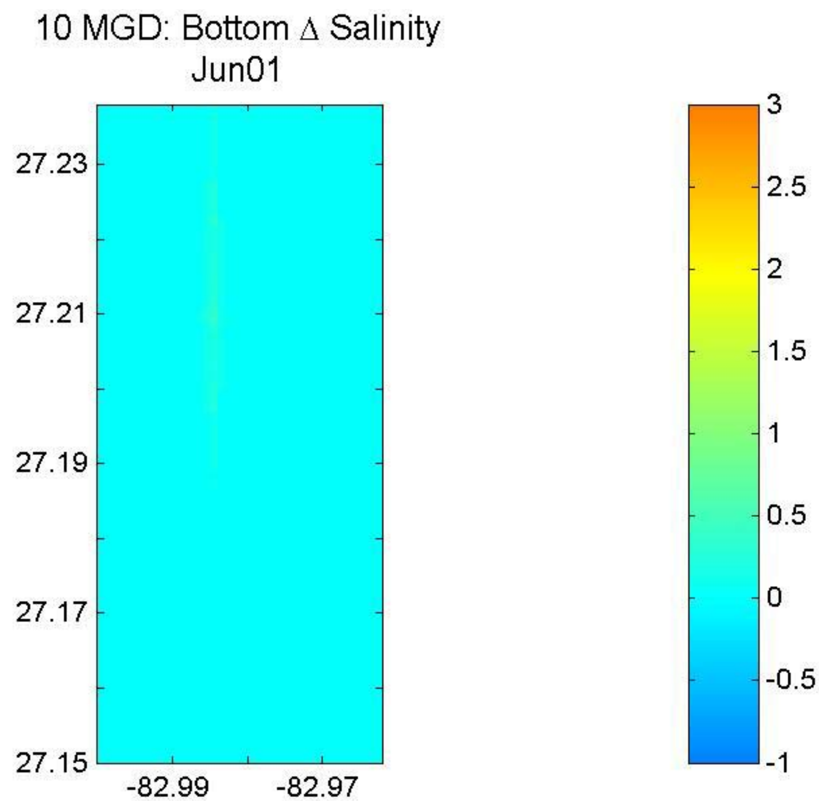

Figure 6.154. Predicted monthly mean bottom salinity change, 10 MGD product water scenario, June 2001.

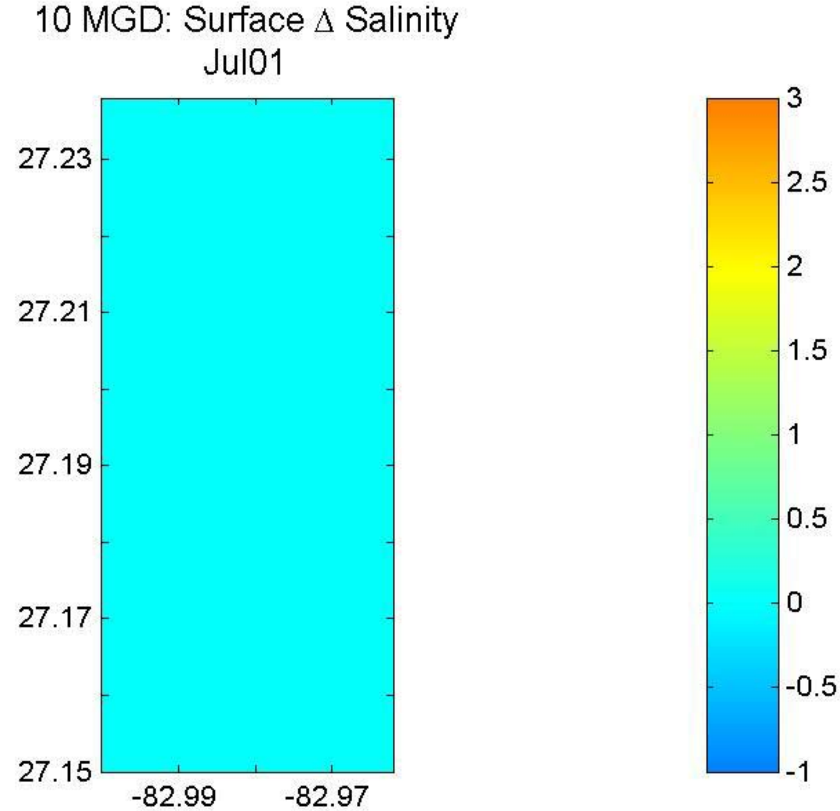

Figure 6.155. Predicted monthly mean surface salinity change, 10 MGD product water scenario, July 2001.

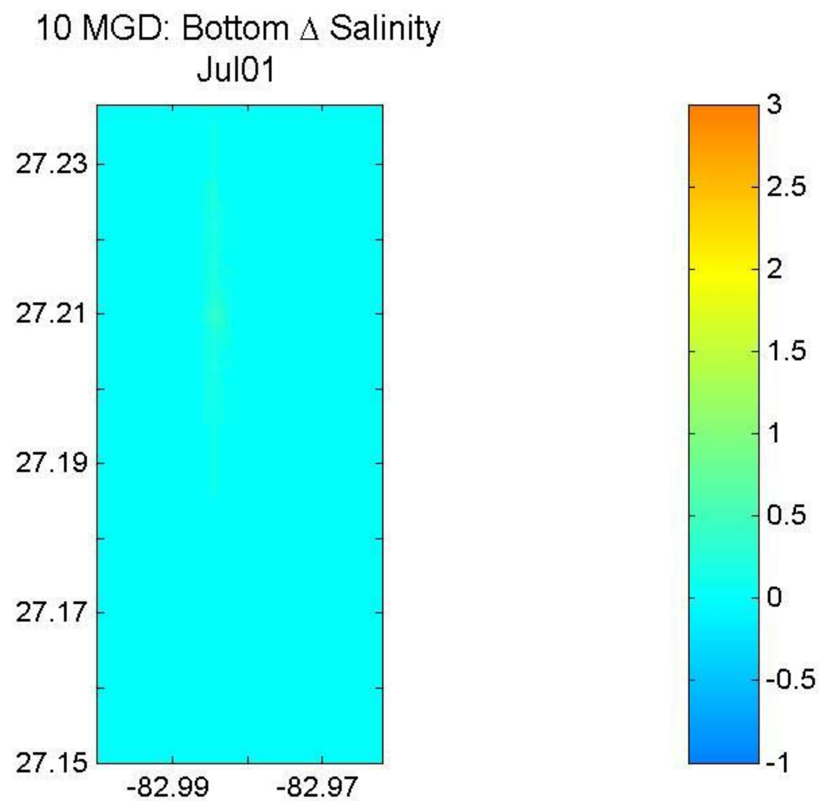

Figure 6.156. Predicted monthly mean bottom salinity change, 10 MGD product water scenario, July 2001.

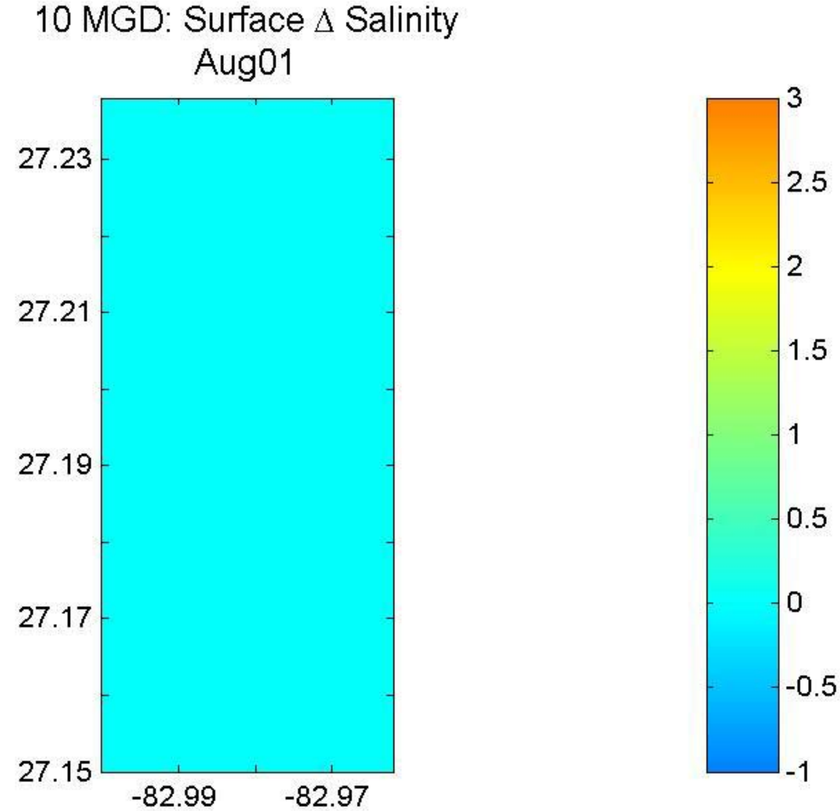

Figure 6.157. Predicted monthly mean surface salinity change, 10 MGD product water scenario, August 2001.

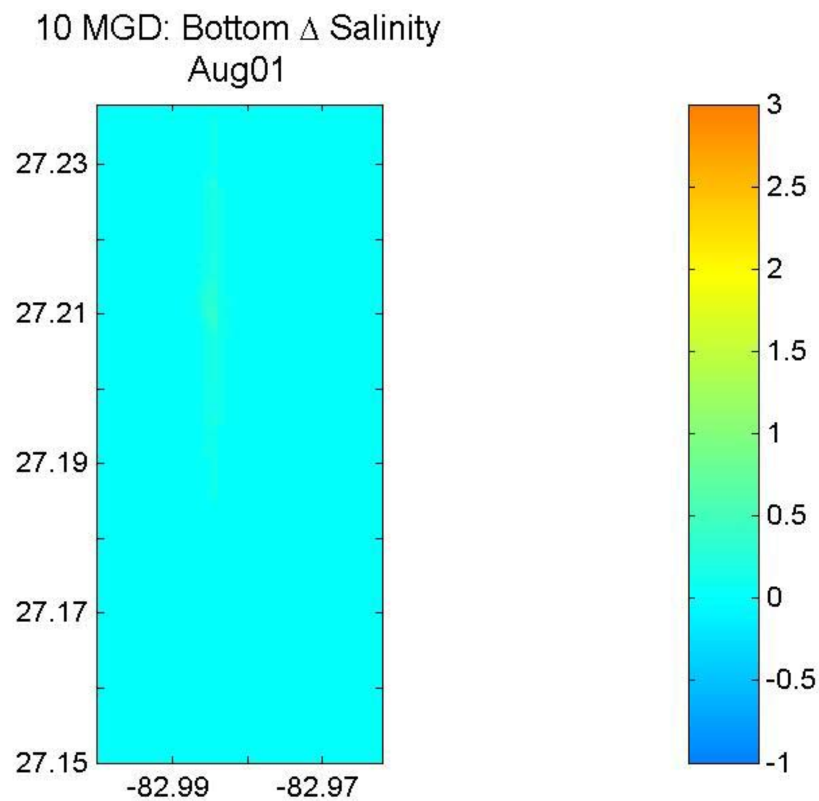

Figure 6.158. Predicted monthly mean bottom salinity change, 10 MGD product water scenario, August 2001.

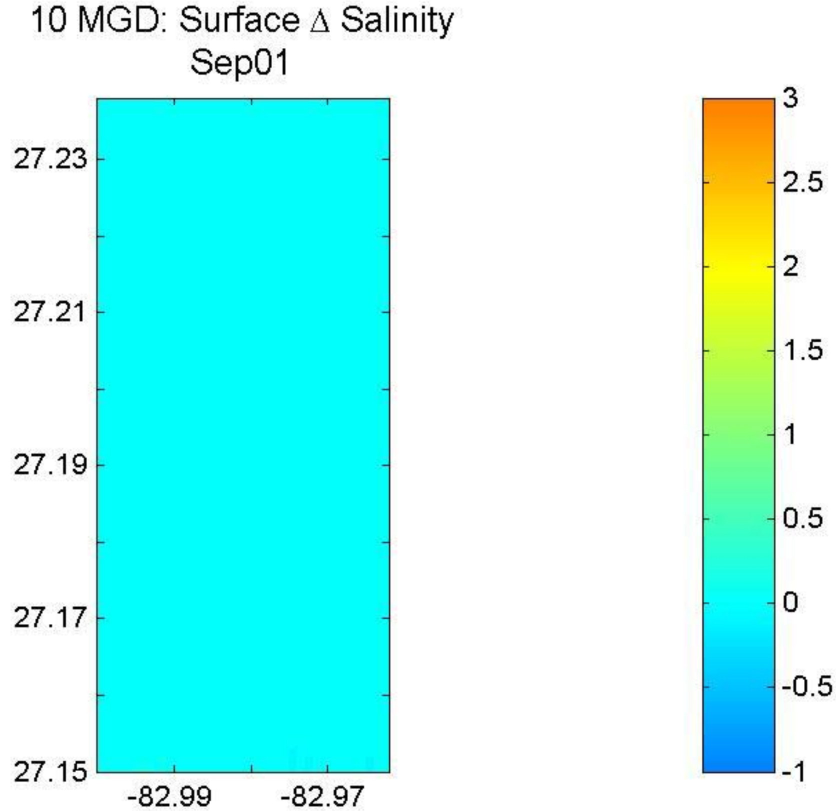

Figure 6.159. Predicted monthly mean surface salinity change, 10 MGD product water scenario, September 2001.

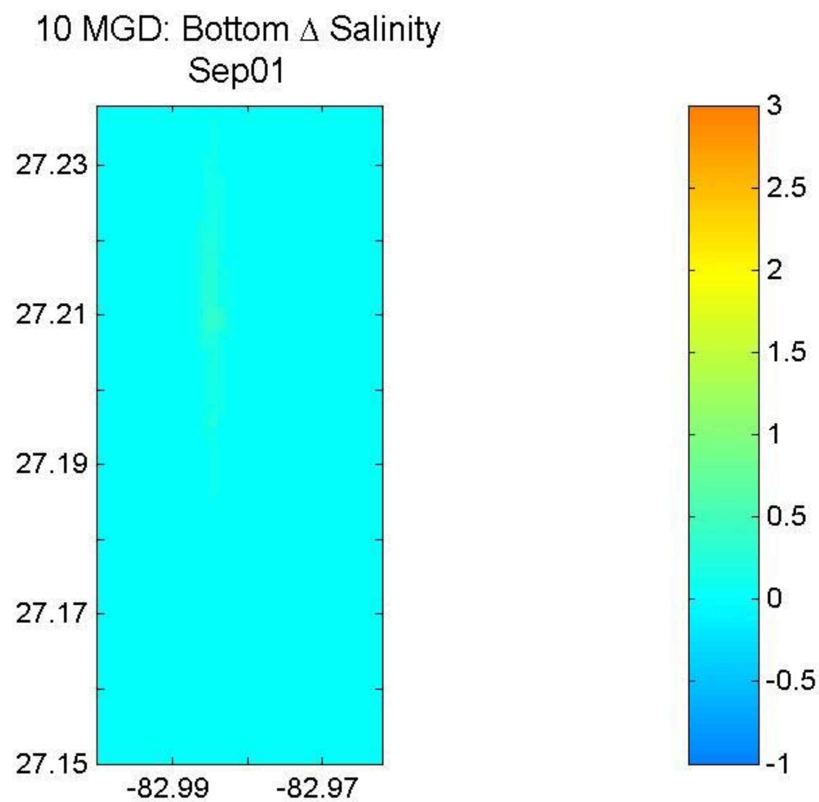

Figure 6.160. Predicted monthly mean bottom salinity change, 10 MGD product water scenario, September 2001.

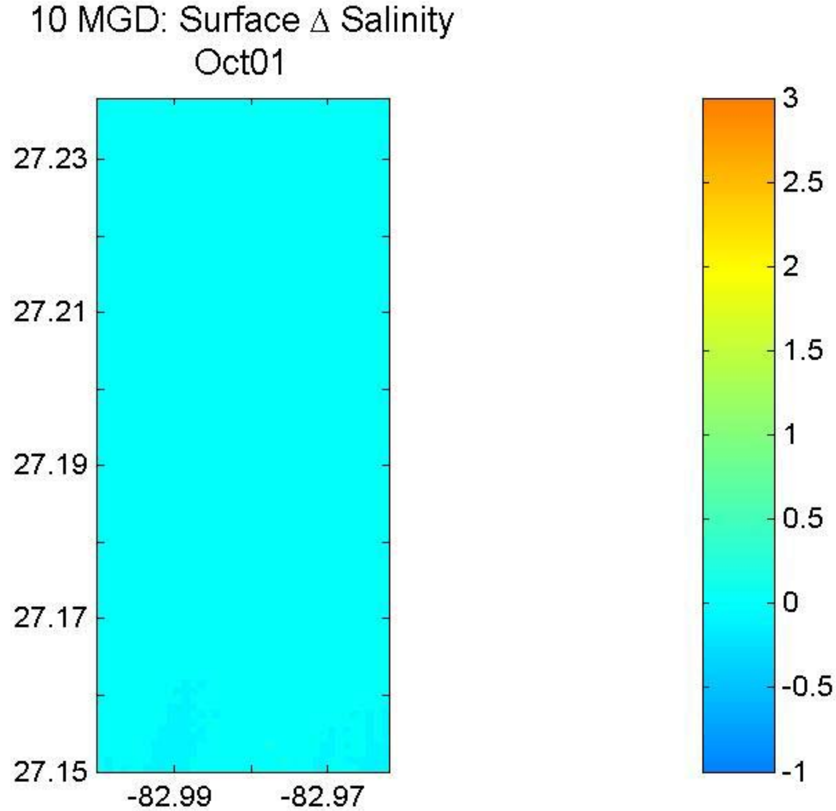

Figure 6.161. Predicted monthly mean surface salinity change, 10 MGD product water scenario, October 2001.

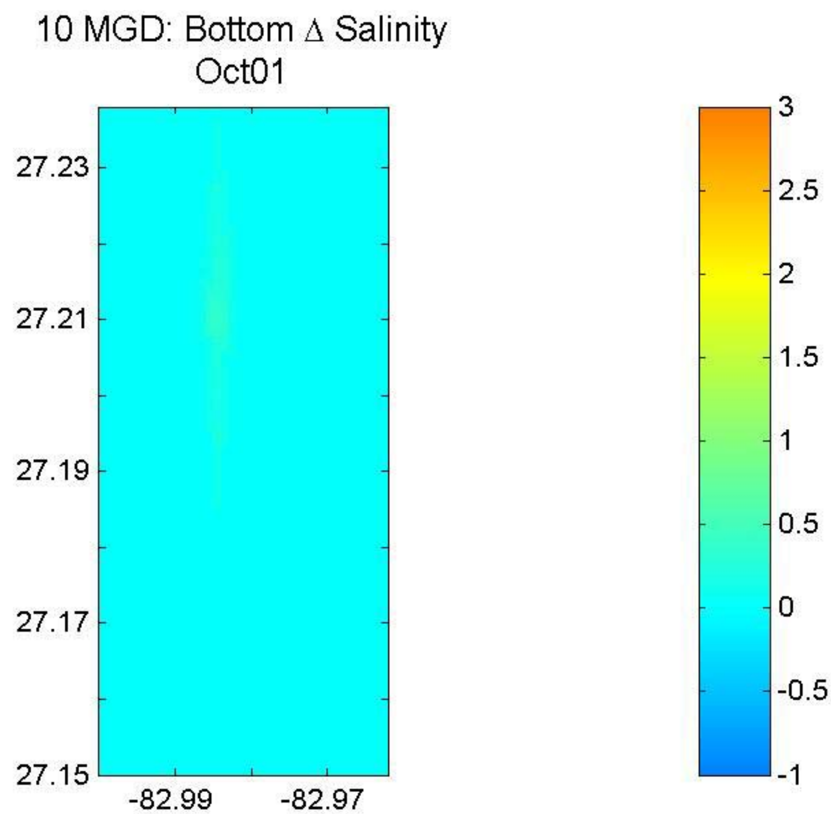

Figure 6.162. Predicted monthly mean bottom salinity change, 10 MGD product water scenario, October 2001.

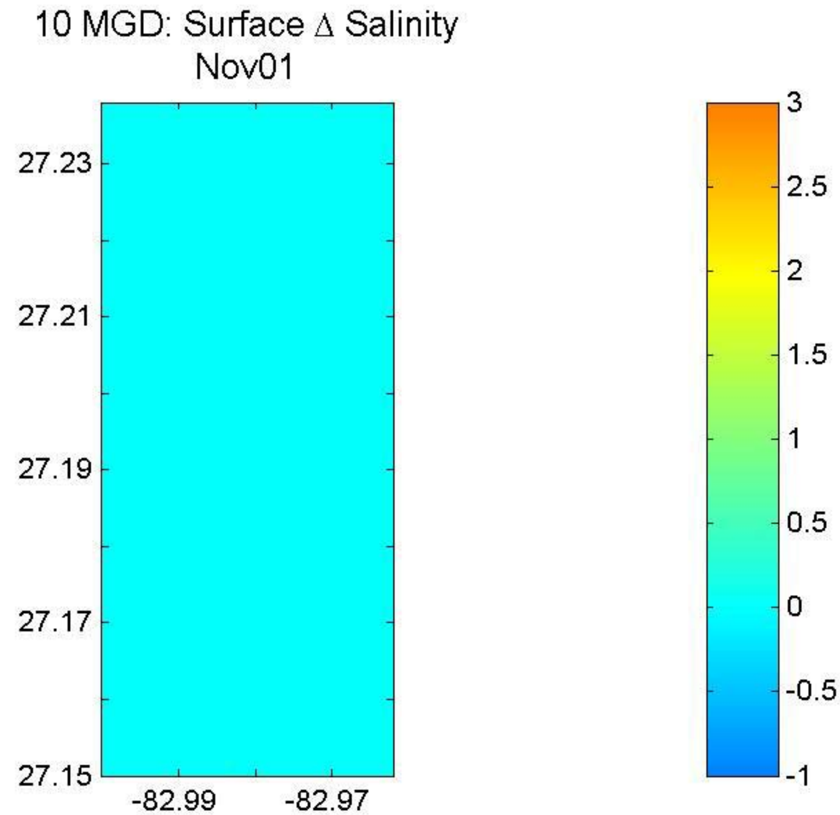

Figure 6.163. Predicted monthly mean surface salinity change, 10 MGD product water scenario, November 2001.

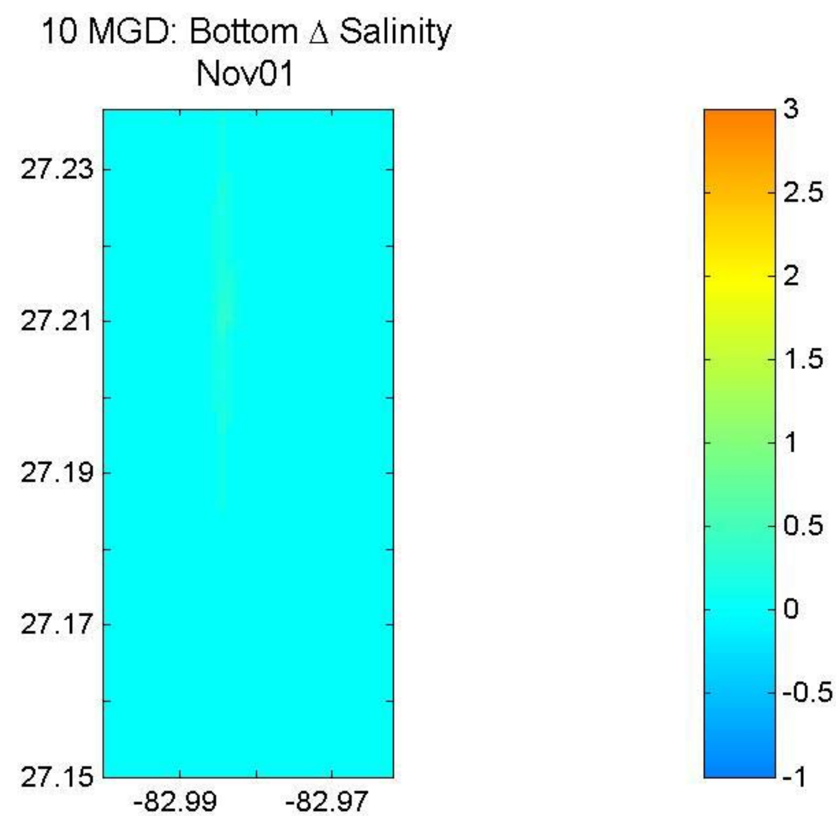

Figure 6.164. Predicted monthly mean bottom salinity change, 10 MGD product water scenario, November 2001.

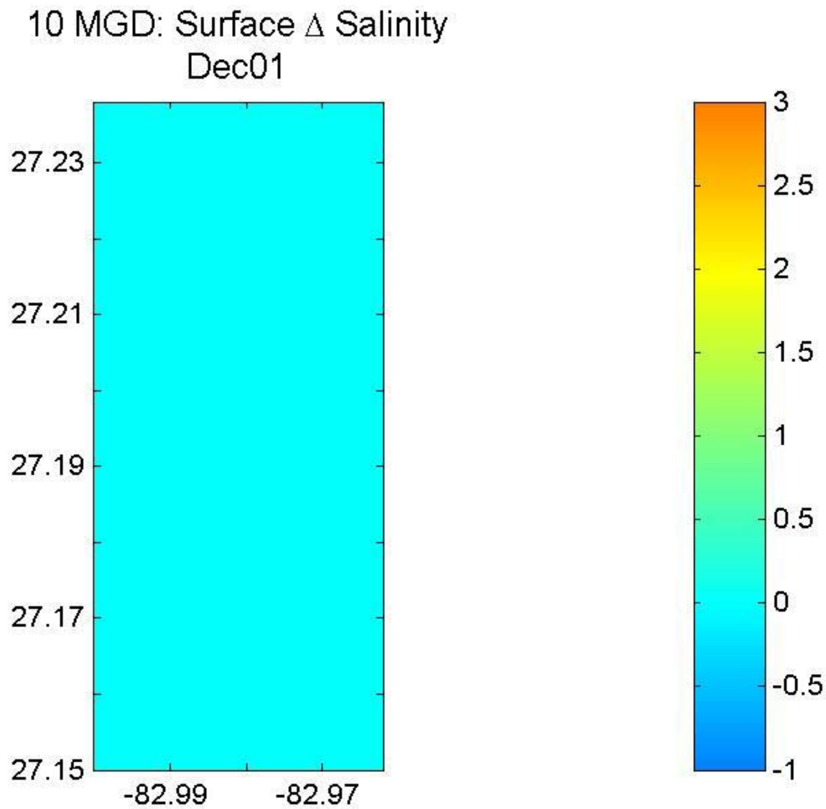

Figure 6.165. Predicted monthly mean surface salinity change, 10 MGD product water scenario, December 2001.

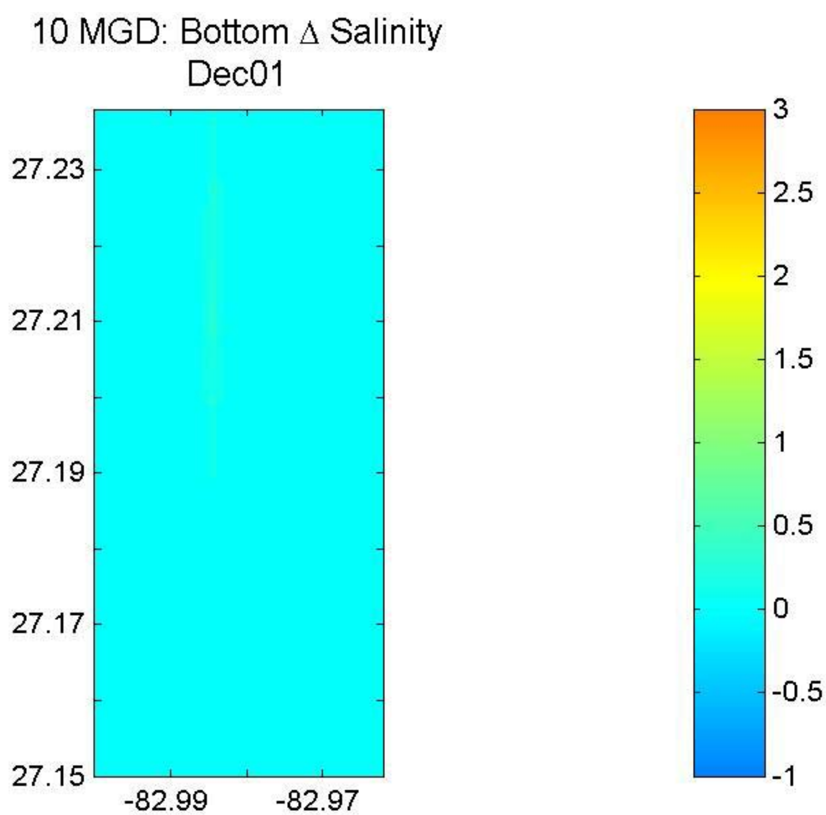

Figure 6.166. Predicted monthly mean bottom salinity change, 10 MGD product water scenario, December 2001.

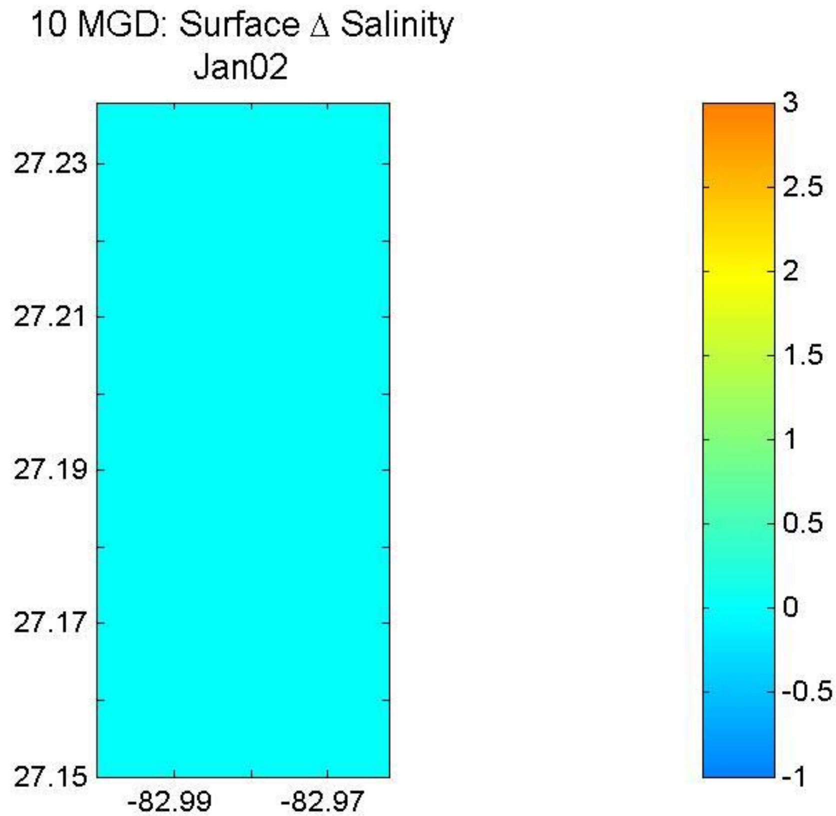

Figure 6.167. Predicted monthly mean surface salinity change, 10 MGD product water scenario, January 2002.

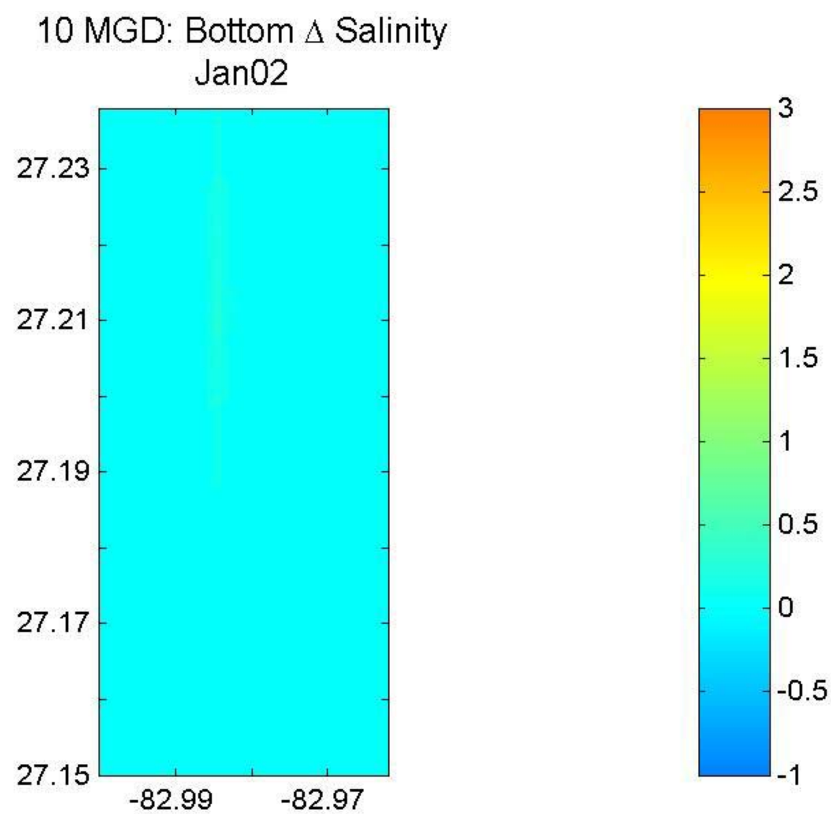

Figure 6.168. Predicted monthly mean bottom salinity change, 10 MGD product water scenario, January 2002.

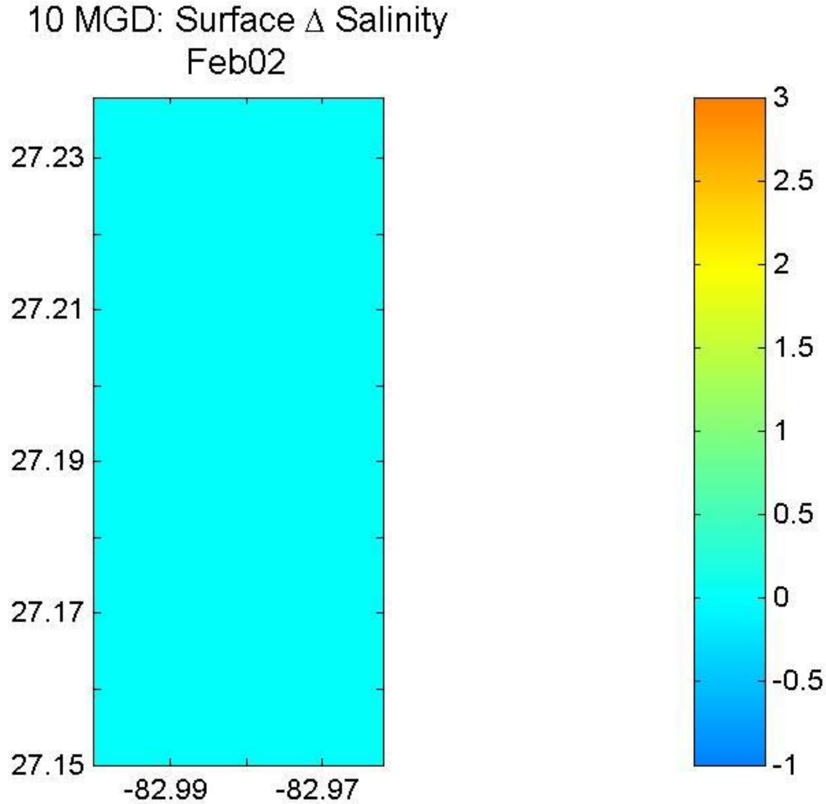

Figure 6.169. Predicted monthly mean surface salinity change, 10 MGD product water scenario, February 2002.

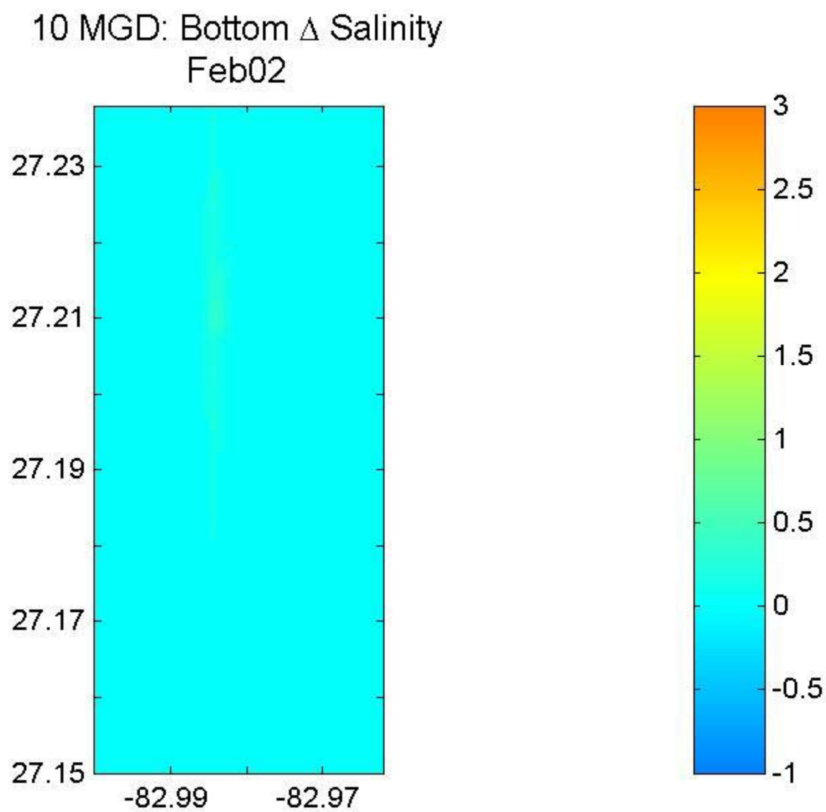

Figure 6.170. Predicted monthly mean bottom salinity change, 10 MGD product water scenario,February 2002.

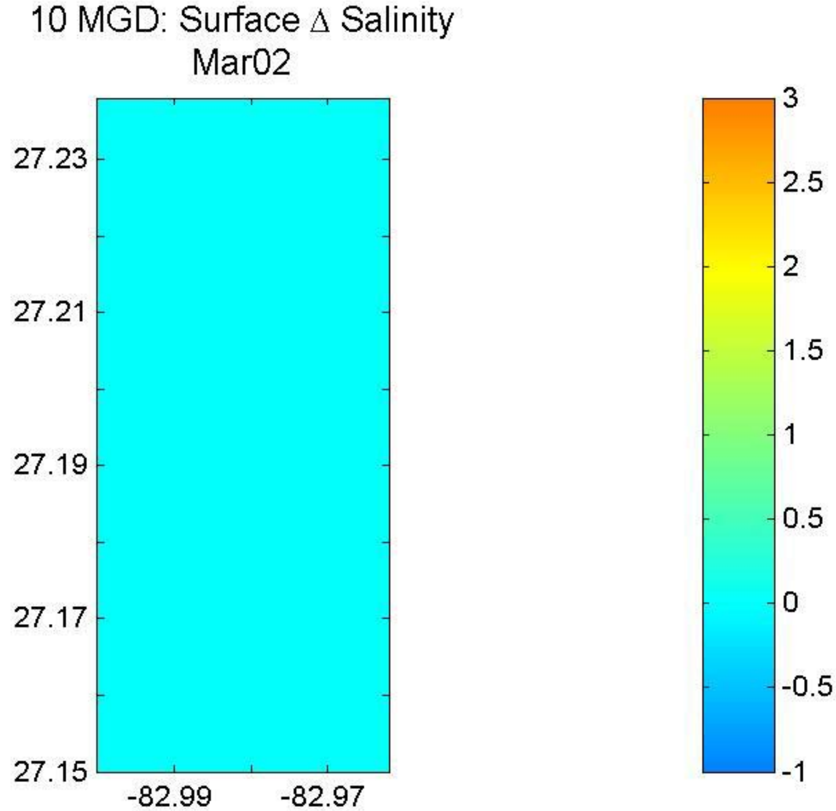

Figure 6.171. Predicted monthly mean surface salinity change, 10 MGD product water scenario, March 2002.

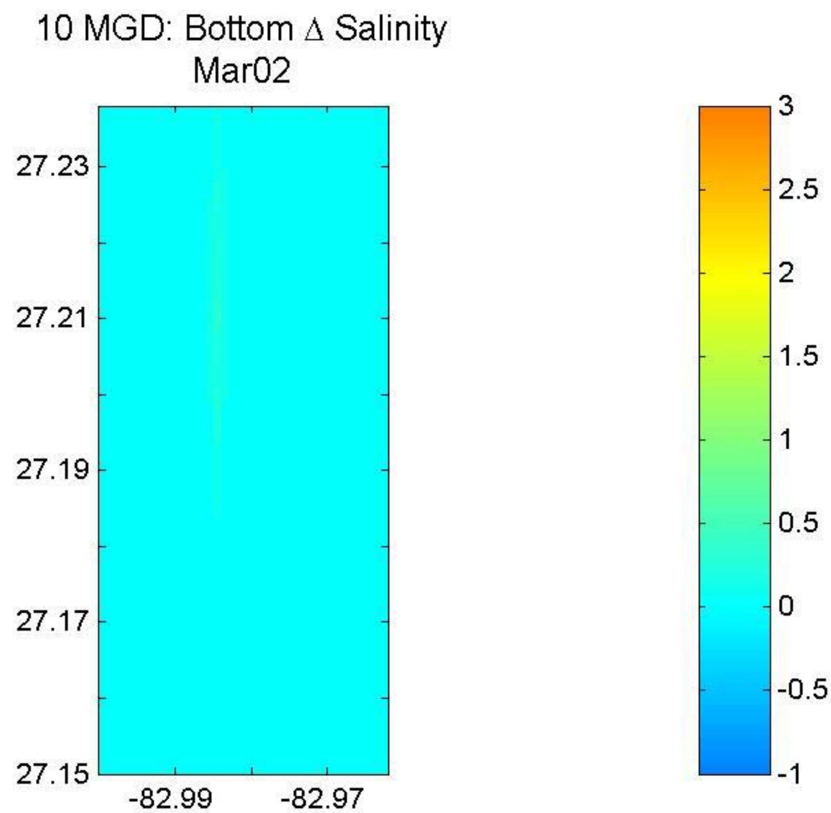

Figure 6.172. Predicted monthly mean bottom salinity change, 10 MGD product water scenario, March 2002.

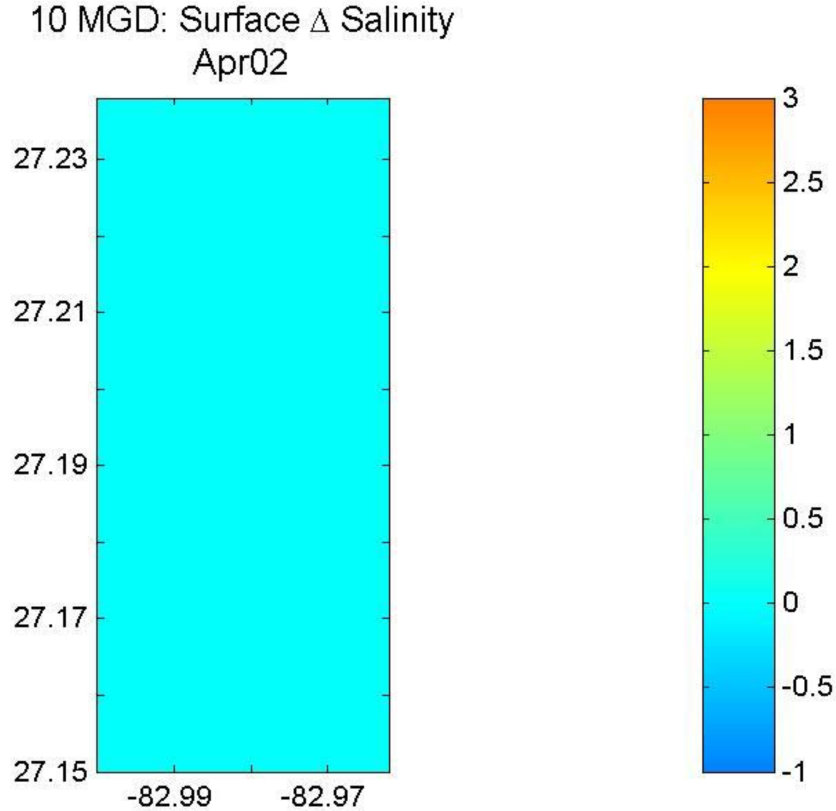

Figure 6.173. Predicted monthly mean surface salinity change, 10 MGD product water scenario, April 2002.

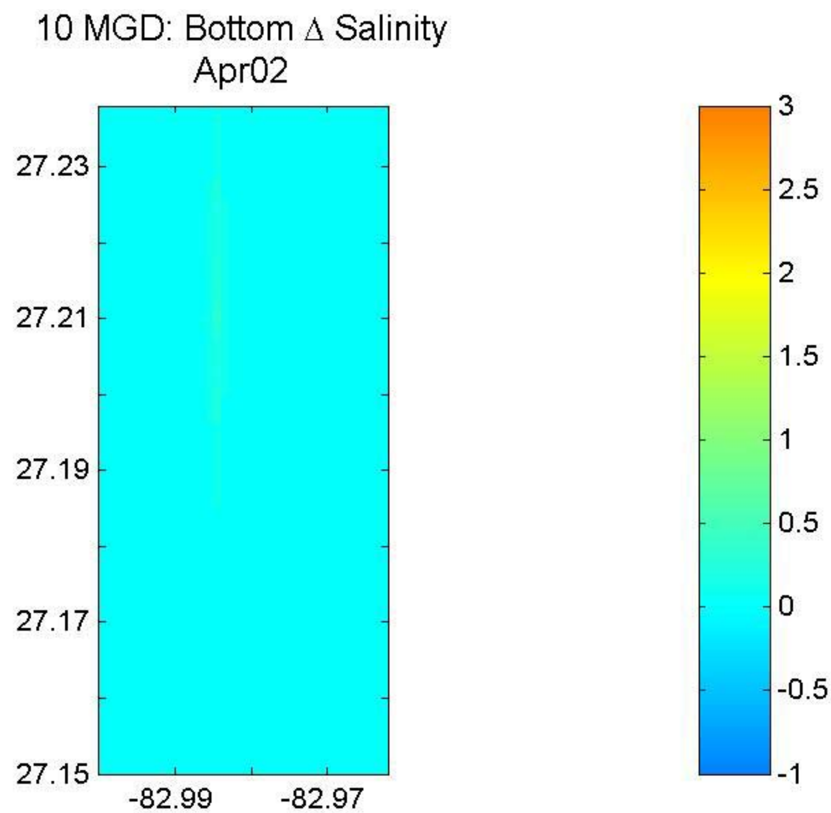

Figure 6.174. Predicted monthly mean bottom salinity change, 10 MGD product water scenario, April 2002.

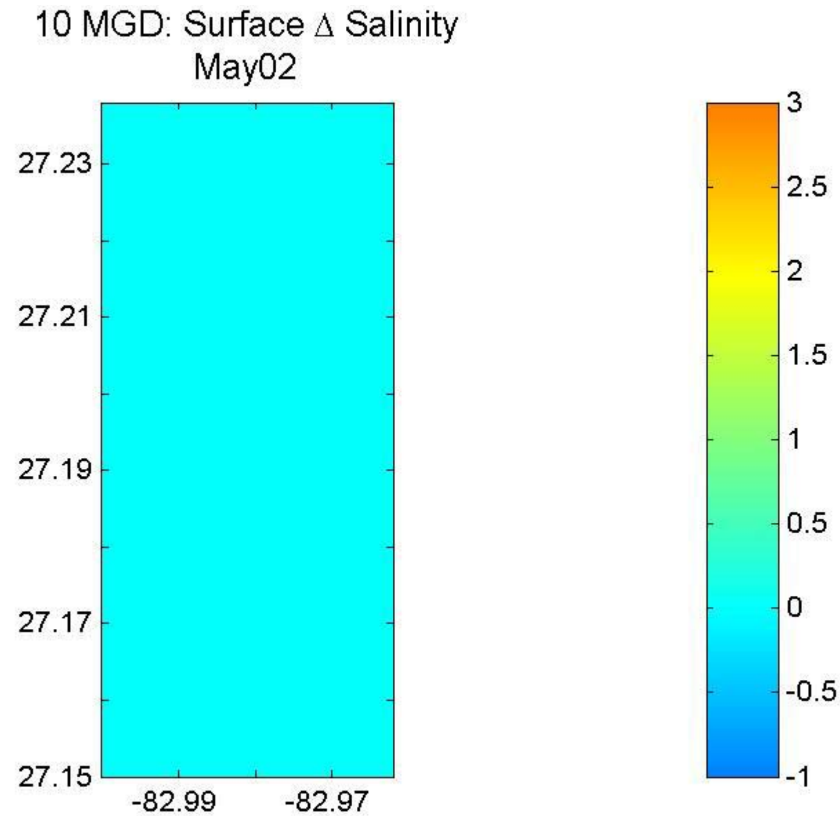

Figure 6.175. Predicted monthly mean surface salinity change, 10 MGD product water scenario, May 2002.

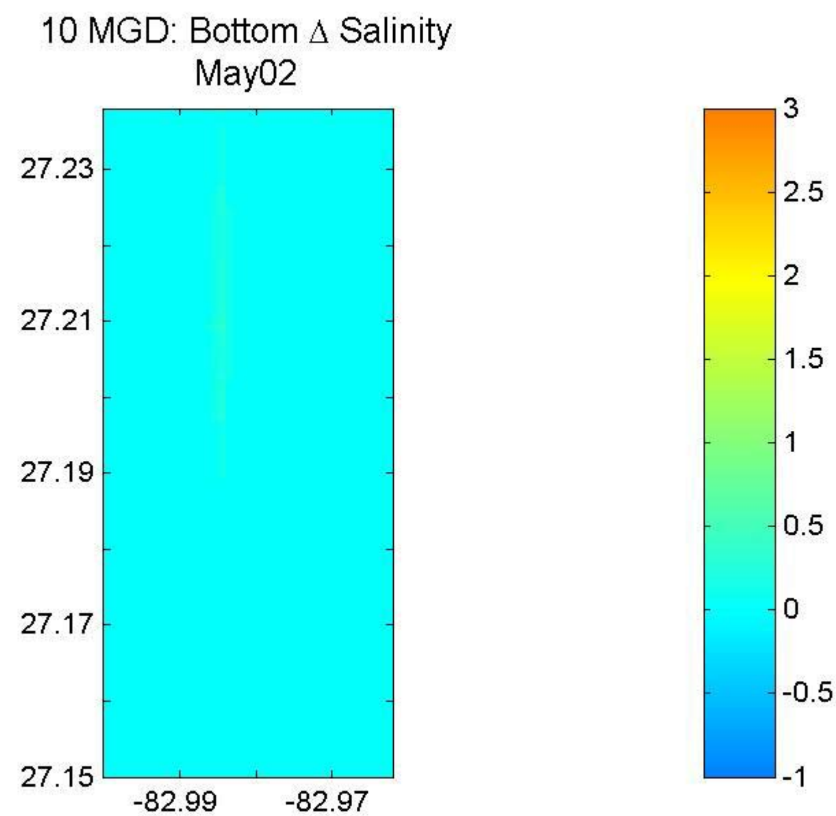

Figure 6.176. Predicted monthly mean bottom salinity change, 10 MGD product water scenario, May 2002.

A time series plot of the daily mean predicted salinity for the 10 MGD product water scenario is presented in Figure 6.177. The predicted salinity in the surface layer is slightly less than that in the bottom layer throughout the year, as in the baseline case.

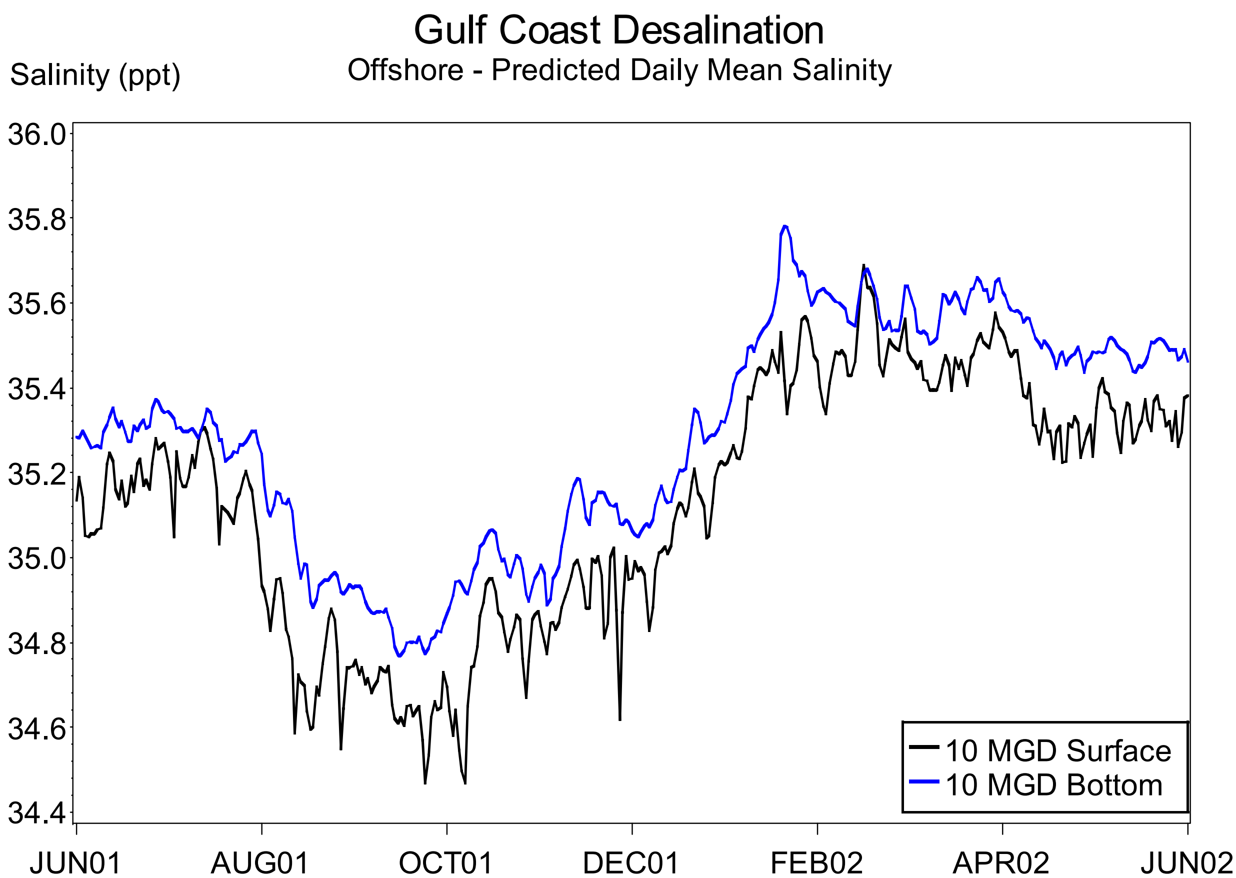

Figure 6.177. Time series of daily mean salinity for surface and bottom layers, 10 MGD, June 2001 to May 2002.

6.2.3 Offshore - 25 MGD Product Water Scenario

The offshore 25 MGD product water scenario results in approximately 40 MGD of concentrate discharging to the offshore small grid. For modeling purposes, the discharge occurs in a 100m x 100m cell near the bottom of the water column. Discharge is via two ports, one facing north and one facing south, with equal amounts of concentrate discharging through both ports. The resultant effects on salinity across the entire small grid system are displayed as monthly mean values in maps below, with time series presentations of daily mean surface and bottom salinity predictions in the offshore small grid as a whole. Additional analyses were performed to examine any differences in circulation resulting from the discharge.

6.2.3.1 Offshore – 25 MGD Product Water Scenario Salinity

The statistics for the daily mean predicted salinity values for the offshore 25 MGD product water scenario are summarized in Table 6.10. Changes in salinity (Δ salinity) are derived from the difference of the predicted salinity values for this scenario and those for the baseline. The 25 MGD product water scenario results in no change in the predicted mean salinity over the offshore grid system. Maps of predicted changes in salinity for all months for the surface and bottom layers are presented in Figures 6.178-6.201. Elevated predicted salinity values in comparison to baseline conditions can be detected in the shallow area near the discharge canal from November to April (the dry season), although the change in salinity is less than 0.5 ppt near the discharge. Greatest increases in salinity values are in March in comparison to the baseline condition, with the least change occurring in September. The mean of the daily values for the Anchorage over the entire year is no different from the same statistic for the offshore baseline scenario (see Table 6.8).

The salinity change maps in Figures 6.178-6.201 suggest that the effects on salinity of the 25 MGD product water scenario are confined to the bottom of the water column in a north-south transect centered on the discharge port, as from the 10 MGD product water scenario. There is very little variation in the increased salinity signal over the year, as the seasonal effects of freshwater inflow and power station cooling water usage do not affect this discharge.

Table 6.10. Statistics for the daily mean predicted salinity for the offshore 25 MGD product water scenario.

Layer	N	Mean	Standard Deviation	Minimum	Maximum
Surface	365	35.1 ppt	0.3 ppt	34.4 ppt	35.7 ppt
Bottom	365	35.3 ppt	0.3 ppt	34.8 ppt	35.8 ppt

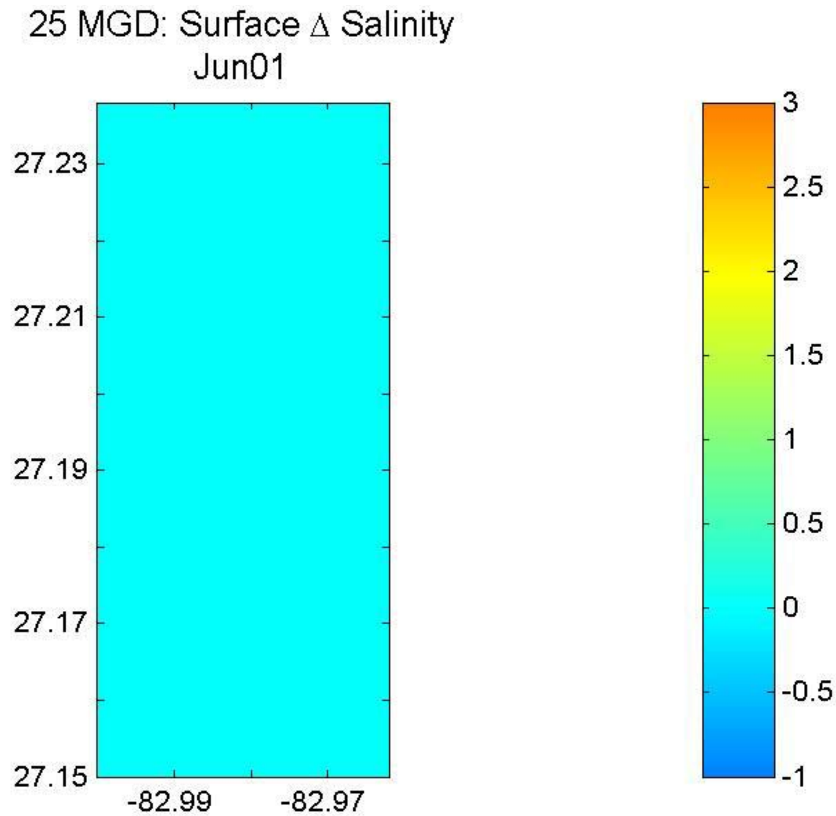

Figure 6.178. Predicted monthly mean surface salinity change, 25 MGD product water scenario, June 2001.

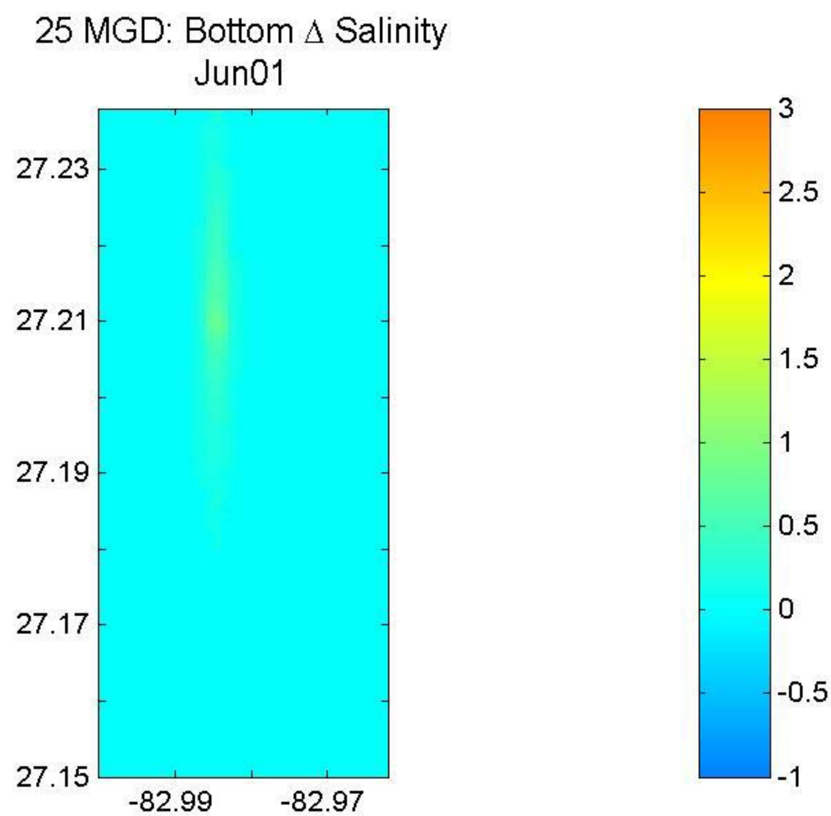

Figure 6.179. Predicted monthly mean bottom salinity change, 25 MGD product water scenario, June 2001.

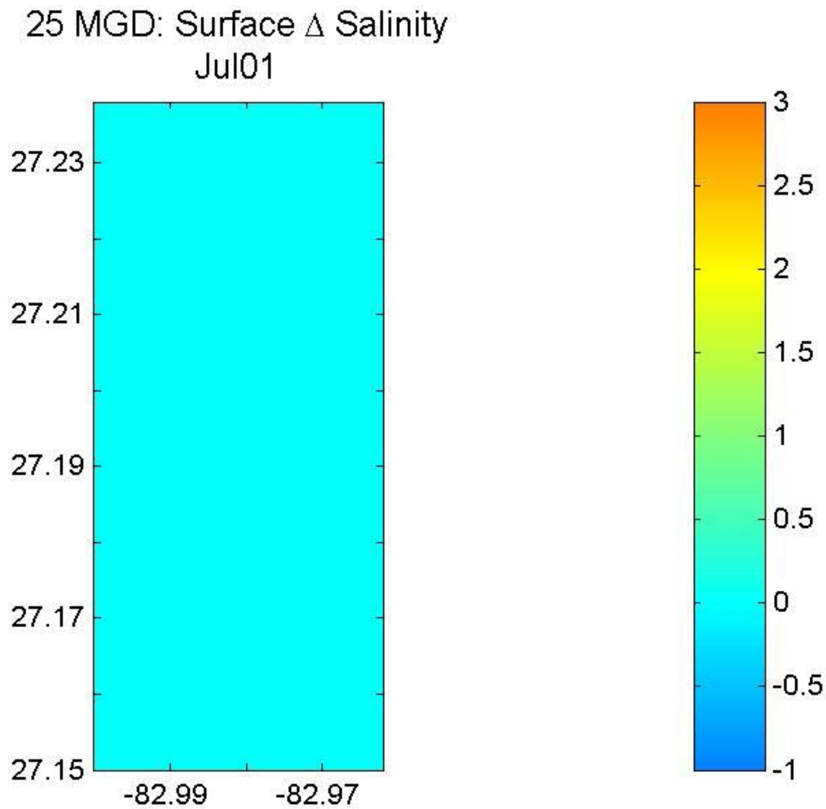

Figure 6.180. Predicted monthly mean surface salinity change, 25 MGD product water scenario, July 2001.

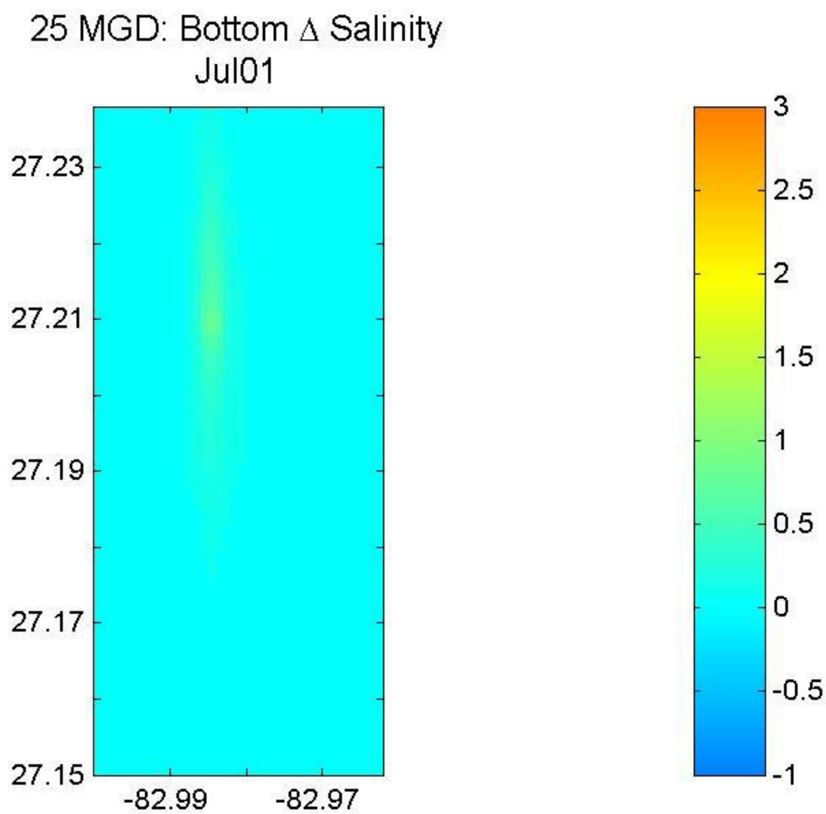

Figure 6.181. Predicted monthly mean bottom salinity change, 25 MGD product water scenario, July 2001.

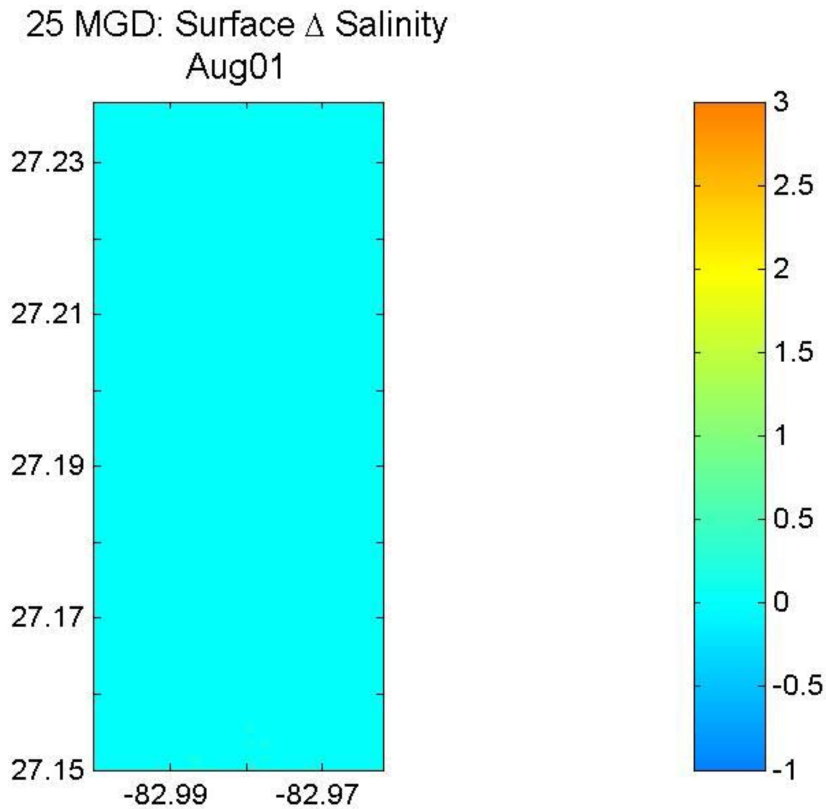

Figure 6.182. Predicted monthly mean surface salinity change, 25 MGD product water scenario, August 2001.

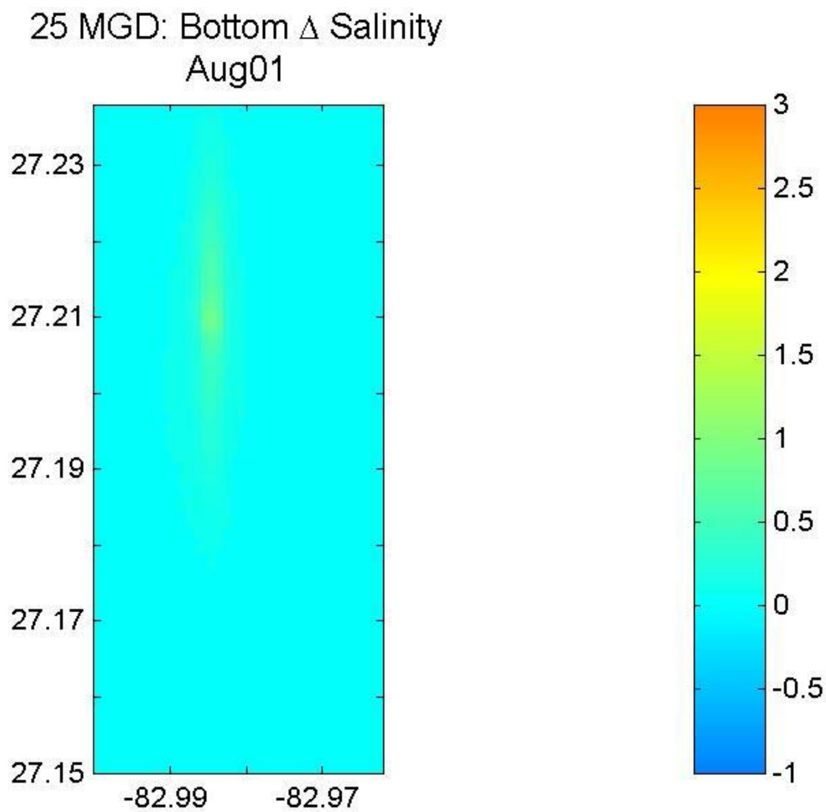

Figure 6.183. Predicted monthly mean bottom salinity change, 25 MGD product water scenario, August 2001.

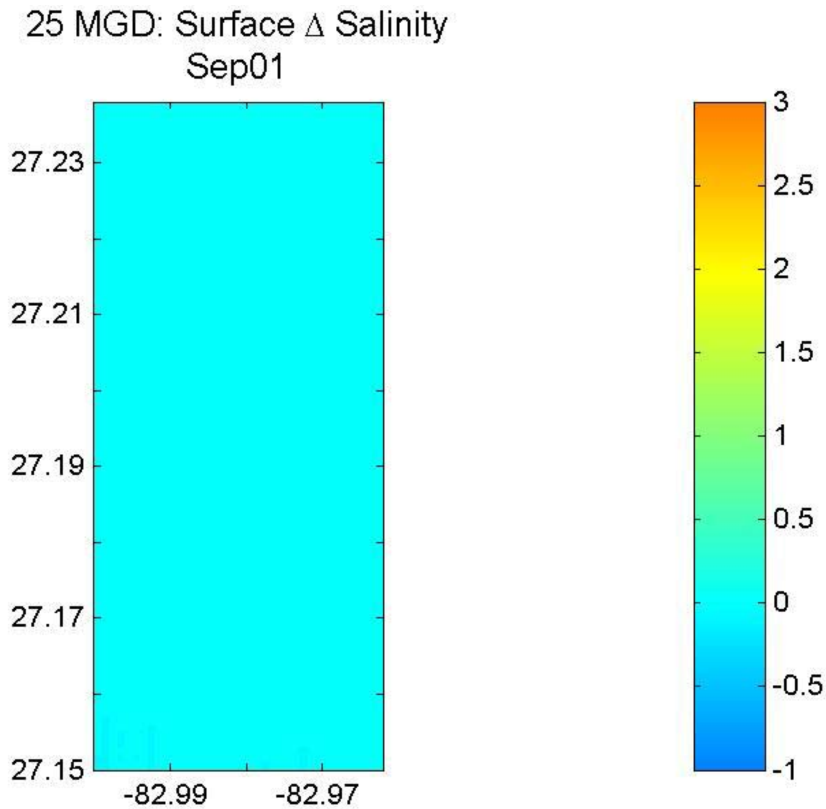

Figure 6.184. Predicted monthly mean surface salinity change, 25 MGD product water scenario, September 2001.

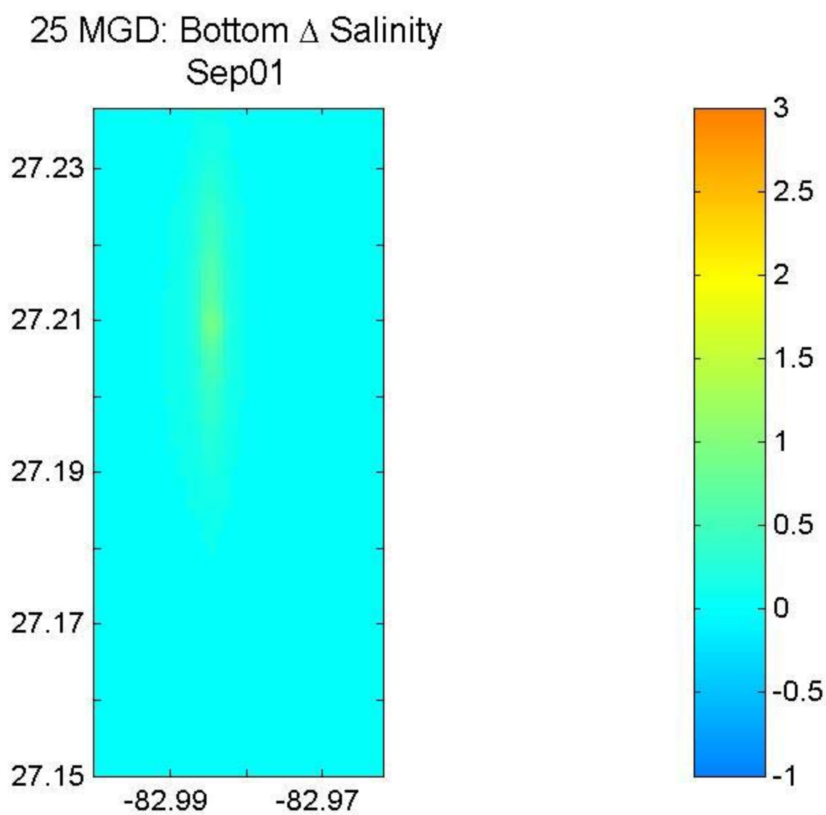

Figure 6.185. Predicted monthly mean bottom salinity change, 25 MGD product water scenario, September 2001.

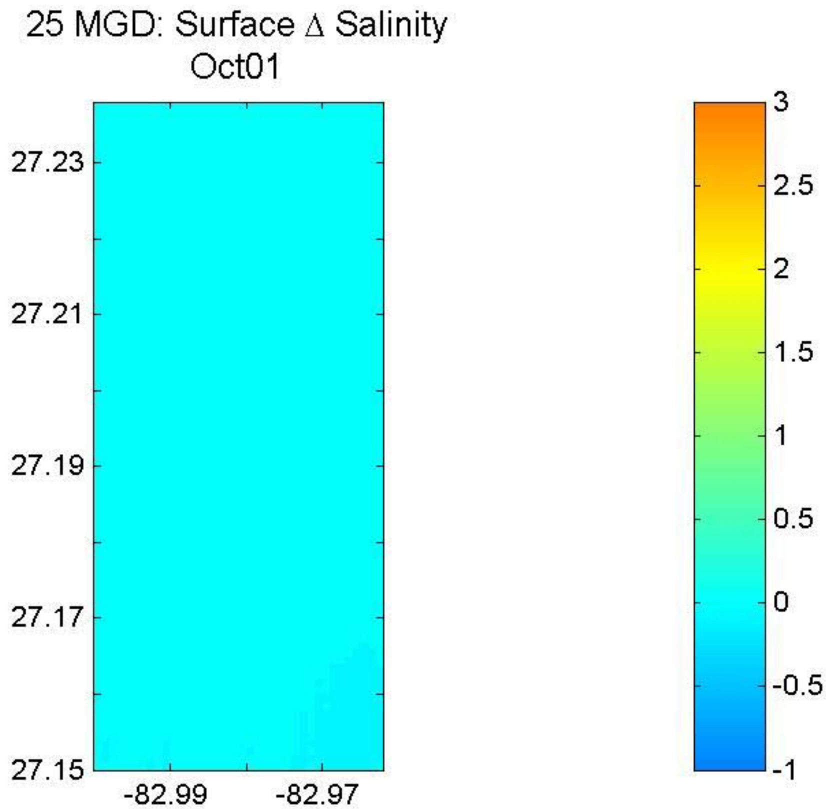

Figure 6.186. Predicted monthly mean surface salinity change, 25 MGD product water scenario, October 2001.

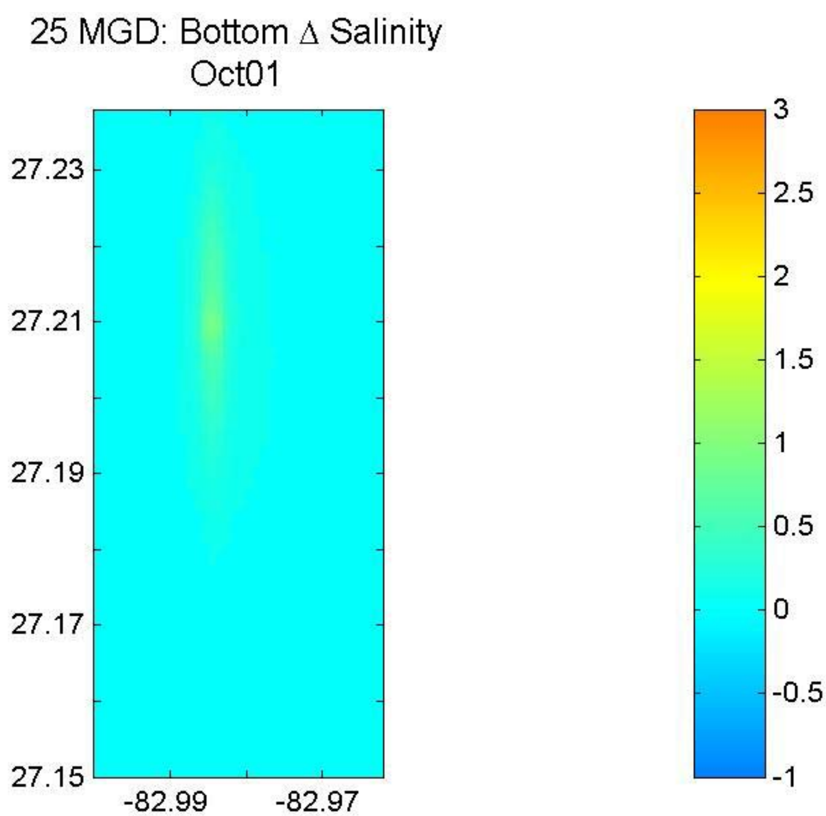

Figure 6.187. Predicted monthly mean bottom salinity change, 25 MGD product water scenario, October 2001.

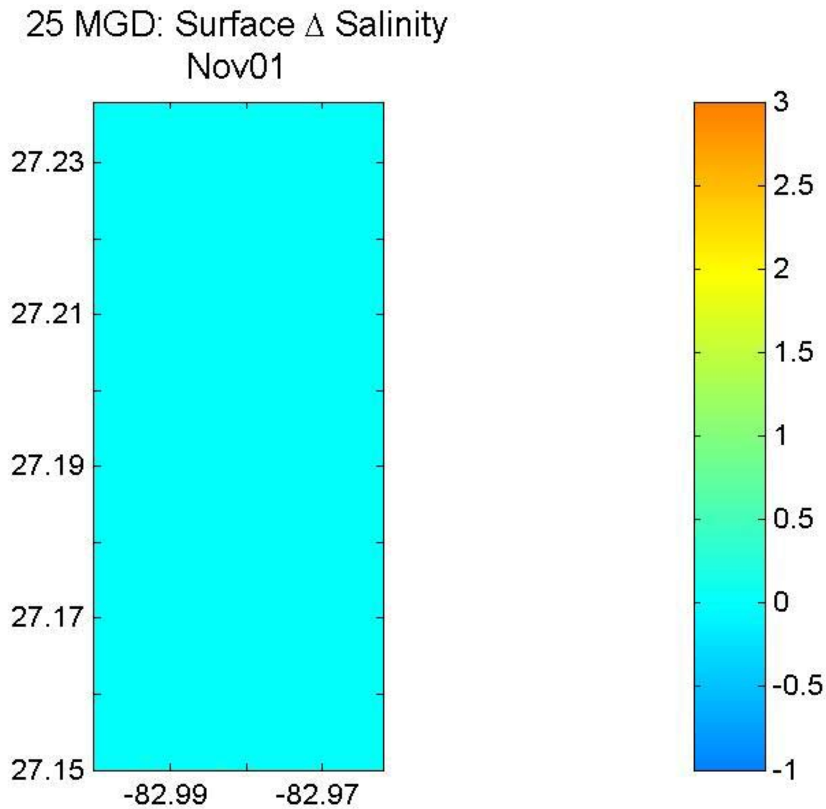

Figure 6.188. Predicted monthly mean surface salinity change, 25 MGD product water scenario, November 2001.

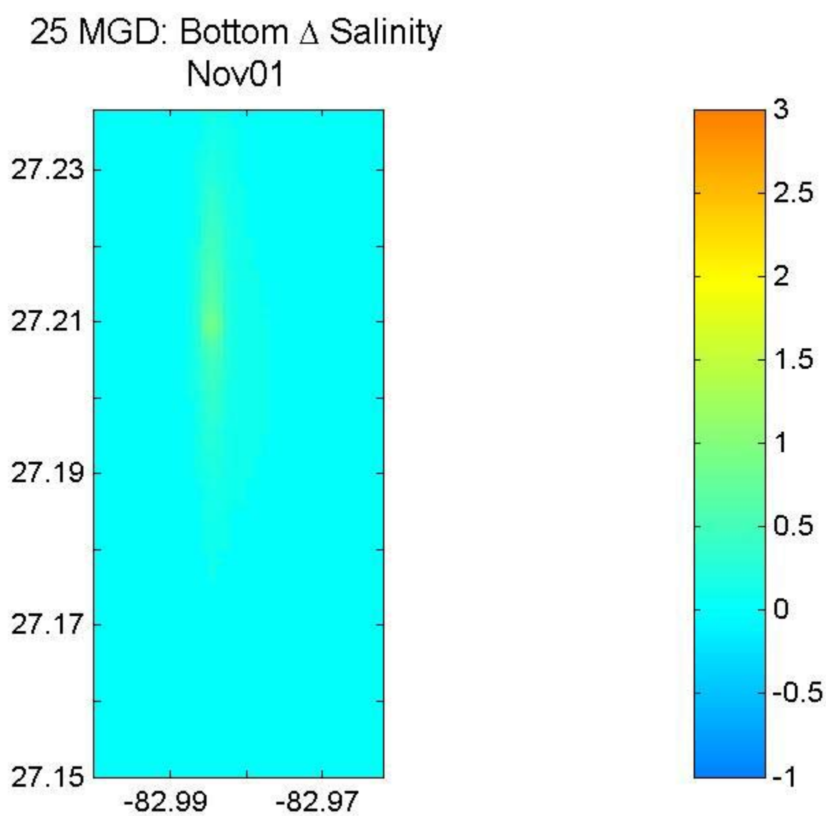

Figure 6.189. Predicted monthly mean bottom salinity change, 25 MGD product water scenario, November 2001.

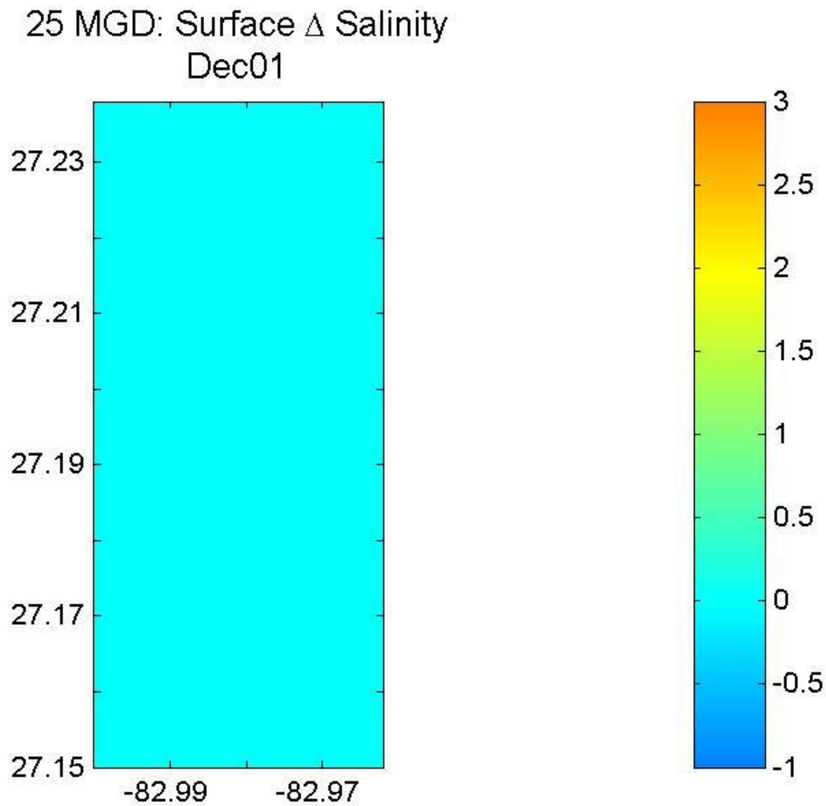

Figure 6.190. Predicted monthly mean surface salinity change, 25 MGD product water scenario, December 2001.

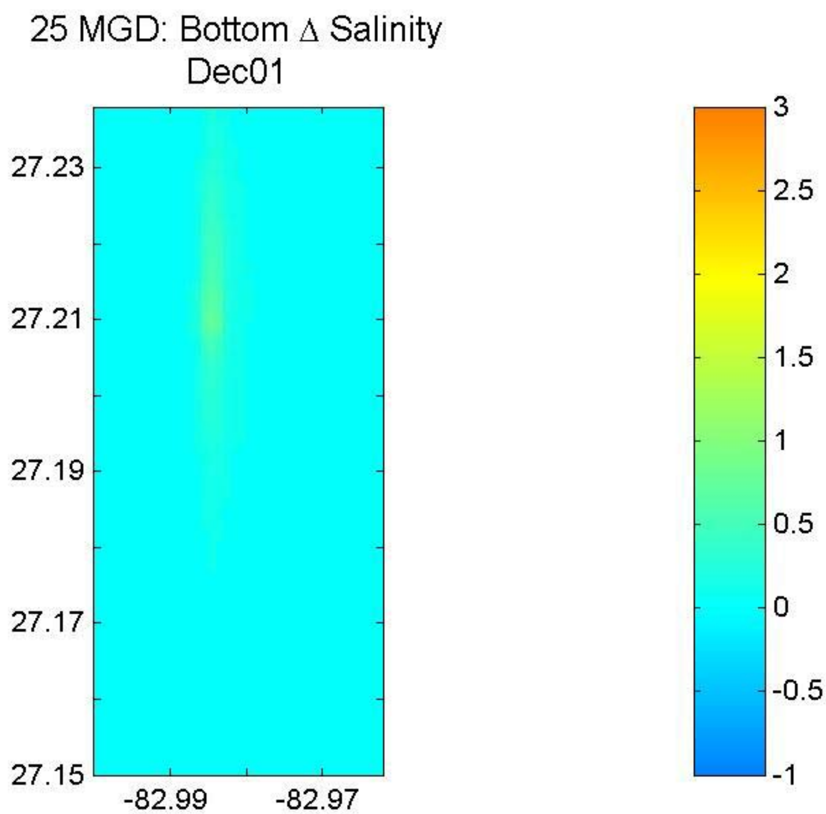

Figure 6.191. Predicted monthly mean bottom salinity change, 25 MGD product water scenario, December 2001.

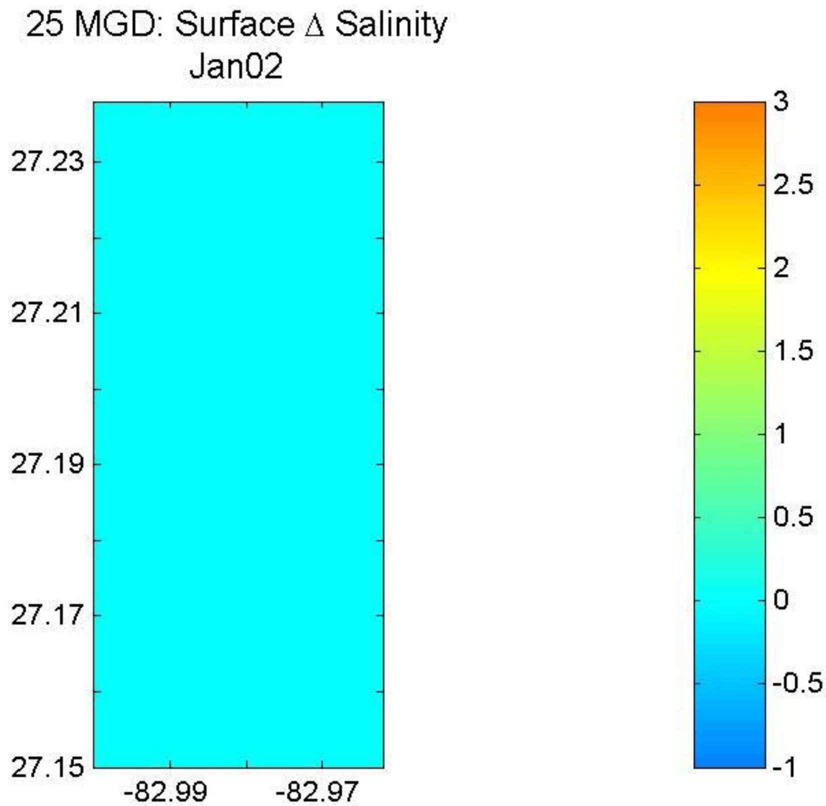

Figure 6.192. Predicted monthly mean surface salinity change, 25 MGD product water scenario, January 2002.

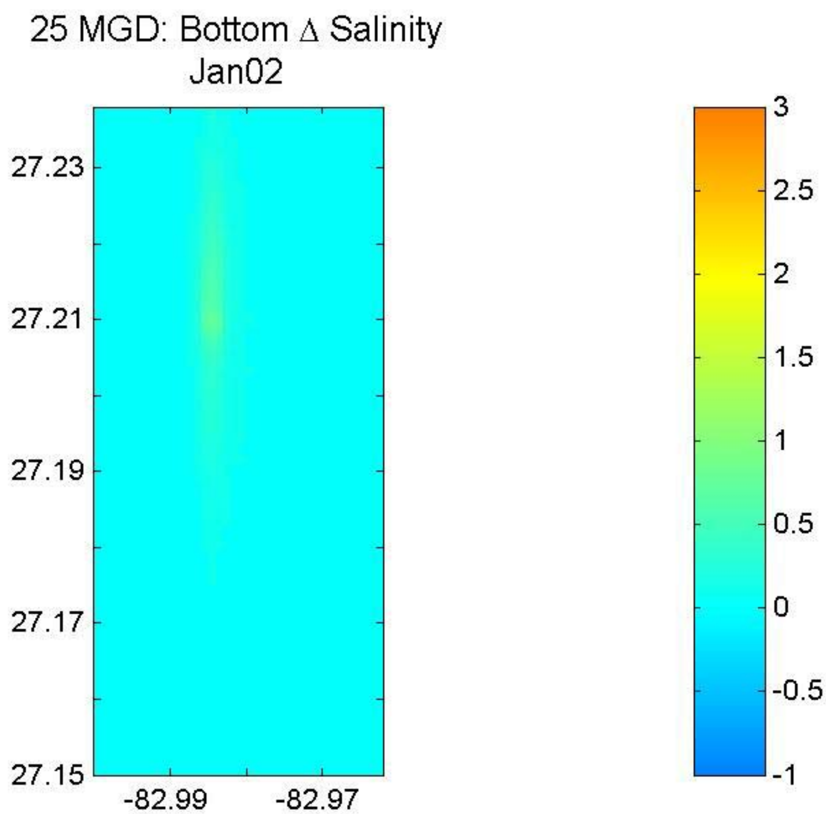

Figure 6.193. Predicted monthly mean bottom salinity change, 25 MGD product water scenario, January 2002.

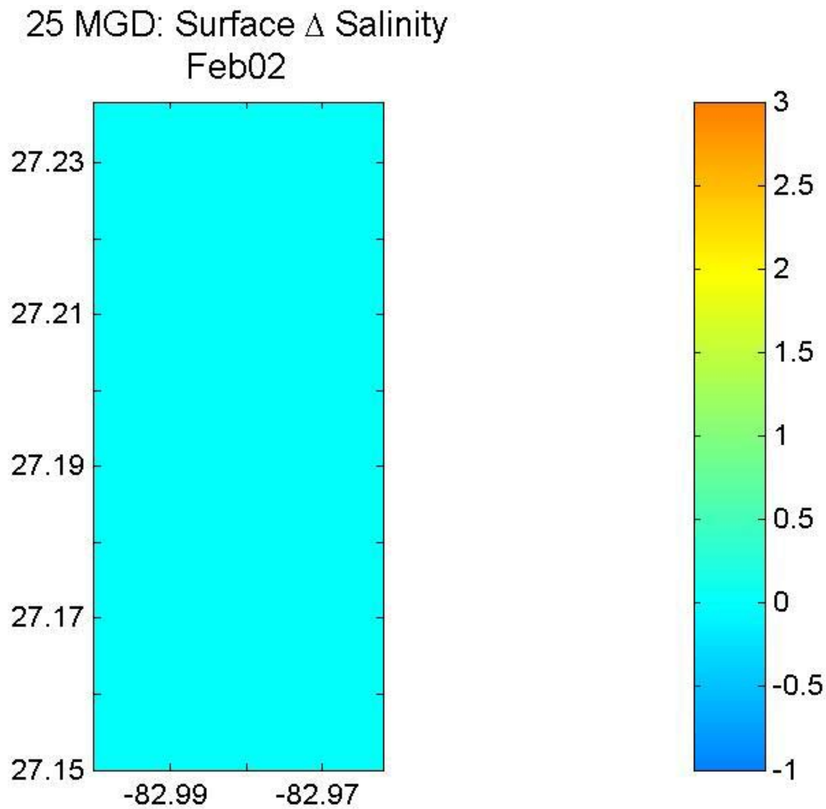

Figure 6.194. Predicted monthly mean surface salinity change, 25 MGD product water scenario, February 2002.

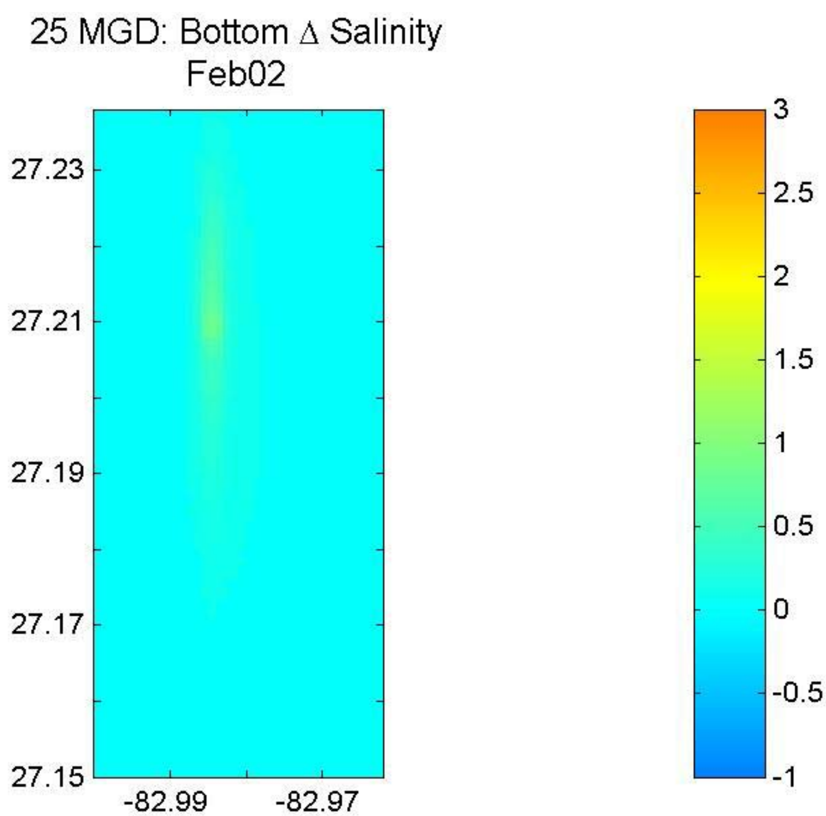

Figure 6.195. Predicted monthly mean bottom salinity change, 25 MGD product water scenario, February 2002.

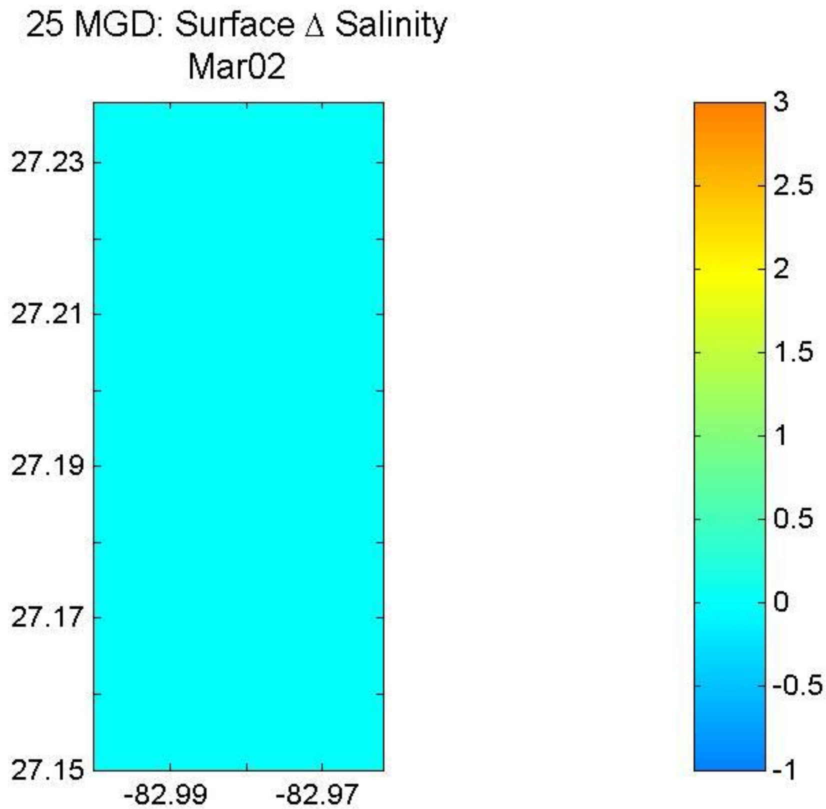

Figure 6.196. Predicted monthly mean surface salinity change, 25 MGD product water scenario, March 2002.

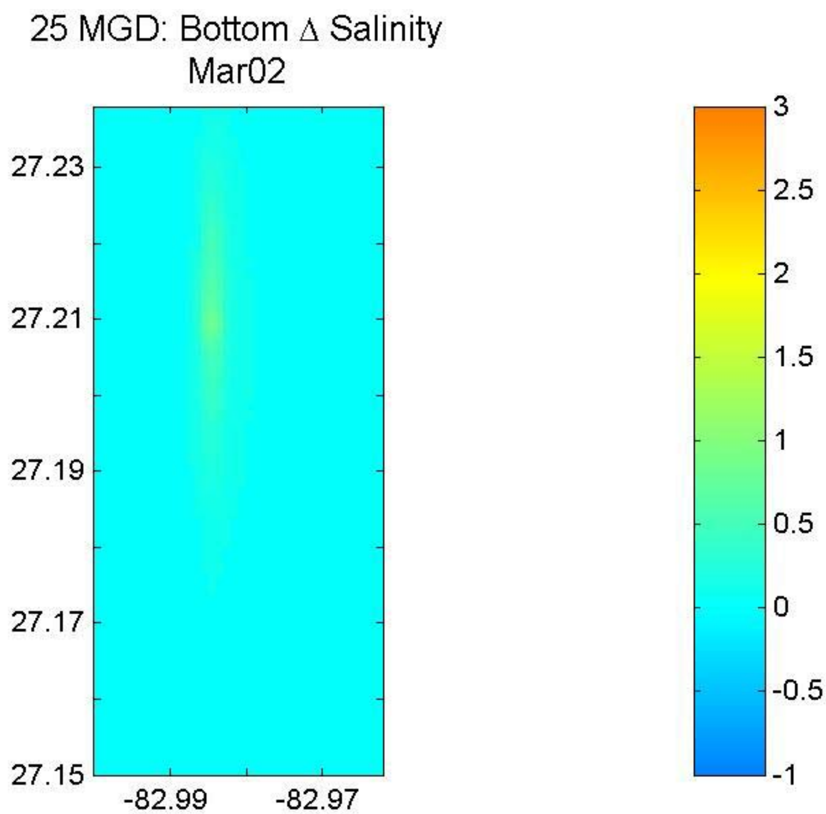

Figure 6.197. Predicted monthly mean bottom salinity change, 25 MGD product water scenario, March 2002.

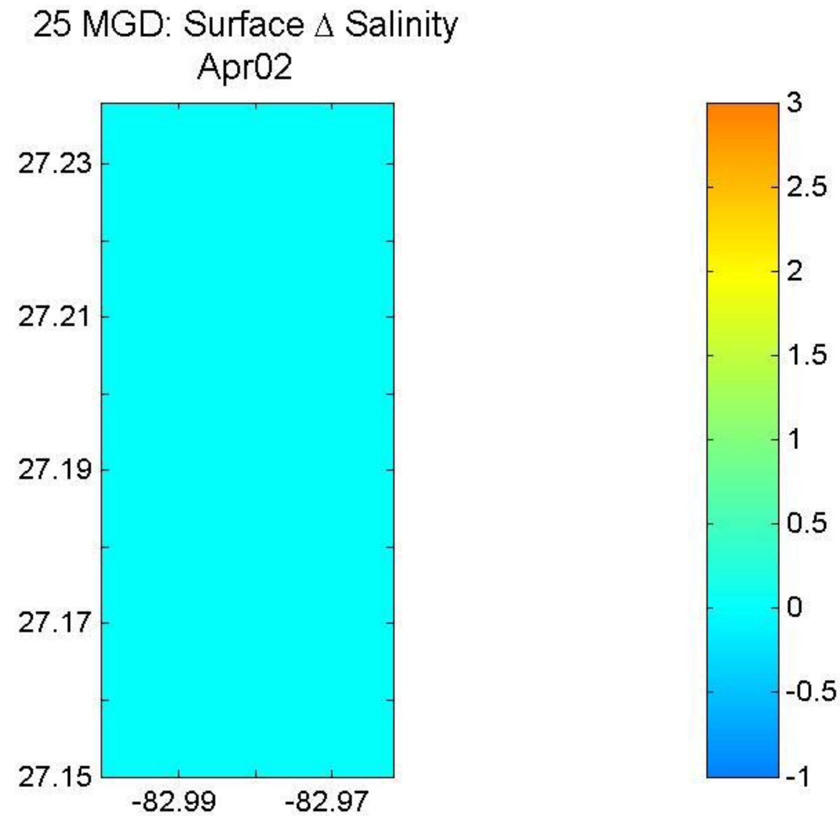

Figure 6.198. Predicted monthly mean surface salinity change, 25 MGD product water scenario, April 2002.

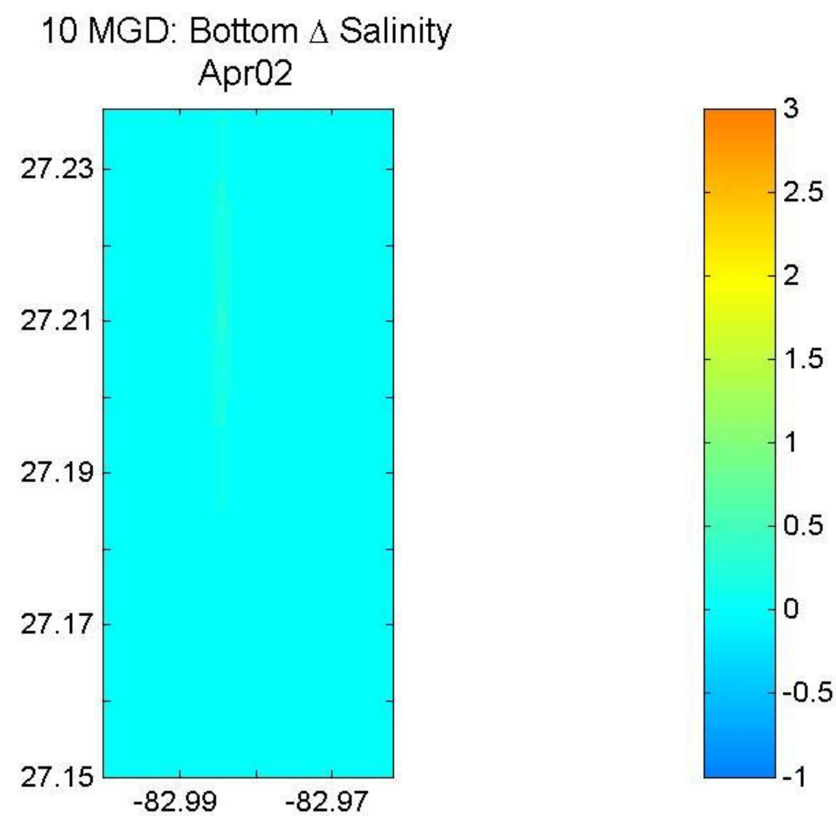

Figure 6.199. Predicted monthly mean bottom salinity change, 25 MGD product water scenario, April 2002.

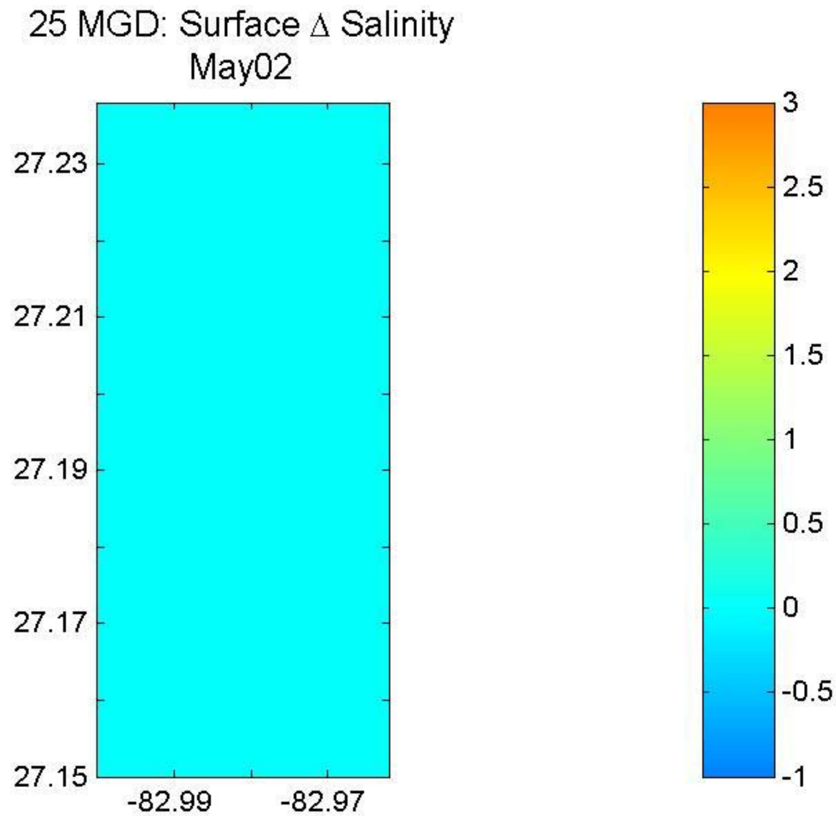

Figure 6.200. Predicted monthly mean surface salinity change, 25 MGD product water scenario, May 2002.

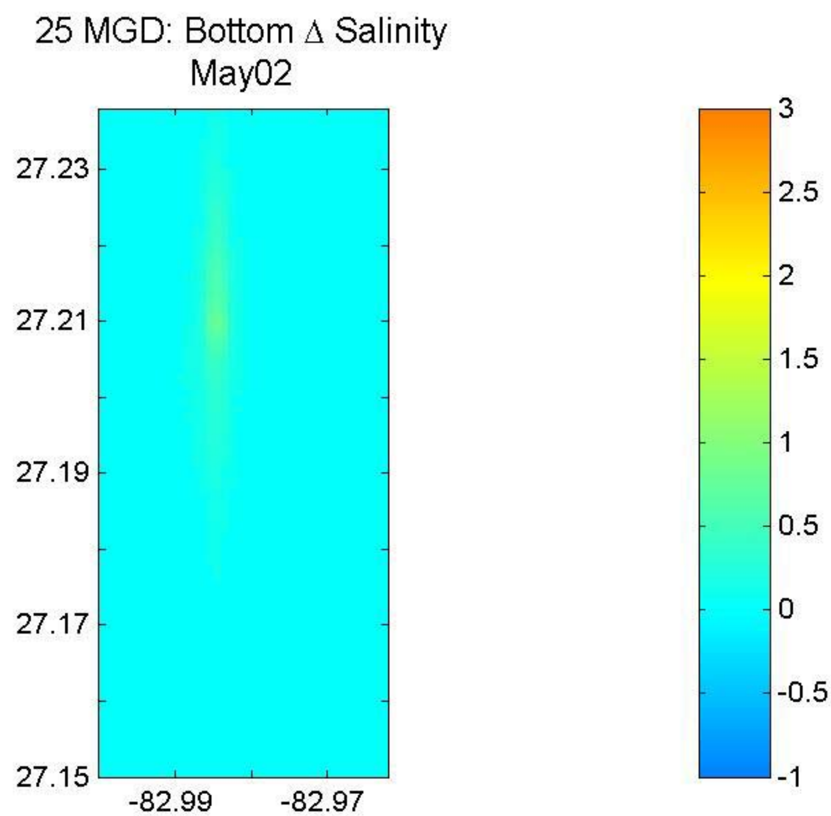

Figure 6.201. Predicted monthly mean bottom salinity change, 25 MGD product water scenario, May 2002.

A time series plot of the daily mean predicted salinity for the 25 MGD product water scenario is presented in Figure 6.202. As for the baseline and 10 MGD product water scenarios, the predicted salinity in the surface layer is slightly less than that in the bottom layer throughout the year. The time series plots of the daily mean salinity values over the offshore grid system are very similar for all three scenarios examined.

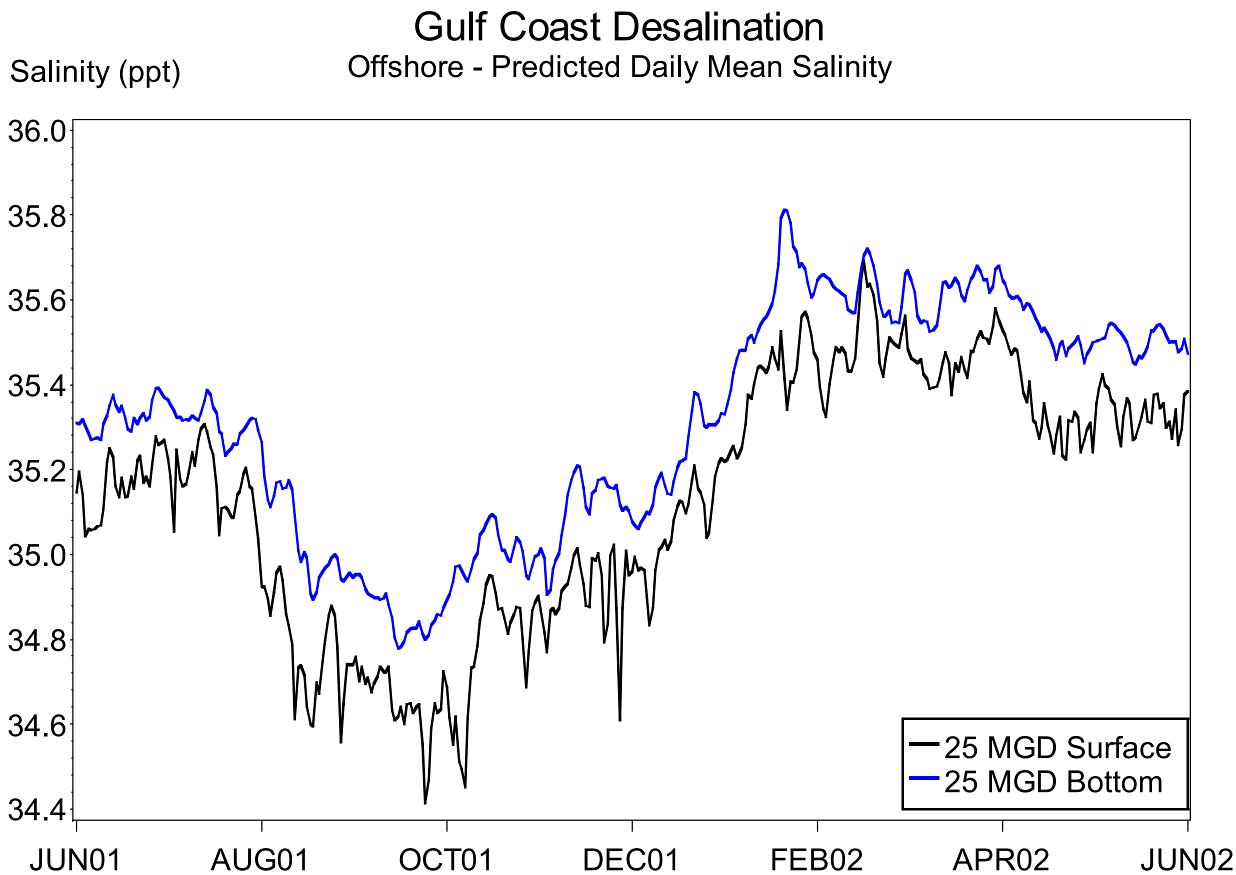

Figure 6.202. Time series of daily mean salinity for surface and bottom layers, 25 MGD, June 2001 to May 2002

6.2.3.2 Nearshore – 25 MGD Product Water Scenario Circulation

Monthly mean predicted circulation maps are presented in Figures 6.203-6.214. As for the baseline scenario maps, the length of the longest vector, in the northwestern corner of the offshore small grid in December, represents a speed of 0.025 m/s. Again, the velocities have been averaged over an area of 10 cells by 10 cells. At this resolution, there are no differences in current speeds to the nearest one hundredth of a meter per second. To place these changes in perspective, current meter measurements are typically accurate to the order of 0.01 m/s. Changes in current speeds adjacent to the discharge of as much as 15% were predicted in January 2002. Changes in integrated water column current speed in the cell where the discharge occurs averaged 0.001 m/s over the year, or a 5.6% change.

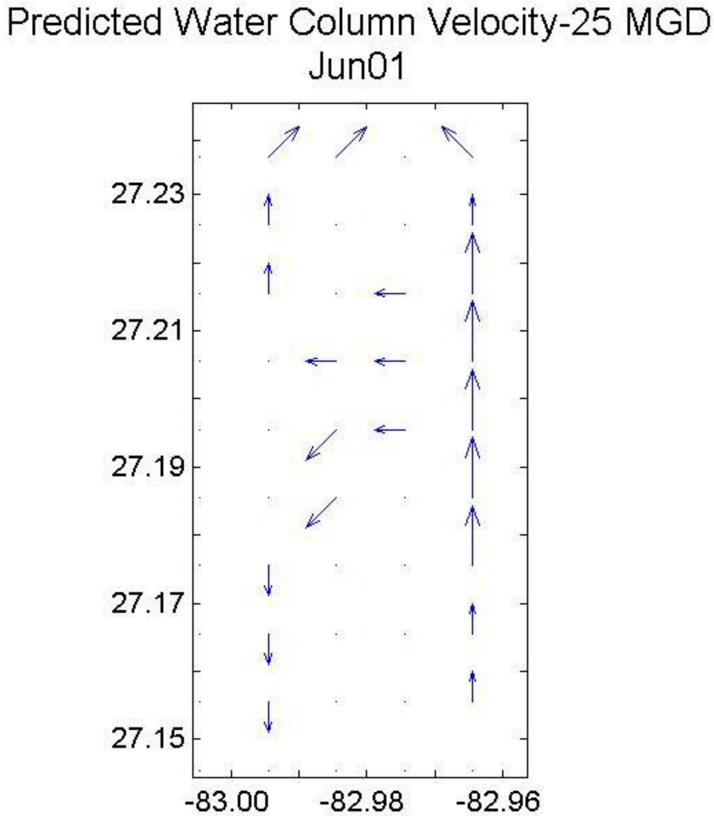

Figure 6.203. Water column monthly mean circulation, 25 MGD product water scenario, June 2001.

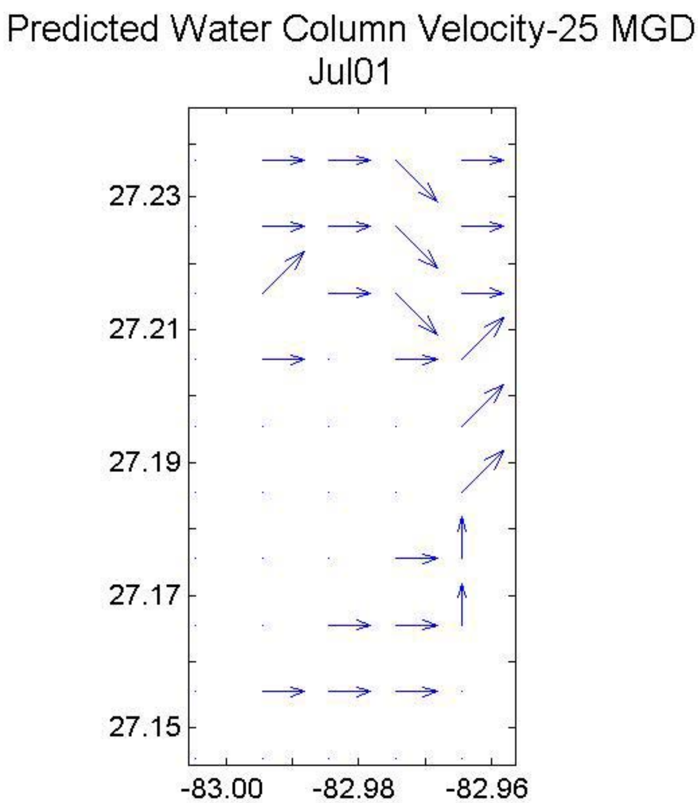

Figure 6.204. Water column monthly mean circulation, 25 MGD product water scenario, July 2001.

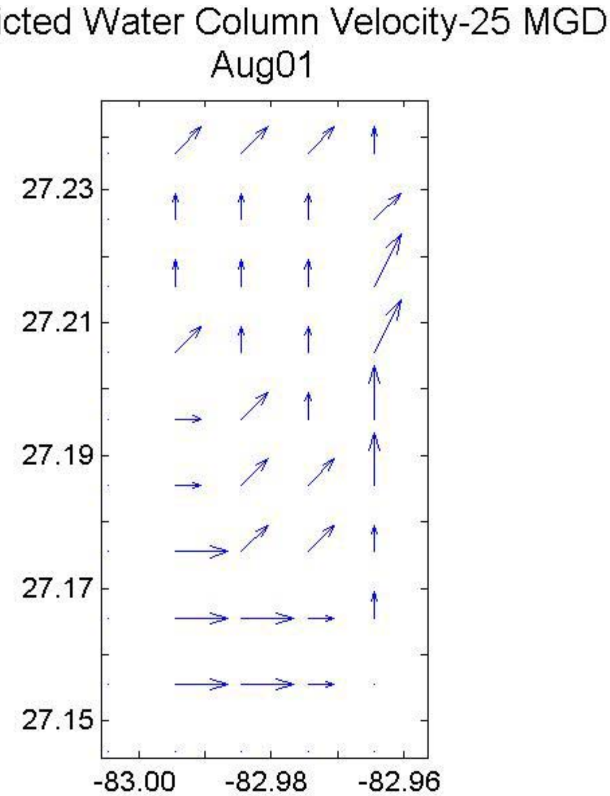

Figure 6.205. Water column monthly mean circulation, 25 MGD product water scenario, August 2001.

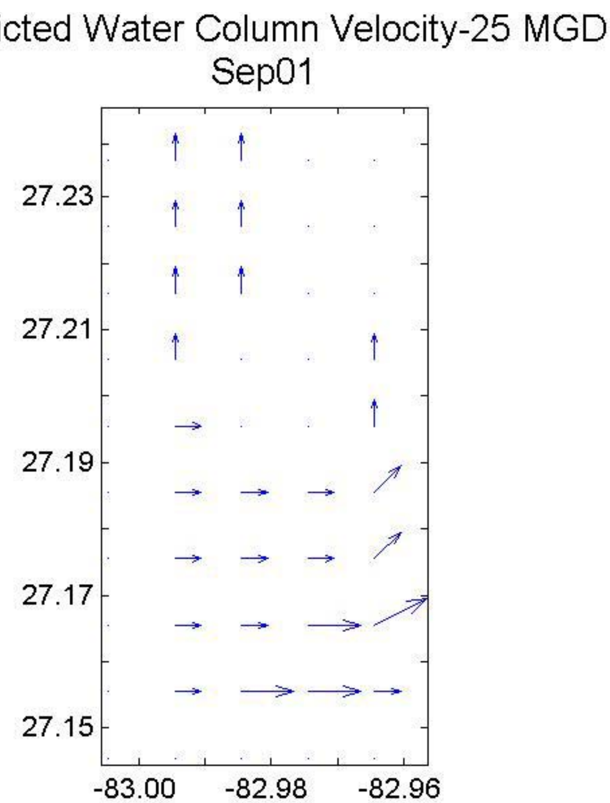

Figure 6.206. Water column monthly mean circulation, 25 MGD product water scenario, September 2001.

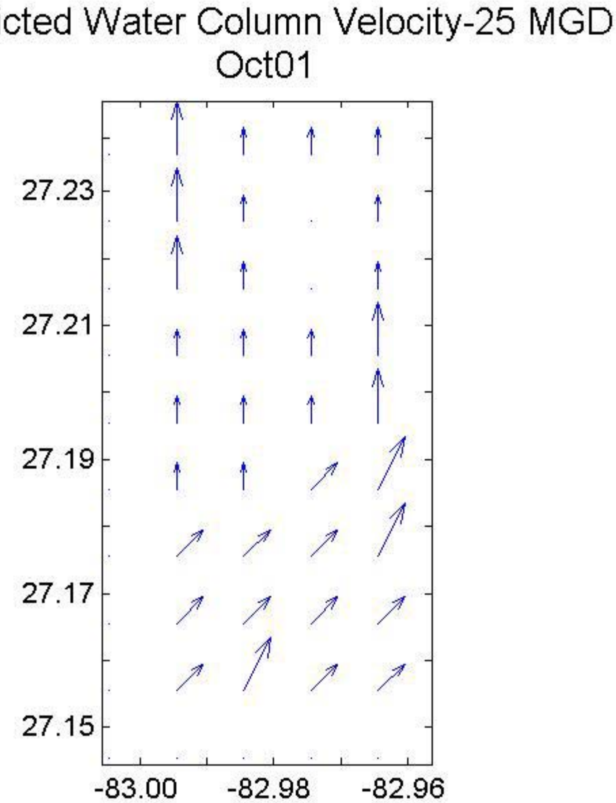

Figure 6.207. Water column monthly mean circulation, 25 MGD product water scenario, October 2001.

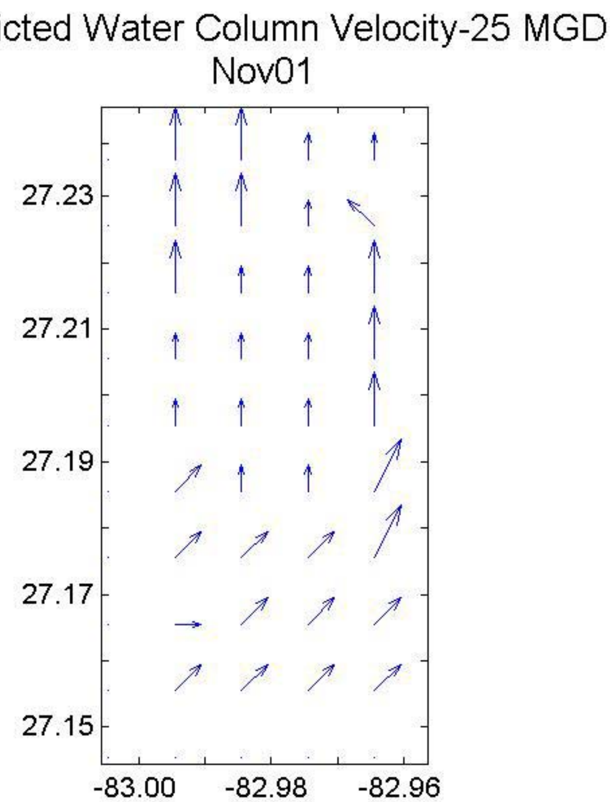

Figure 6.208. Water column monthly mean circulation, 25 MGD product water scenario, November 2001.

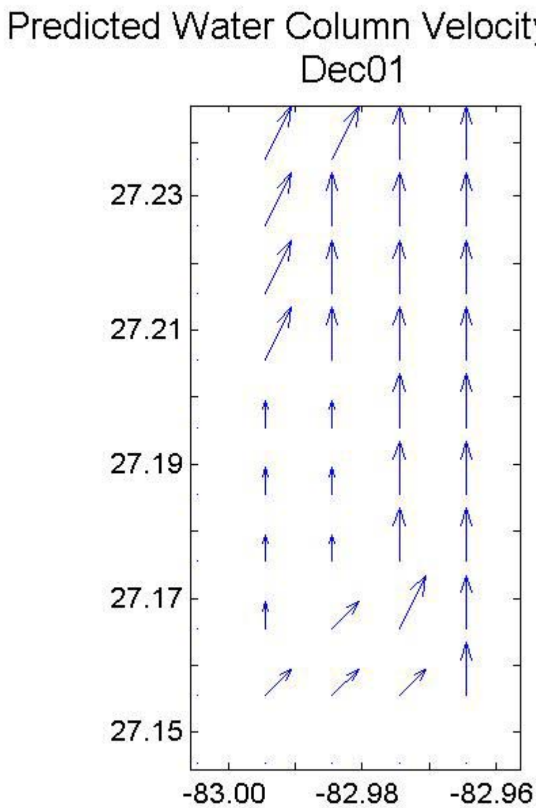

Figure 6.209. Water column monthly mean circulation, 25 MGD product water scenario, December 2001.

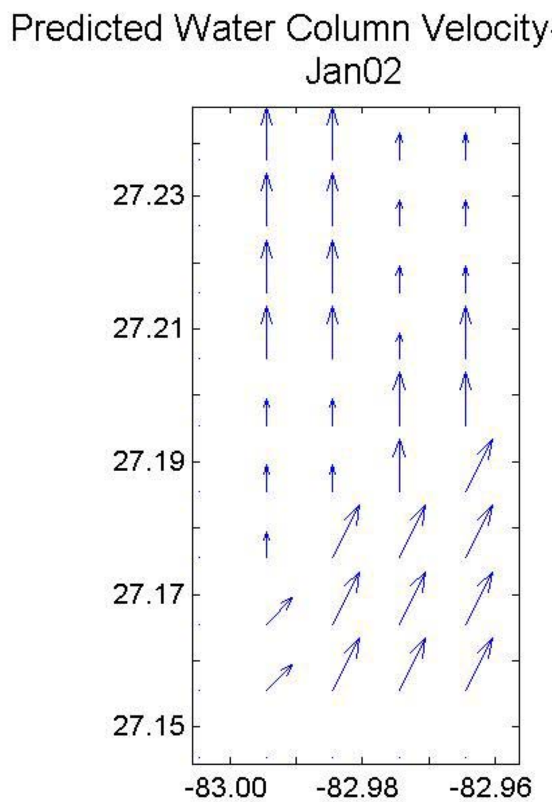

Figure 6.210. Water column monthly mean circulation, 25 MGD product water scenario, January 2002.

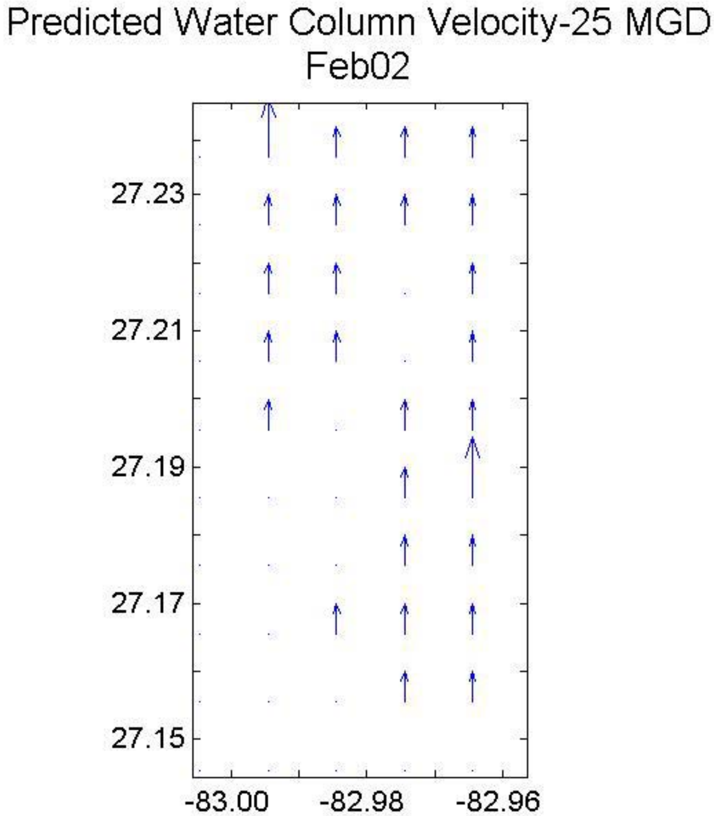

Figure 6.211. Water column monthly mean circulation, 25 MGD product water scenario, February 2002.

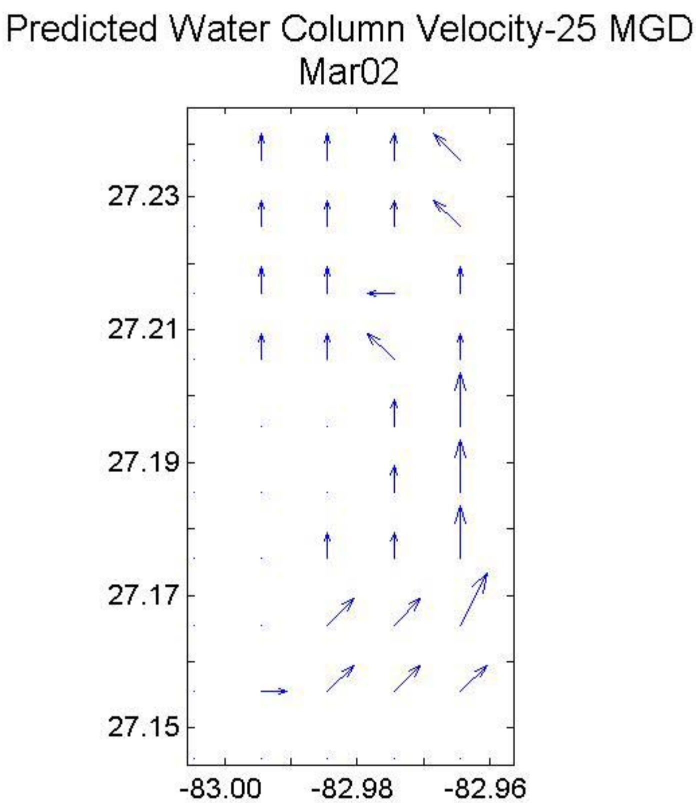

Figure 6.212. Water column monthly mean circulation, 25 MGD product water scenario, March 2002.

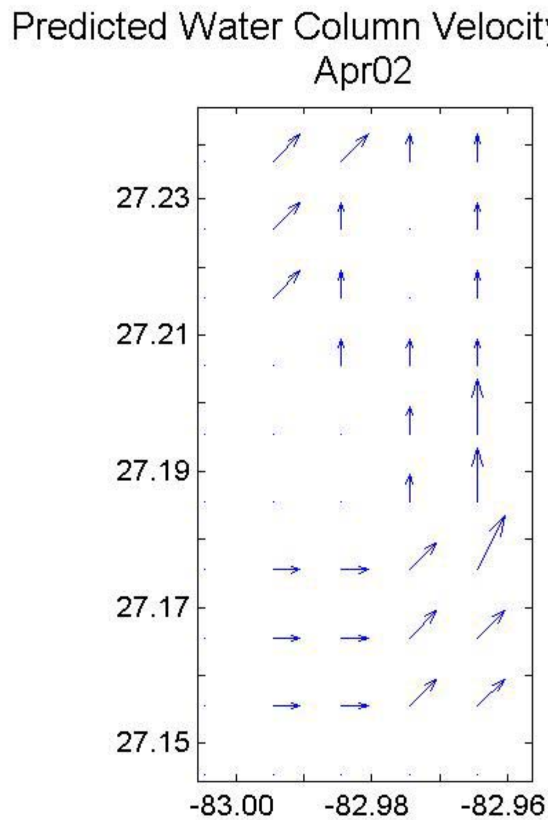

Figure 6.213. Water column monthly mean circulation, 25 MGD product water scenario, April 2002.

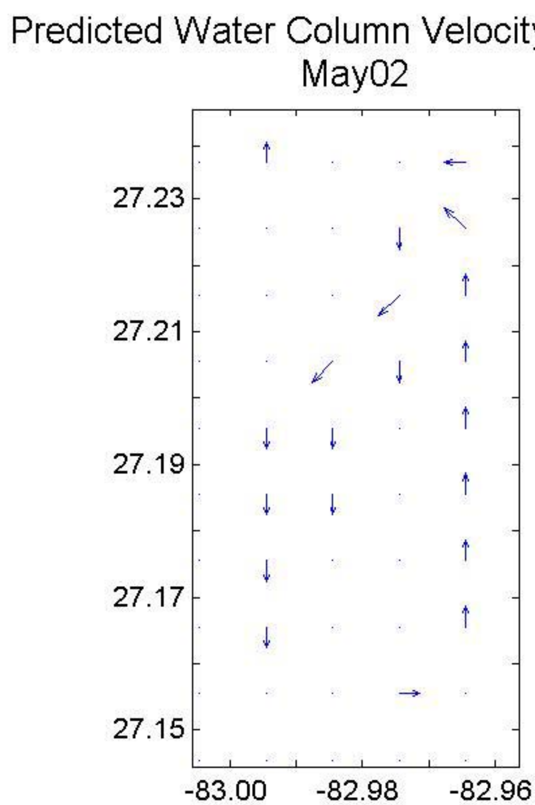

Figure 6.214. Water column monthly mean circulation, 25 MGD product water scenario, May 2002.

7.0 Summary

Two discharge locations were considered for discharge of desalination concentrate. A hydrodynamic model was developed to examine the relative effects of the discharge locations. The model was calibrated using recently collected data. For each of the locations considered, various desalination product water scenarios were examined. The results of the suite of model scenarios described above suggest that the effects of desalination on the circulation and salinity patterns of the Anclote Anchorage will be small in magnitude and limited to the nearshore shallow area adjacent to the discharge. Model results for the offshore area suggest minimal changes in salinity near the bottom in the area adjacent to the discharge. Results for each discharge location are summarized below.

7.1 Nearshore

The maximum daily mean predicted changes in salinity for an individual cell within the model domain (the Anchorage during the period June 2001-May 2002) for each product water scenario are shown in Tables 7.1 and 7.2 for surface and bottom, respectively. The changes in salinity are based on daily averages for each grid cell of the model. Almost all the maximum changes occur next to the shore, in very shallow areas (less than one meter). The only exception is for the surface in the 10 MGD scenario, with the maximum change in a cell directly north of the discharge canal mouth. This area is still very shallow, however. The maximum predicted changes in daily mean salinity are expected to occur during the winter/spring period, when freshwater flows are lowest and cooling plant discharges are lowest. As expected, the maximum change in salinity increases with increasing product water quantity, as the concentrate volume increases. The maximum changes at the surface and bottom are almost the same. For the 35 MGD product water scenario, daily mean maximum changes in salinity are predicted to be approximately 4.7 ppt in one 100m x 100m cell of the bottom layer.

Table 7.1. Surface maximum Δ salinity for nearshore scenarios.

Product Water Scenario	Δ Salinity	Location	Date
10 MGD	1.8 ppt	North of canal mouth ~0.7 km	01/20/2002
15 MGD	2.3 ppt	SW of canal mouth ~0.7 km	03/11/2002
18 MGD	2.6 ppt	SW of canal mouth ~0.7 km	03/11/2002
21 MGD	3.0 ppt	SW of canal mouth ~0.7 km	03/24/2002
25 MGD	3.4 ppt	SW of canal mouth ~0.7 km	03/11/2002
35 MGD	4.4 ppt	SW of canal mouth ~0.7 km	03/11/2002

Table 7.2. Bottom maximum Δ salinity for nearshore scenarios.

Product Water Scenario	Δ Salinity	Location	Date
10 MGD	1.7 ppt	SW of canal mouth ~0.4 km	02/21/2002
15 MGD	2.3 ppt	SW of canal mouth ~0.4 km	02/21/2002
18 MGD	2.6 ppt	SW of canal mouth ~0.4 km	02/21/2002
21 MGD	3.2 ppt	SW of canal mouth ~0.7 km	02/21/2002
25 MGD	3.6 ppt	SW of canal mouth ~0.7 km	02/21/2002
35 MGD	4.7 ppt	SW of canal mouth ~0.7 km	03/24/2002

Tables 7.3 and 7.4 provide the mean annual predicted salinity values for the surface and bottom over three areas: the Anclote Anchorage as a whole, the shallow area, and near the discharge. The extents of the shallow area and near discharge area are provided in Figure 6.64 above. The near discharge area is most affected by the change in salinity, with mean increases of 1.4 ppt and 1.3 ppt for the 35 MGD scenario in the surface and bottom, respectively. The shallow area increase in salinity is predicted to be approximately 0.4-0.5 ppt, and there is almost no change in salinity throughout the Anchorage as a whole. For a 25 MGD model developed by Vincent et al. (2000) for the Tampa Bay Desalination plant, 20-day mean salinities were calculated for the model cell that receives concentrate discharge. Mean change in salinity between the baseline and 25 MGD scenario was 1.3 ppt higher with a range of +0.6 to +1.6 ppt.

Table 7.3. Mean annual surface salinity for nearshore scenarios.

Product Water Scenario	Anchorage	Shallow	Near Discharge
Baseline	34.9 ppt	34.2 ppt	32.8 ppt
10 MGD	34.9 ppt	34.3 ppt	33.2 ppt
15 MGD	35.0 ppt	34.4 ppt	33.4 ppt
18 MGD	35.0 ppt	34.4 ppt	33.5 ppt
21 MGD	35.0 ppt	34.4 ppt	33.6 ppt
25 MGD	35.0 ppt	34.4 ppt	33.8 ppt
35 MGD	35.0 ppt	34.6 ppt	34.2 ppt

Table 7.4. Mean annual bottom salinity for nearshore scenarios.

Product Water Scenario	Anchorage	Shallow	Near Discharge
Baseline	35.0 ppt	34.3 ppt	33.1 ppt
10 MGD	35.0 ppt	34.4 ppt	33.5 ppt
15 MGD	35.0 ppt	34.5 ppt	33.7 ppt
18 MGD	35.0 ppt	34.6 ppt	33.8 ppt
21 MGD	35.0 ppt	34.6 ppt	33.9 ppt
25 MGD	35.0 ppt	34.6 ppt	34.1 ppt
35 MGD	35.1 ppt	34.8 ppt	34.4 ppt

The cumulative distribution frequencies for predicted mean daily salinity for each of the three areas, the Anchorage, the shallow, and the near discharge areas, are shown in Figures 7.1 through 7.6. Each figure provides the frequency distribution of predicted daily mean salinity for the seven scenarios, with a figure for each area displaying the mean daily surface salinity frequency distribution, and one displaying the mean daily bottom salinity frequency distribution.

Figures 7.1 and 7.2 show that at lower predicted salinity values in the near discharge area, only very small changes in salinity are predicted to occur as a result of desalination operations. It is only at higher salinity values, most likely to occur during the dry season of low freshwater input and low cooling plant discharge, that differences in predicted salinity values are found among the scenarios. A similar pattern is seen for the shallow area, in Figures 7.3 and 7.4, with differences in predicted salinity values occurring only at relatively high levels of 32 ppt or more. For the Anchorage as a whole, the frequency distributions shown in Figures 7.5 and 7.6 indicate very little change in salinity, regardless of the season.

Time series of mean daily salinity predictions for the surface and bottom in each of the three areas are shown in Figures 7.7 through 7.12. The time series support the contention that only small differences are predicted during the wet season, when relatively high freshwater inflows and high cooling water discharges occur. Larger salinity changes occur during the period when freshwater inflows are low and cooling water discharges are low. Greatest changes are predicted in the area near the discharge, while changes over the entire Anchorage are predicted to be minimal.

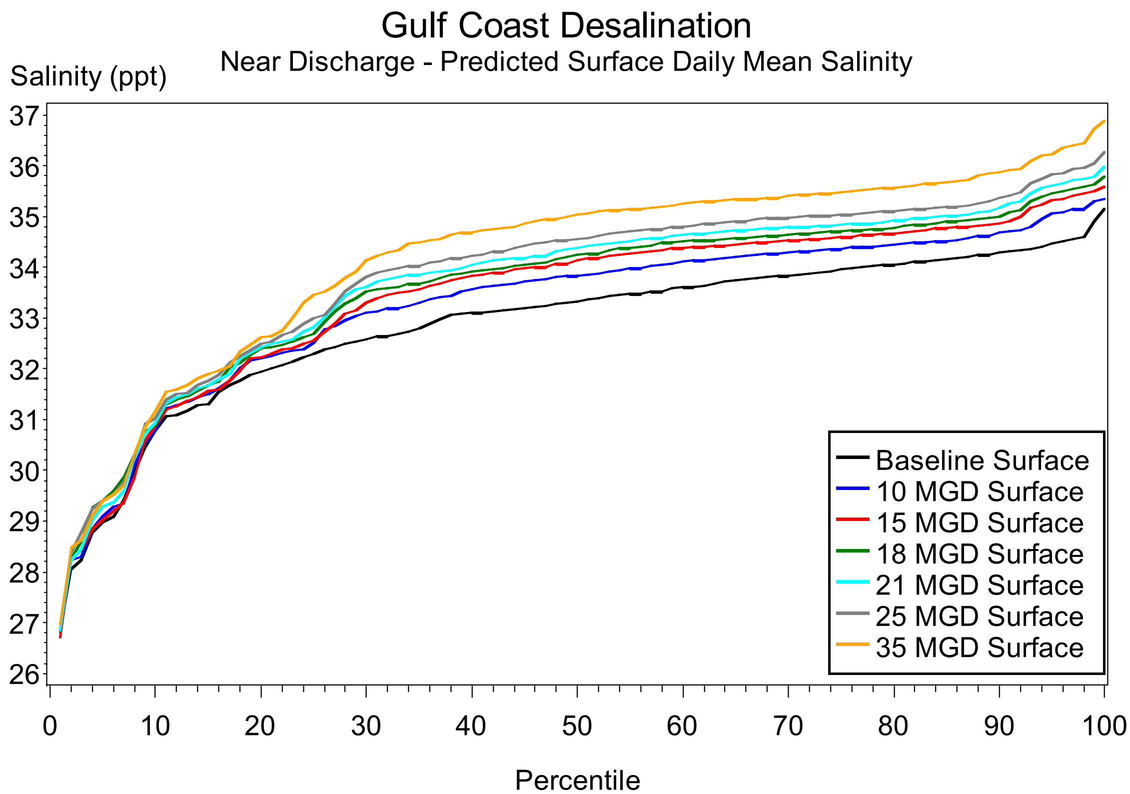

Figure 7.1. Cumulative distribution frequency of daily mean surface salinity near the discharge (as shown in Figure 6.64).

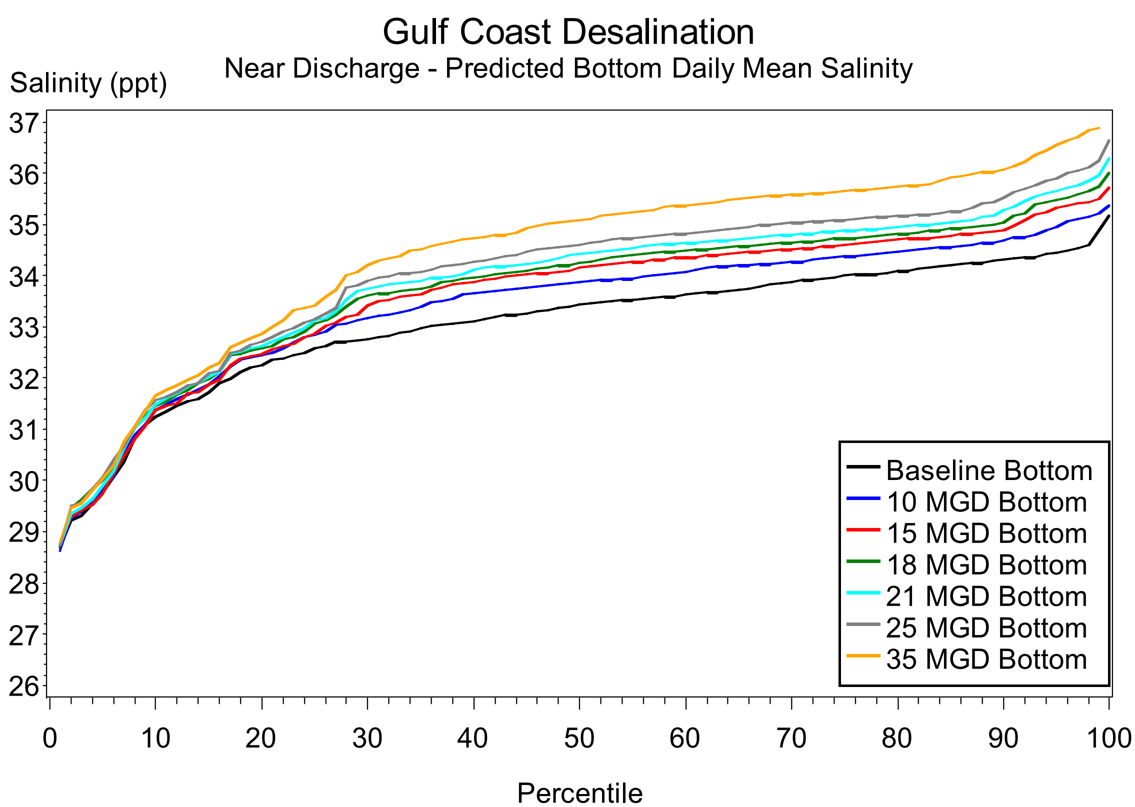

Figure 7.2. Cumulative distribution frequency of daily mean bottom salinity near the discharge (as shown in Figure 6.64).

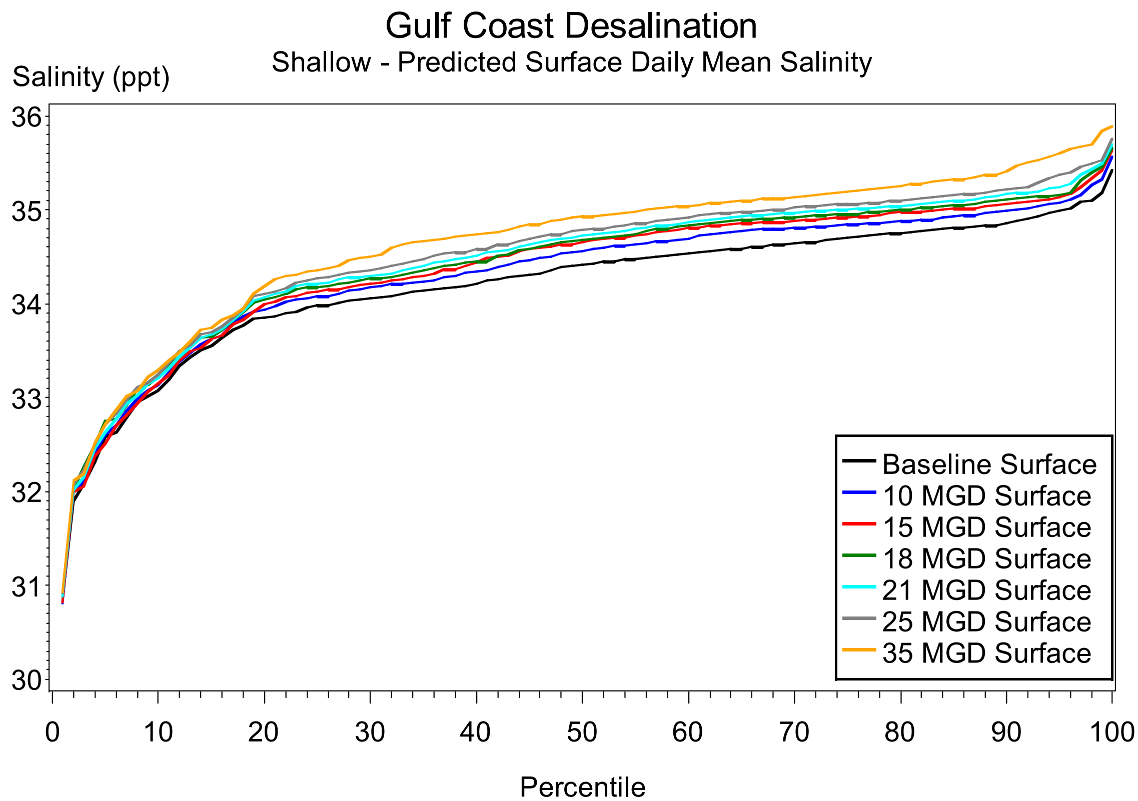

Figure 7.3. Cumulative distribution frequency of daily mean surface salinity in the shallow area (as shown in Figure 6.64).

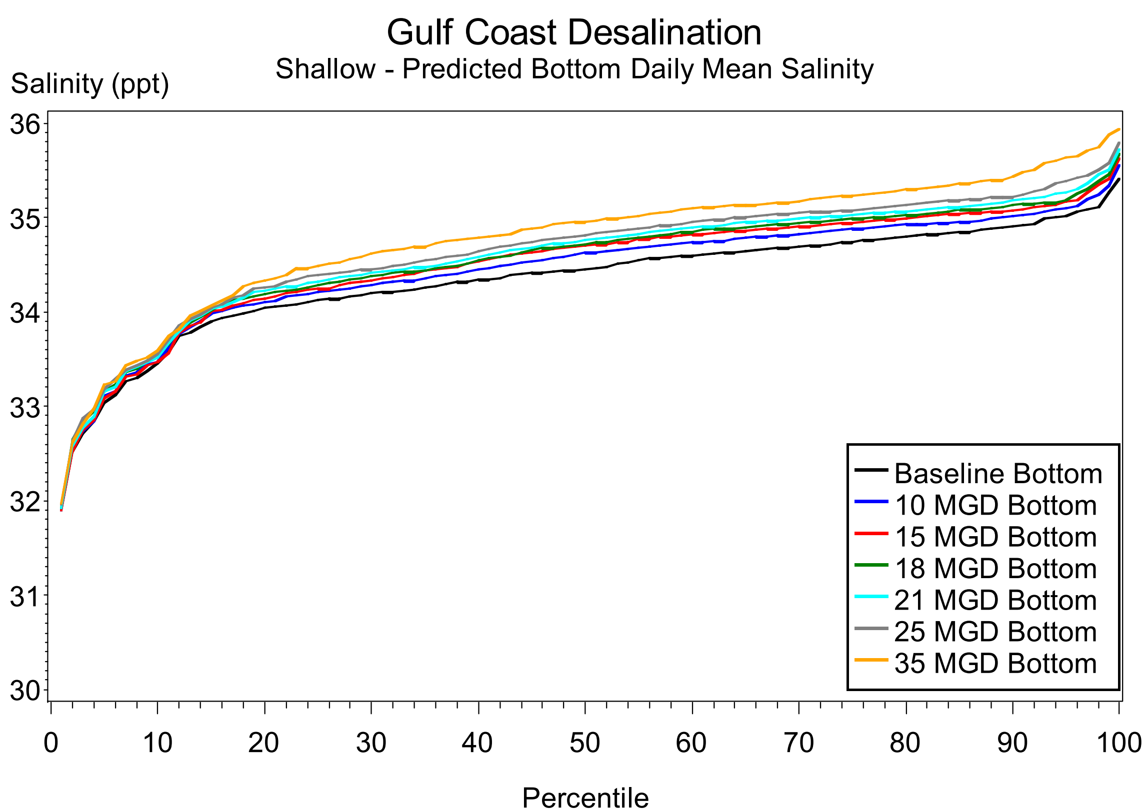

Figure 7.4. Cumulative distribution frequency of daily mean bottom salinity in the shallow area (as shown in Figure 6.64).

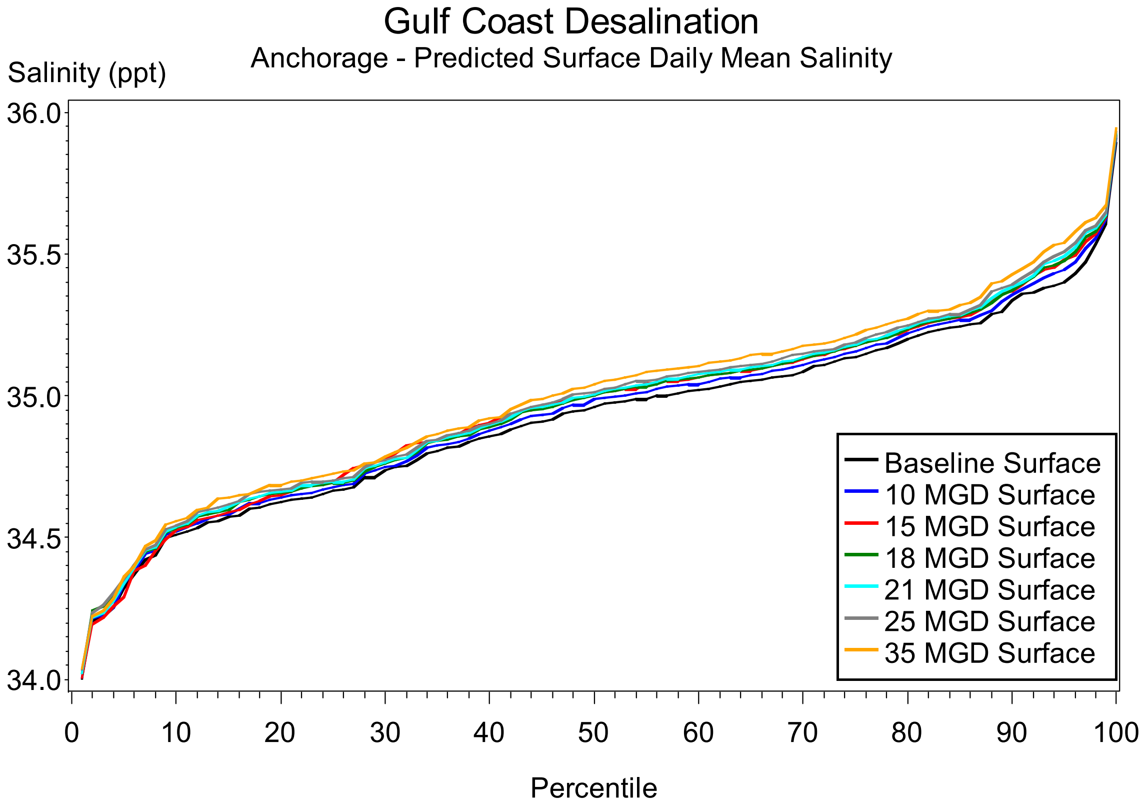

Figure 7.5. Cumulative distribution frequency of daily mean surface salinity in the Anchorage.

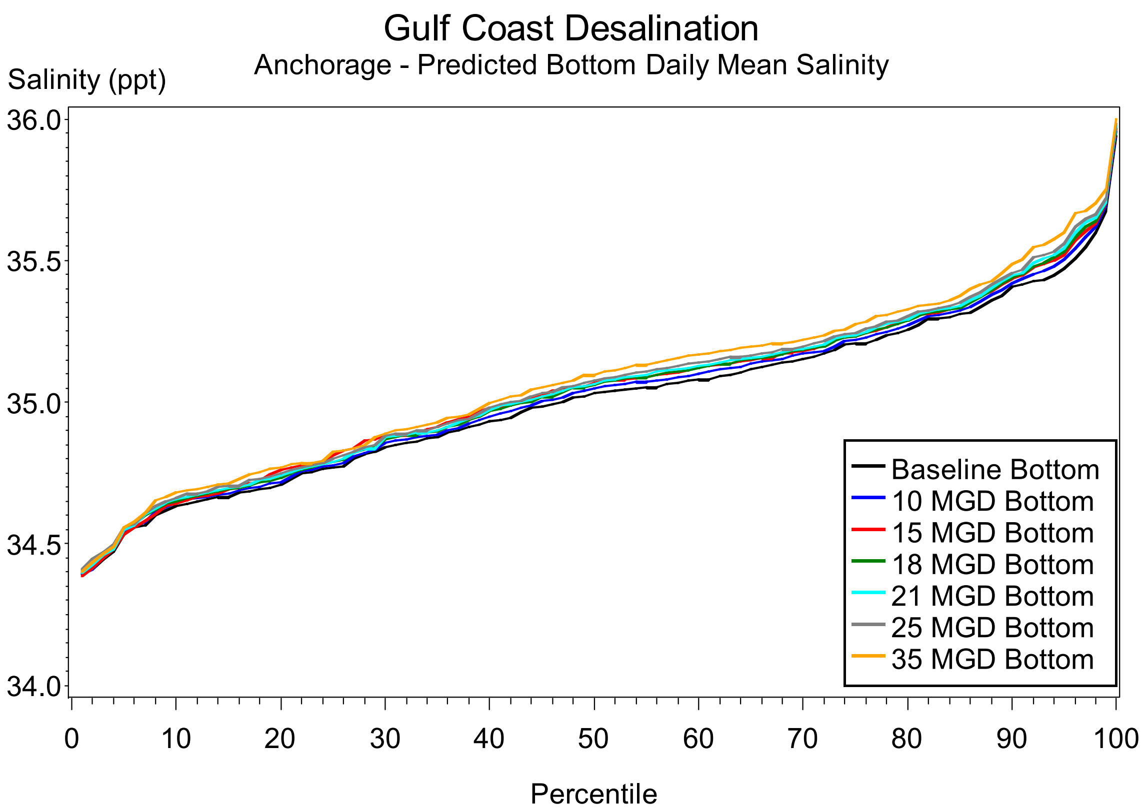

Figure 7.6. Cumulative distribution frequency of daily mean bottom salinity in the Anchorage.

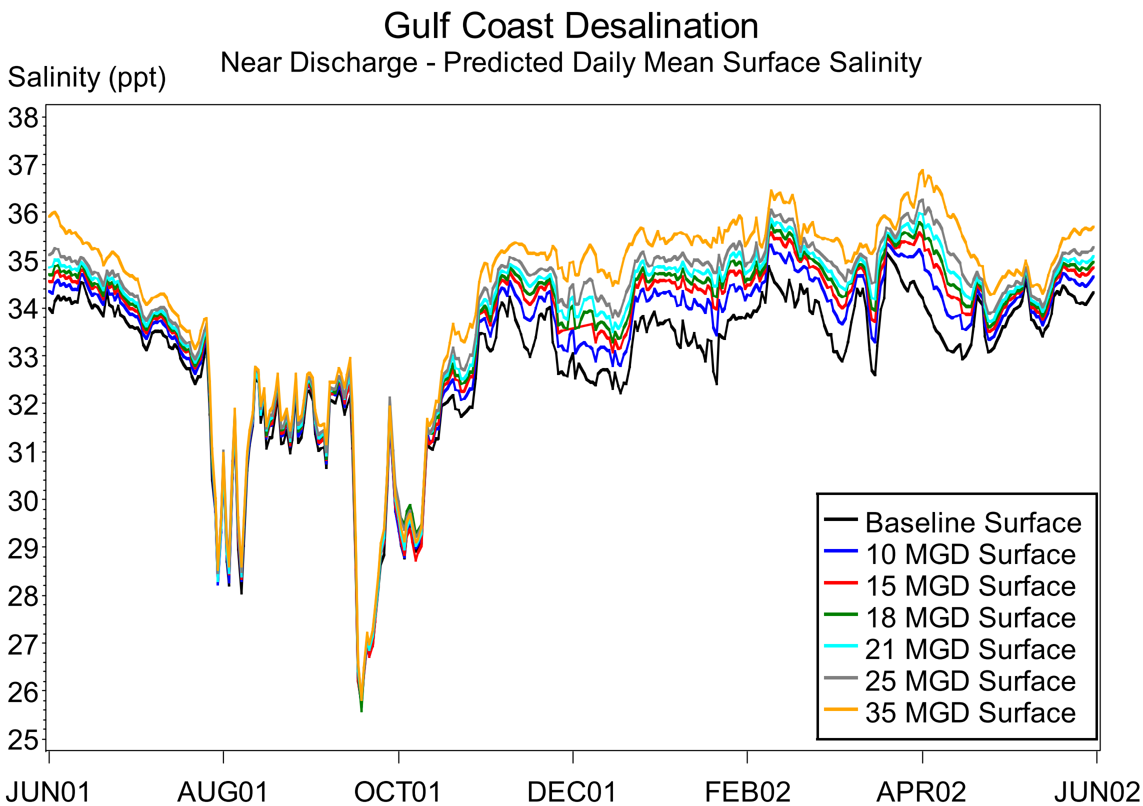

Figure 7.7. Time series of daily mean surface salinity near the discharge (as shown in Figure 6.64).

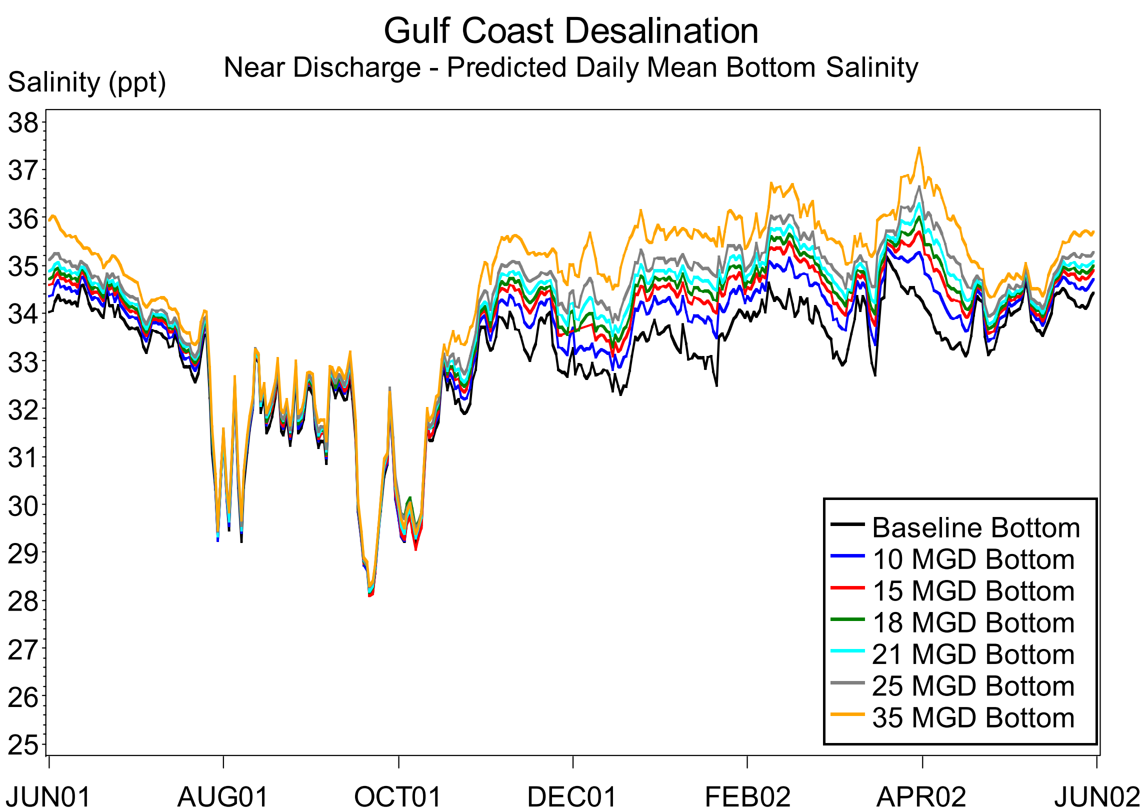

Figure 7.8. Time series of daily mean bottom salinity near the discharge (as shown in Figure 6.64).

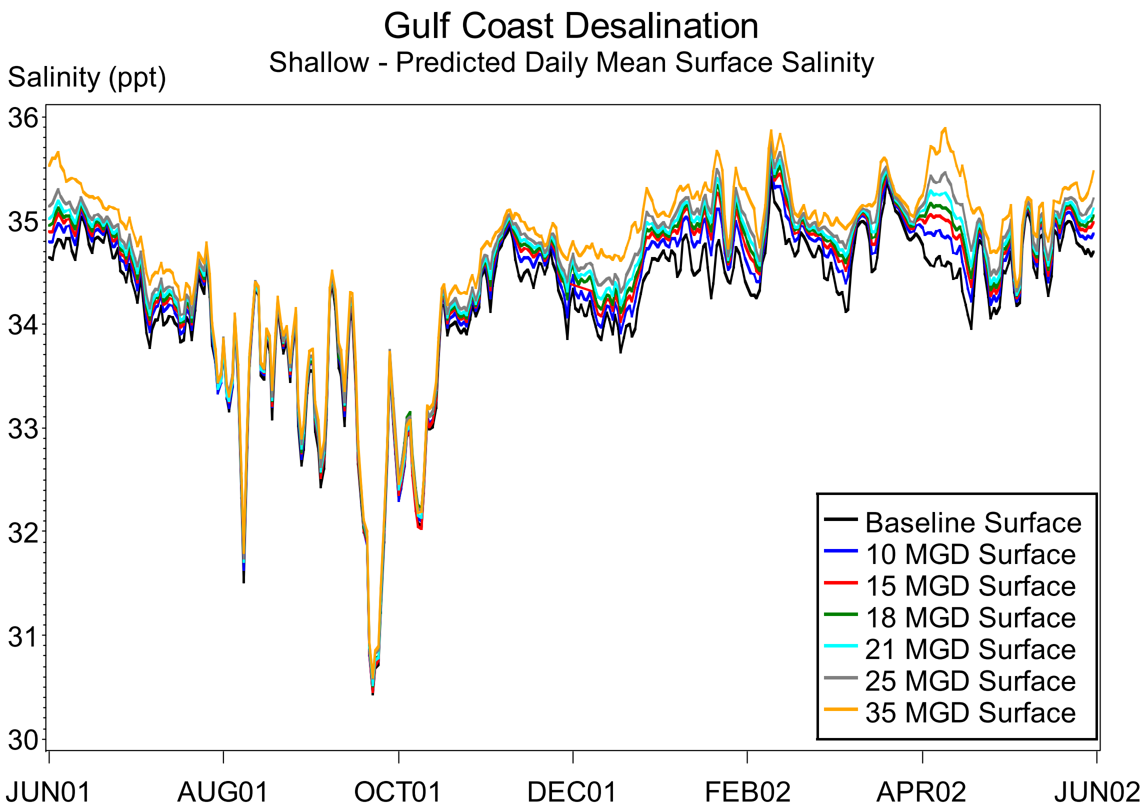

Figure 7.9. Time series of daily mean surface salinity in the shallow area (as shown in Figure 6.64).

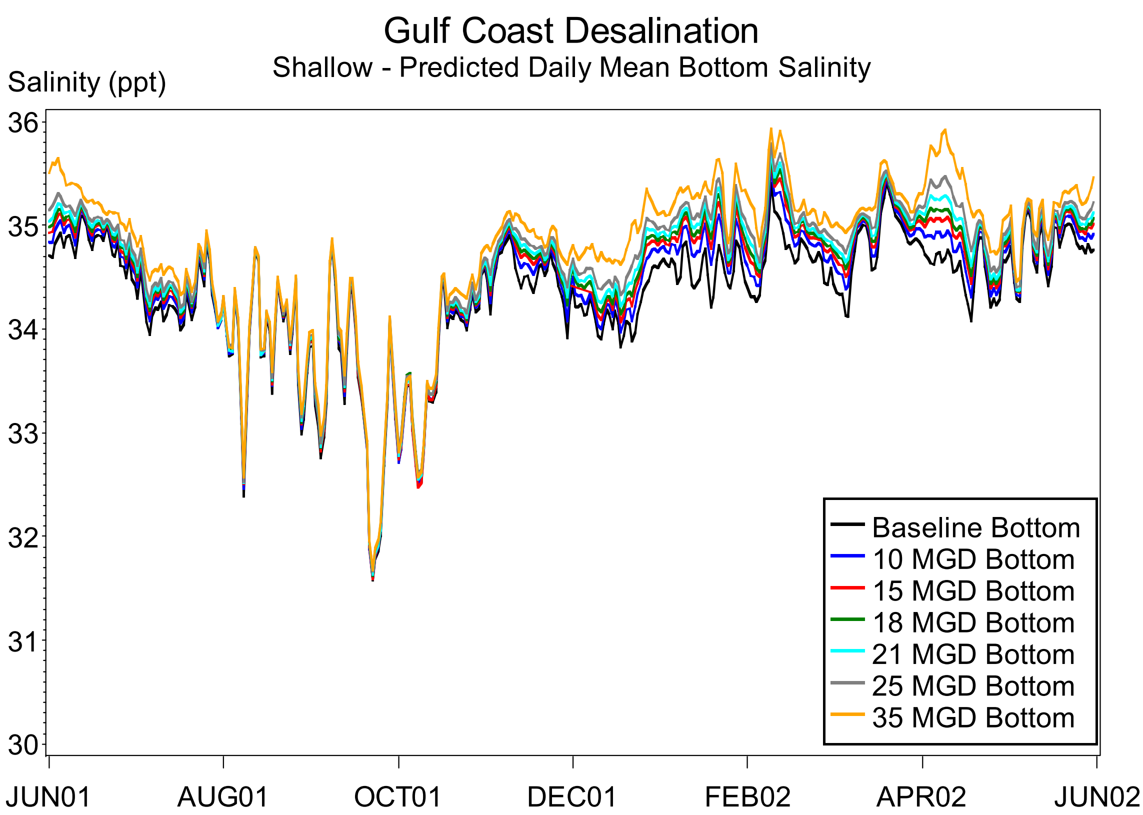

Figure 7.10. Time series of daily mean bottom salinity in the shallow area (as shown in Figure 6.64).

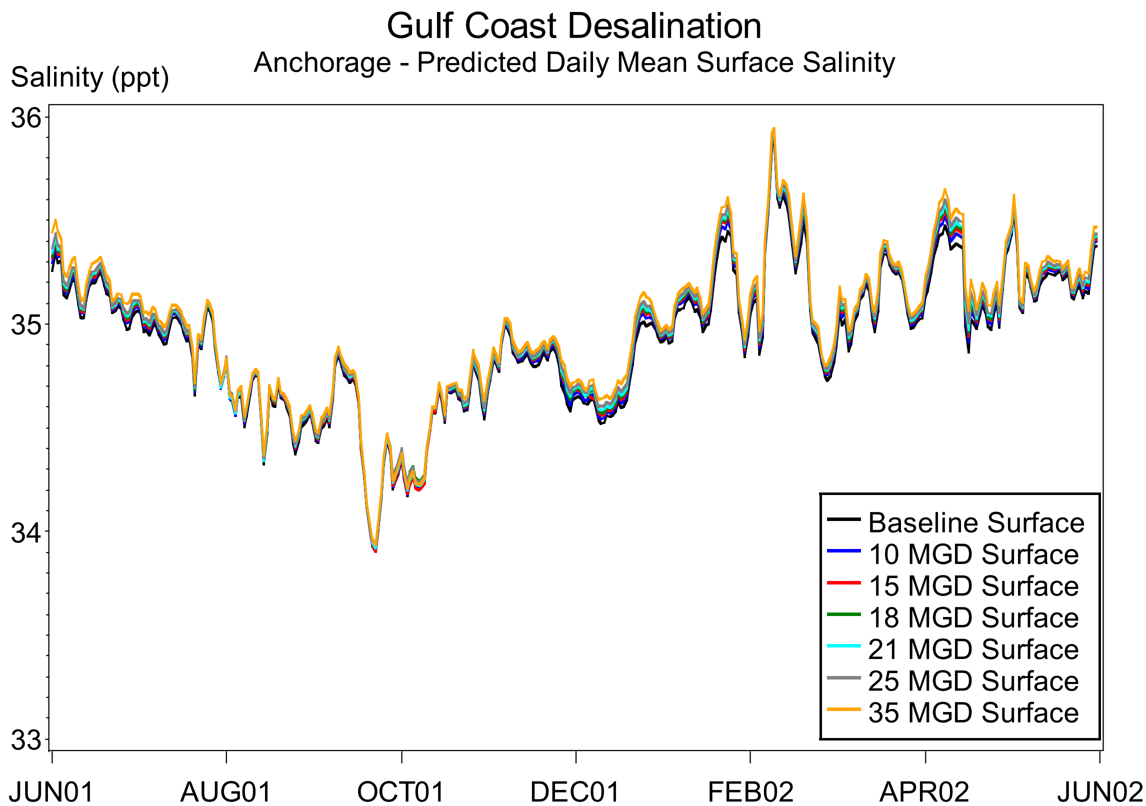

Figure 7.11. Time series of daily mean surface salinity in the Anchorage.

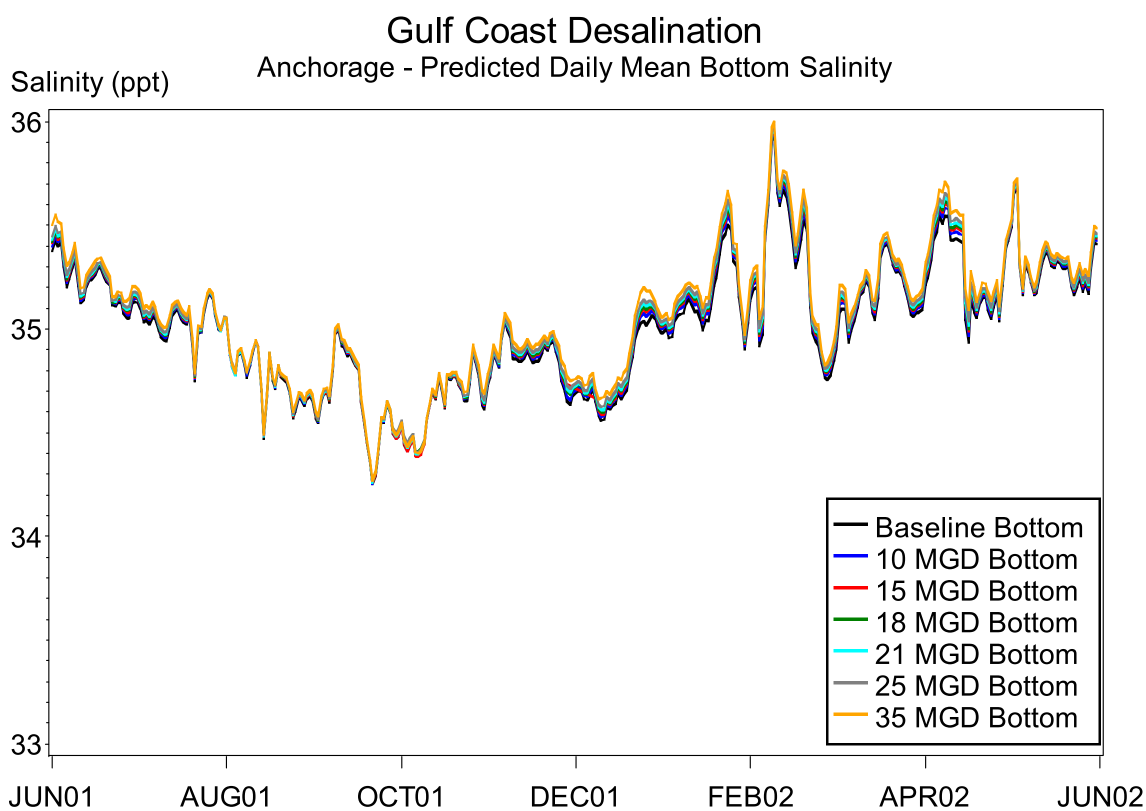

Figure 7.12. Time series of daily mean bottom salinity in the Anchorage.

To evaluate the potential longer term effects on salinity resulting from the desalination operations, a five-year run of the 25 MGD product water scenario was completed for the nearshore grid. The model output data were examined for any inter-annual predicted changes in salinity distribution. As discussed previously, there was no change from year to year in the predicted salinity within the Anchorage, with salinity distributions repeating in an annual cycle.

7.2 Offshore

Predicted daily mean salinity changes in the offshore discharge area are as high as 2.1 ppt in the bottom layer for the 25 MGD product water scenario. This is the maximum change within any model grid cell, however. The maximum daily mean predicted changes in salinity within the model domain (the offshore grid during the period June 2001-May 2002) for each product water scenario are shown in Tables 7.1 and 7.2 for surface and bottom, respectively. The changes in salinity are based on daily averages for each grid cell of the model. Almost all the maximum changes occur next to the shore, in very shallow areas. The only exception is for the surface in the 10 MGD scenario, with the maximum change in a cell directly north of the discharge canal mouth. This area is still very shallow, however.

The data provided in Tables 7.5 and 7.6 show that the maximum predicted changes in salinity are expected to occur during June and July, although there is little seasonality associated with the signal. The maximum change at the surface is much less than that at the bottom, as expected given the location of the discharge near the bottom and the depth of the water column. For the 25 MGD product water scenario, maximum changes in daily mean salinity are predicted to be approximately 2.0 ppt in the 100m x 100m cell where discharge occurs.

Table 7.5. Surface maximum Δ salinity for offshore scenarios.

Product Water Scenario	Δ Salinity	Location	Date
10 MGD	0.4 ppt	North of southern boundary ~0.8 km, west of eastern boundary ~1.6 km	07/03/01
25 MGD	0.4 ppt	North of southern boundary ~0.7 km, west of eastern boundary ~3.4 km	08/04/01

Table 7.6. Bottom maximum Δ salinity for offshore scenarios.

Product Water Scenario	Δ Salinity	Location	Date
10 MGD	1.1 ppt	At discharge	7/12/01
25 MGD	2.1 ppt	At discharge	6/15/01

Tables 7.7 and 7.8 provide the mean annual predicted salinity values for the surface and bottom in the offshore grid. There is almost no change in salinity over the offshore discharge area, with predicted mean annual surface and bottom salinity values differing by less than 0.1 ppt.

Table 7.7. Mean annual surface salinity for offshore scenarios.	
Product Water Scenario	**Offshore Grid**
Baseline	35.1 ppt
10 MGD	35.1 ppt
25 MGD	35.1 ppt

Table 7.8. Mean annual bottom salinity for offshore scenarios.	
Product Water Scenario	**Offshore Grid**
Baseline	35.3 ppt
10 MGD	35.3 ppt
25 MGD	35.3 ppt

The cumulative distribution frequencies for predicted mean daily salinity for the offshore grid are shown in Figures 7.13 and 7.14 for surface and bottom, respectively. Each figure provides the frequency distribution of predicted daily mean salinity for the three scenarios.

Figures 7.13 and 7.14 show that at lower predicted salinity values in the near discharge area, only very small changes in salinity are predicted to occur as a result of desalination operations. It is only at higher salinity values, most likely to occur during the dry season of low freshwater input and low cooling plant discharge, that differences in predicted salinity values are found among the scenarios. A similar pattern is seen for the shallow area, in Figures 7.3 and 7.4, with differences in predicted salinity values occurring only at relatively high levels of 32 ppt or more. For the Anchorage as a whole, the frequency distributions shown in Figures 7.5 and 7.6 indicate very little change in salinity, regardless of the season.

Time series of mean daily salinity predictions for the surface and bottom in each of the three areas are shown in Figures 7.7 through 7.12. The time series support the contention that only small differences are predicted during the wet season, when relatively high freshwater inflows and high cooling water discharges occur. Larger salinity changes occur during the period when freshwater inflows are low and cooling water discharges are low. Greatest changes are predicted in the area near the discharge, while changes over the entire Anchorage are predicted to be minimal.

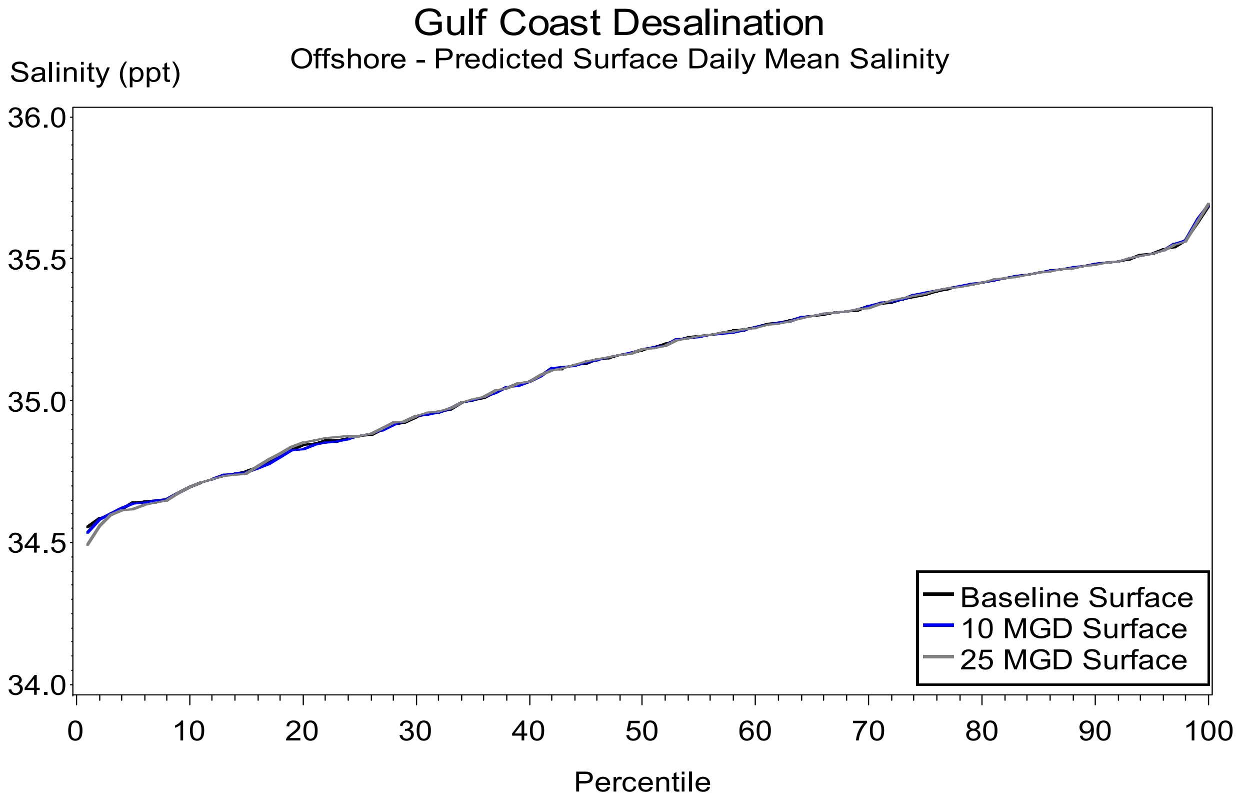

Figure 7.13. Cumulative distribution frequency of daily mean surface salinity for the offshore grid.

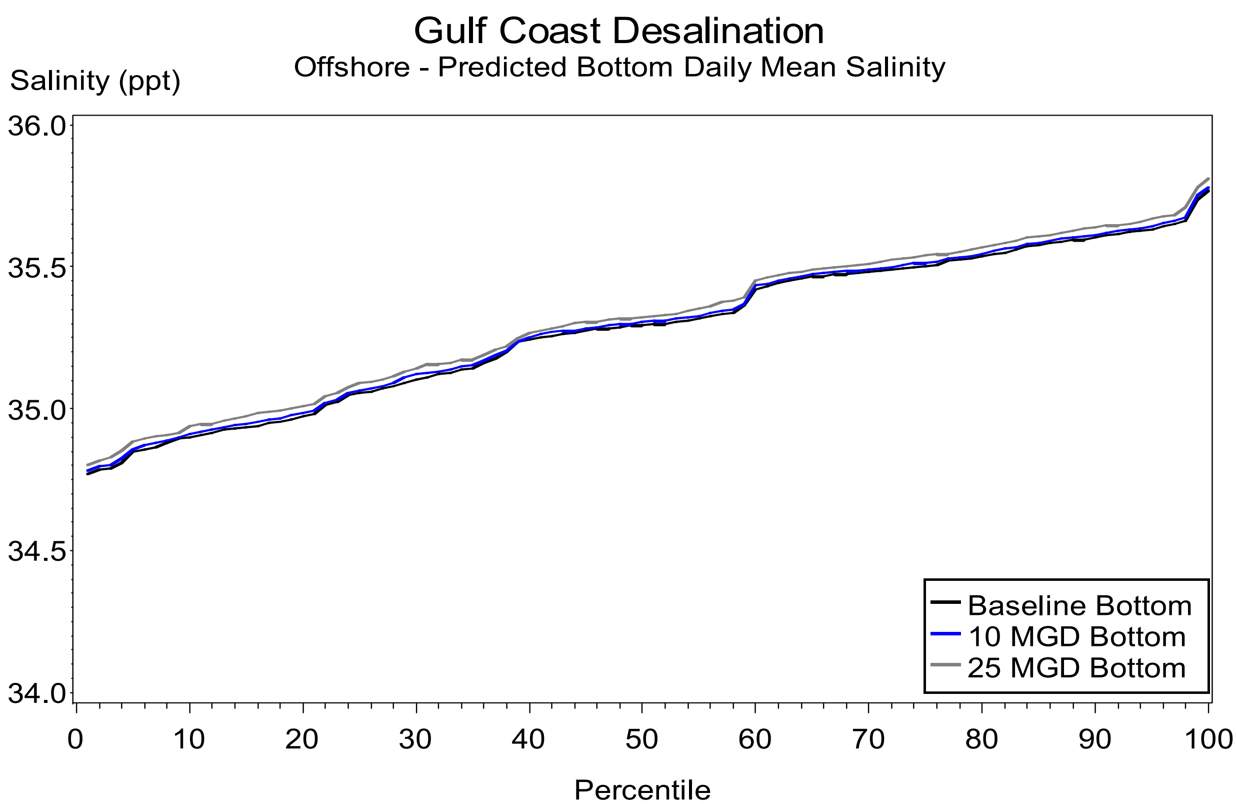

Figure 7.14. Cumulative distribution frequency of daily mean bottom salinity for the offshore grid.

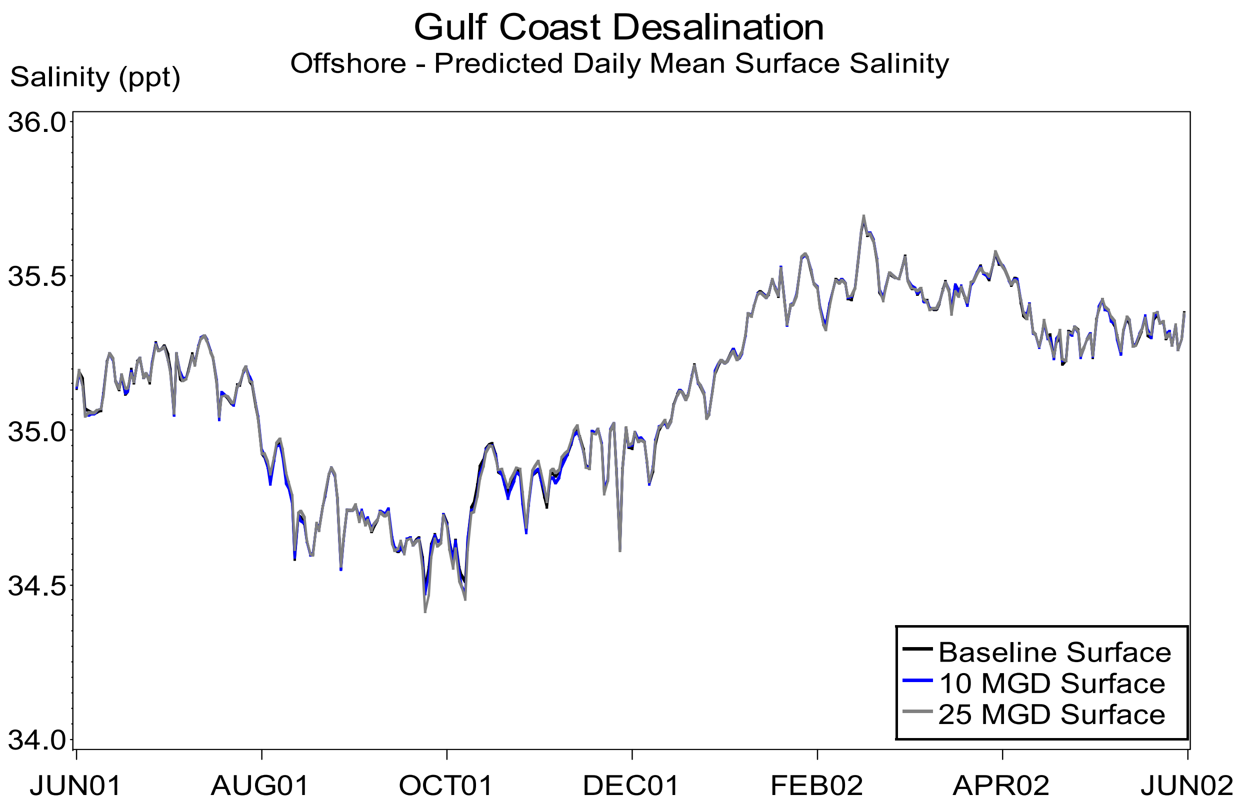

Figure 7.15. Time series of daily mean surface salinity in the offshore grid.

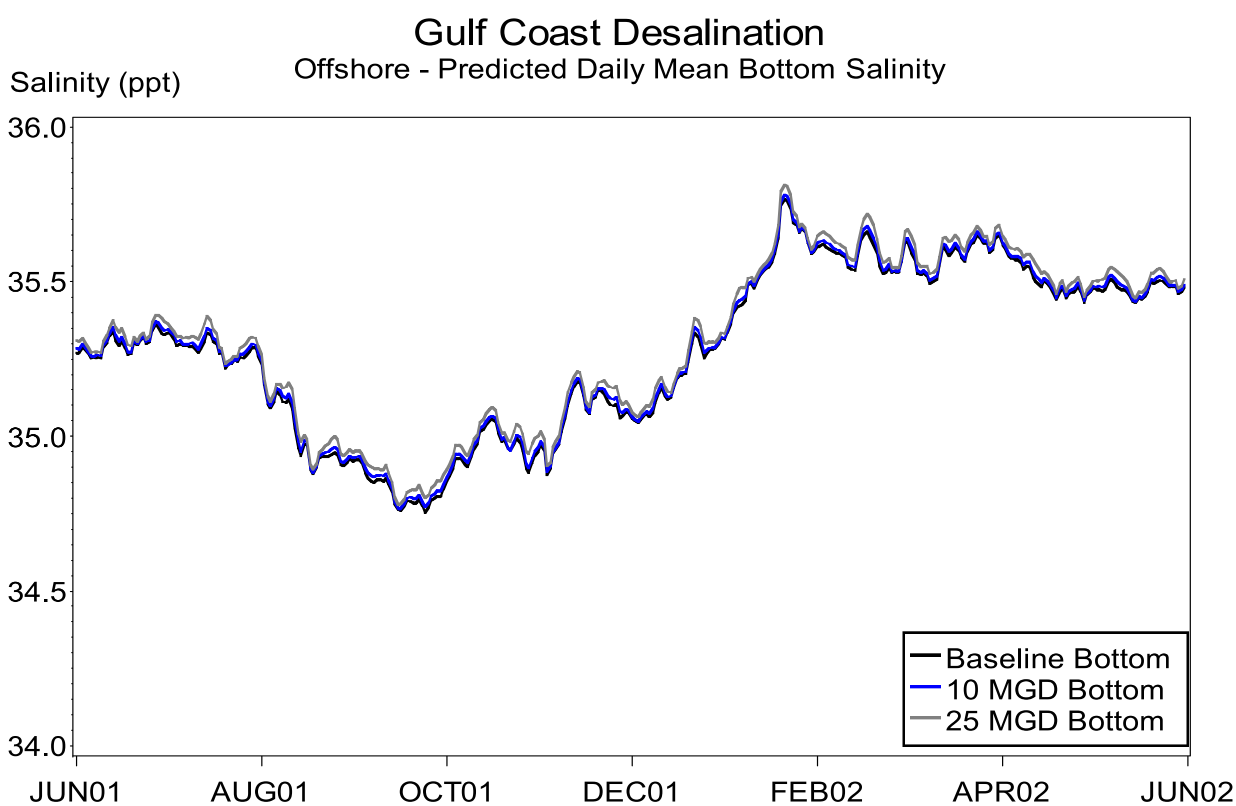

Figure 7.16. Time series of daily mean bottom salinity in the offshore grid.

8.0 Conclusions

To meet required reductions in groundwater pumping, Tampa Bay Water has identified several alternative sources, including seawater desalination. A seawater desalination plant is currently being considered near the Anclote River on Florida's Gulf Coast. The major advantage of seawater desalination is that it provides a drought-proof water source. However, the desalination process produces a concentrate with a salinity that is approximately twice that of the source water. The discharge of this concentrate, therefore, will increase the salinity of the receiving waters. Depending upon the duration and magnitude, salinity changes can effect the distribution of organisms in the receiving waters. The task is to identify the least environmentally intrusive method of discharge (including how and where) of the concentrate.

Two locations were considered for discharge of the desalination concentrate, nearshore (into the Progress Energy discharge canal) and offshore (where depths are approximately 30 feet or more). A hydrodynamic model was developed to examine the relative effects of the discharge locations on salinity in the receiving waters. The objectives of this report are to

- describe the hydrodynamic model of the potential offshore and nearshore discharge areas, and

- to predict and compare the changes in salinity in these areas that would result from a series of potential concentrate volumes.

The predicted changes in salinity in the offshore area were consistently less than 2 ppt for both the 10 MGD and 25 MGD product water scenarios examined. For the nearshore area, the following desalination product water scenarios were examined: 10 MGD, 15 MGD, 18 MGD, 21 MGD, 25 MGD, and 35 MGD. The nearshore discharge into the power plant discharge also resulted in increases in salinity. The increase in salinity occurs in a nearshore area of relatively shallow water, primarily in the area immediately outside the discharge canal. The increase in salinity in this area ranges from less than 0.5 ppt to approximately 2 ppt, depending upon the volume of concentrate discharged. As expected, the magnitude of the change increases with the amount of product water produced, and therefore the amount of concentrate produced.

For the nearshore location, model predictions for both short-term (hour to hour) and long-term (over a 5-year period) time scales were examined. The increases in salinity varied within a year from month to month, depending upon river flow and, more importantly, the amount of cooling water used by the power plant. The greatest increases in salinity were found in March, in the area immediately outside the discharge canal. For March, the mean salinity change for each nearshore scenario is as follows:

- 10 MGD: 0.6 ppt
- 15 MGD: 0.8 ppt
- 18 MGD: 1.0 ppt
- 21 MGD: 1.1 ppt
- 25 MGD: 1.3 ppt
- 35 MGD: 1.7 ppt

During the months of May, June, July, August, September, and October, the predicted change in salinity in the near-discharge area averaged less than 1 ppt for all scenarios. Model predictions suggest that no increasing trends in salinity (over a 5-year period) are to be expected.

An ecological characterization of aquatic (inshore and offshore) habitats of the Anclote River estuary and the Anclote Anchorage has been completed. This document presents details of the project area including climate and meteorology, wind patterns, hydrology and hydrodynamics, water quality, major habitat types, and biota. Historical data show that salinity in the offshore area, as expected, is relatively constant at 35-36 ppt. In the Anclote Anchorage area, the salinity is typically lower and more variable, ranging from 23 to 38 ppt during 2000-2001. Critical habitats in the offshore area include hard and soft bottoms. Hard bottom habitats contain sponges, clams, and corals. Seagrass beds represent critical habitat in the nearshore area.

A review of the spatial and temporal variation of salinity within estuarine and offshore environments has been completed, providing information regarding the tolerance of the vegetation, invertebrates, fish, and marine mammals commonly found in the Anclote Anchorage and offshore areas to withstand changes in salinity. Organisms most likely found in the offshore areas require relatively higher, more constant salinity waters. Organisms found in the nearshore area typically tolerate a wider range of salinity. In particular, turtle grass, the predominant seagrass found in the Anclote Anchorage, is typically found in waters that range in salinity from 20-40 ppt, and is typically limited by lower salinities. Other important biota and their associated salinity tolerances include spotted seatrout (5-35 ppt), snook (0-35 ppt), oysters (2-40 ppt), corals (26-44 ppt), and manatees (0-35 ppt).

The predicted changes in salinity in both the offshore and nearshore waters resulting from the discharge of the desalination concentrate have been compared to the salinity tolerances for the biota exposed to the expected salinity changes. This comparison shows that the expected changes in salinity will not be of sufficient magnitude nor duration as to cause impacts to the biota of the receiving waters.

9.0 Literature Cited

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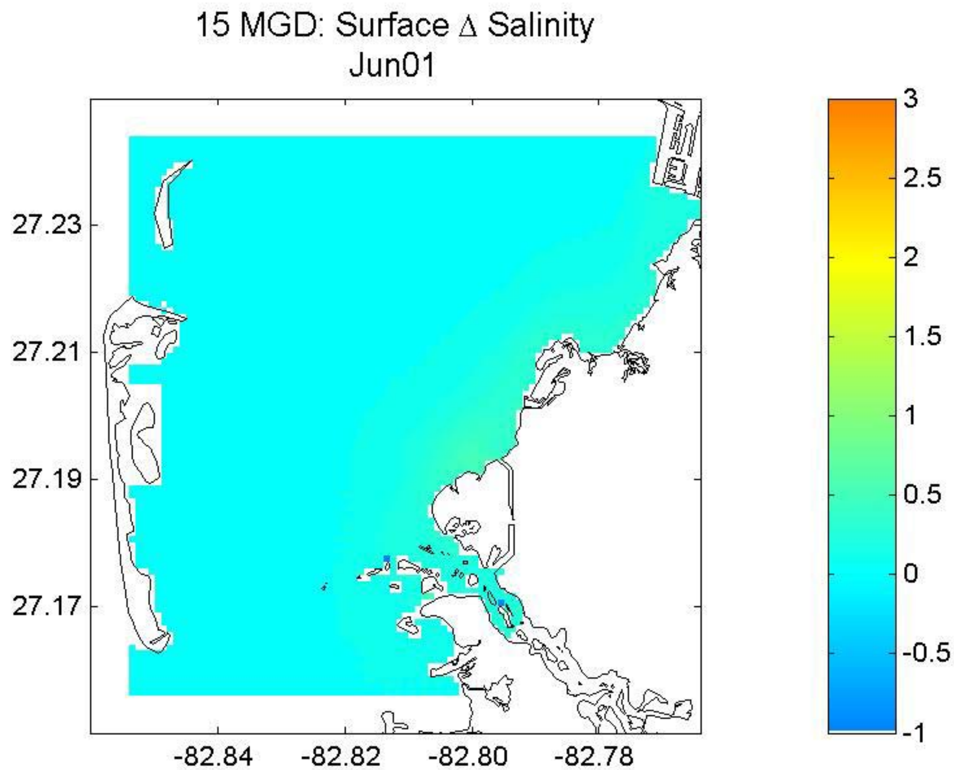
Appendix I

Monthly Change in Nearshore Salinity from 15 MGD Product Water Scenario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27.23
27.21
27.19
27.17
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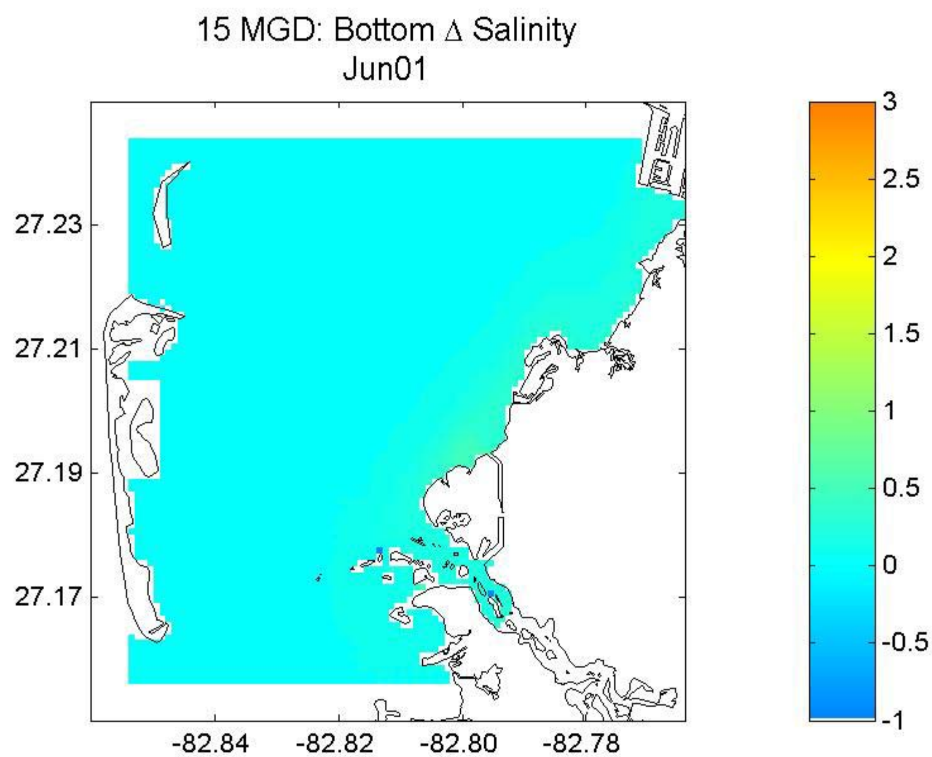
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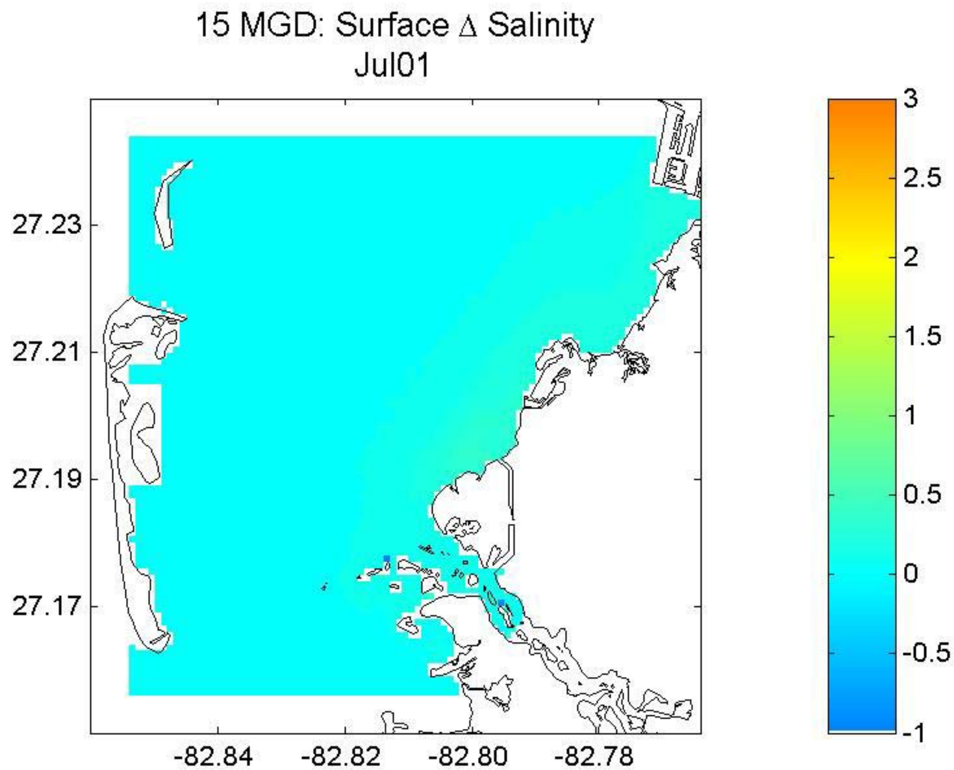
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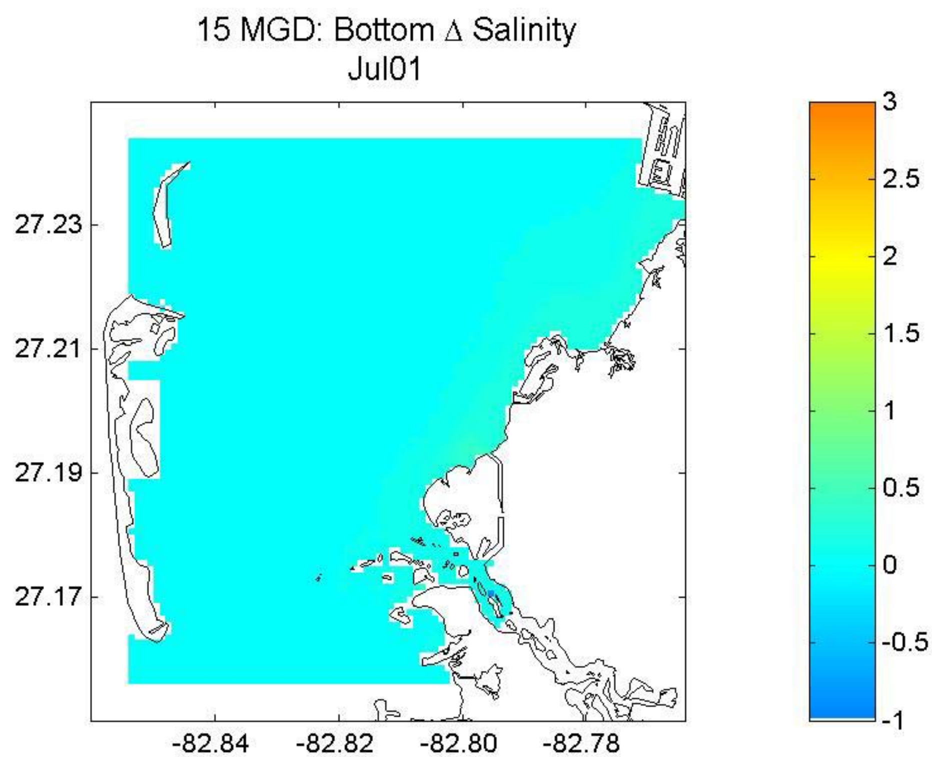
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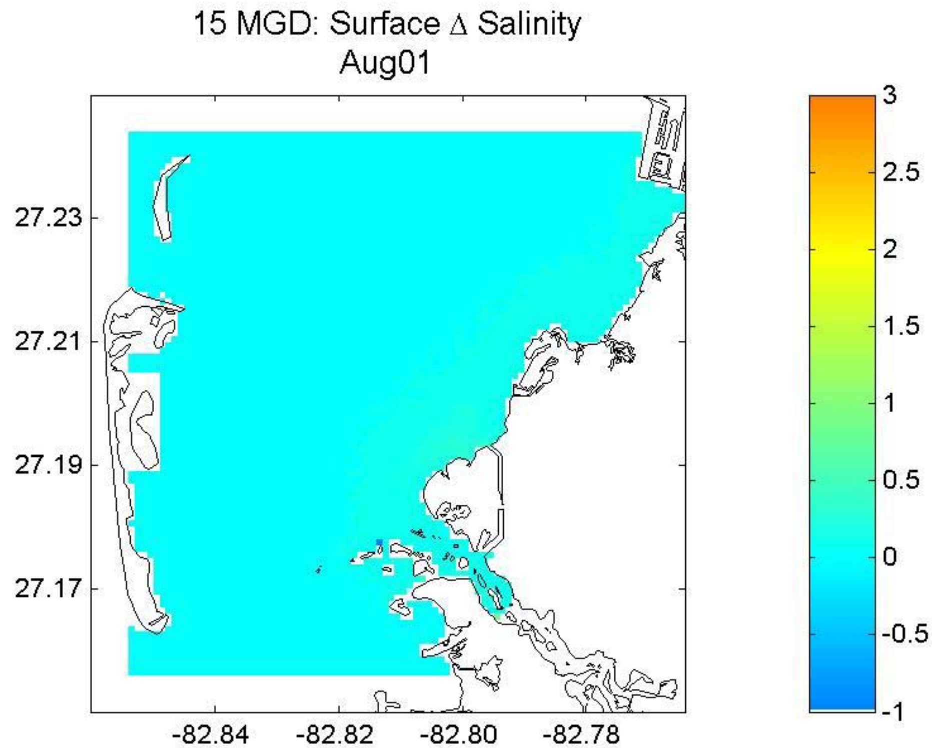
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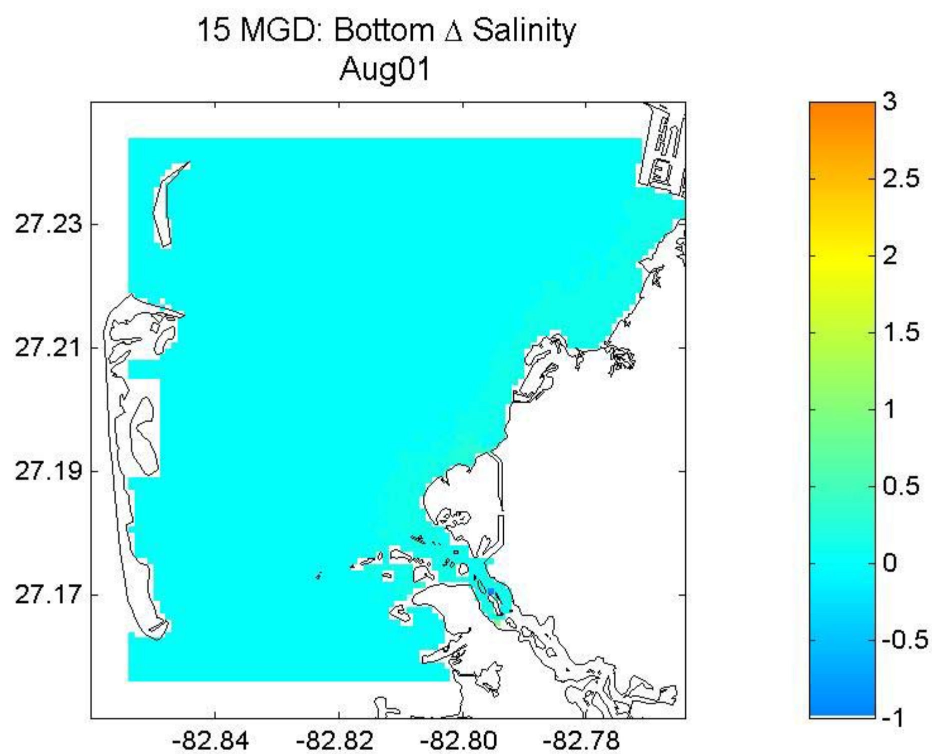
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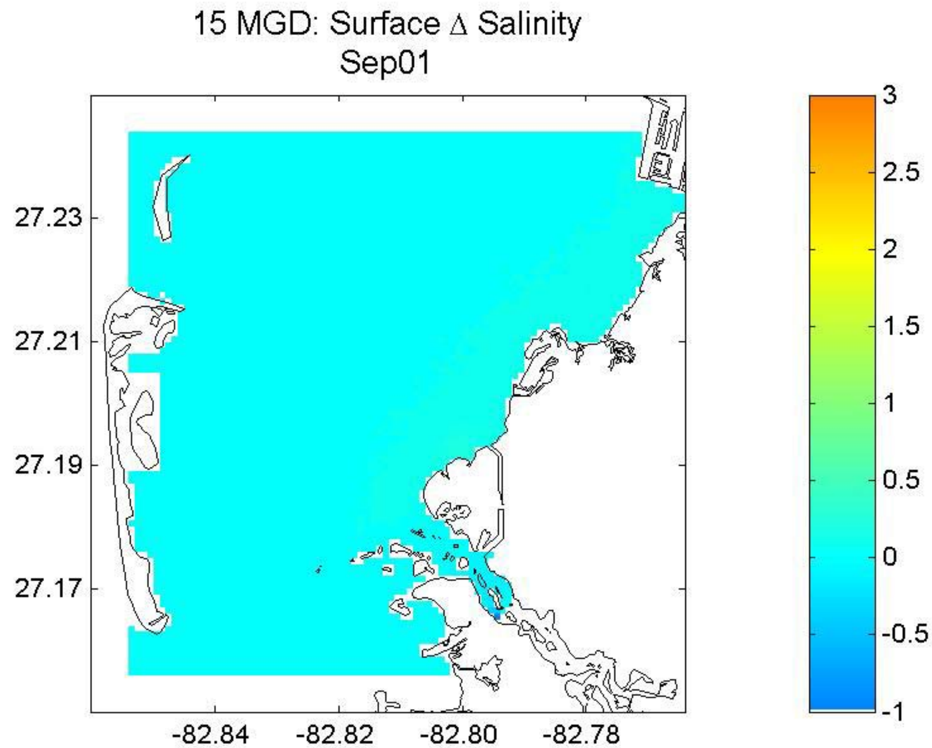
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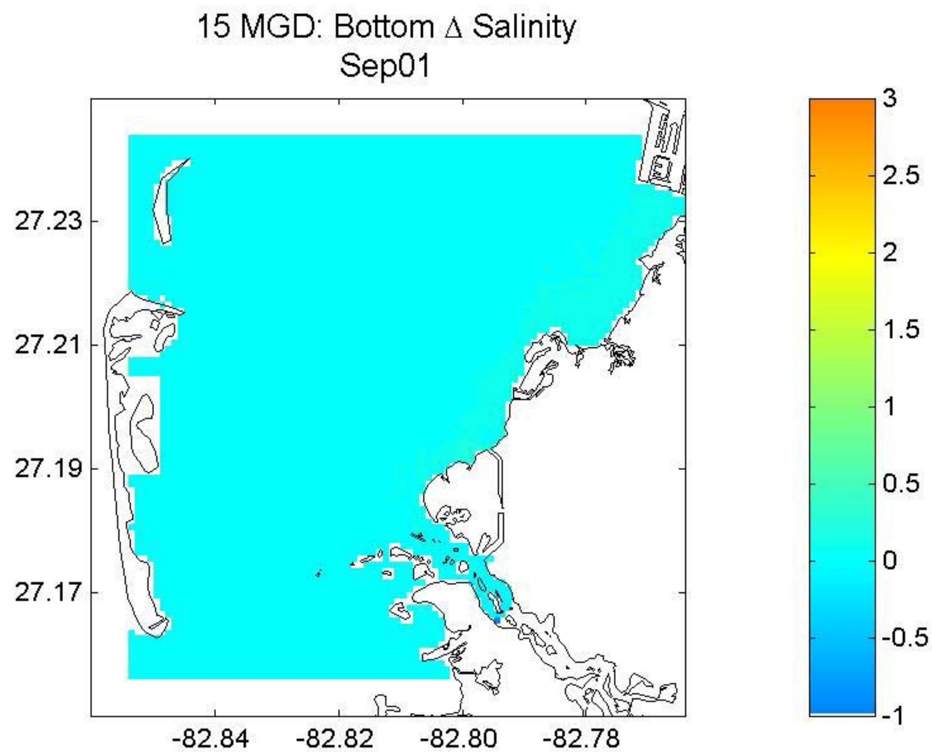
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Sep01
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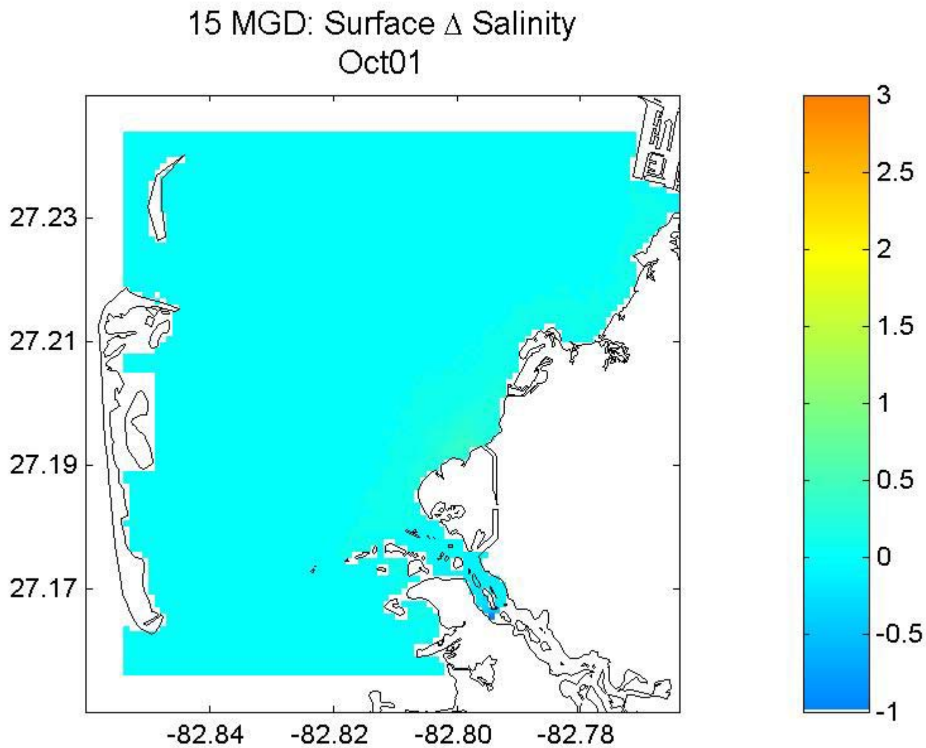
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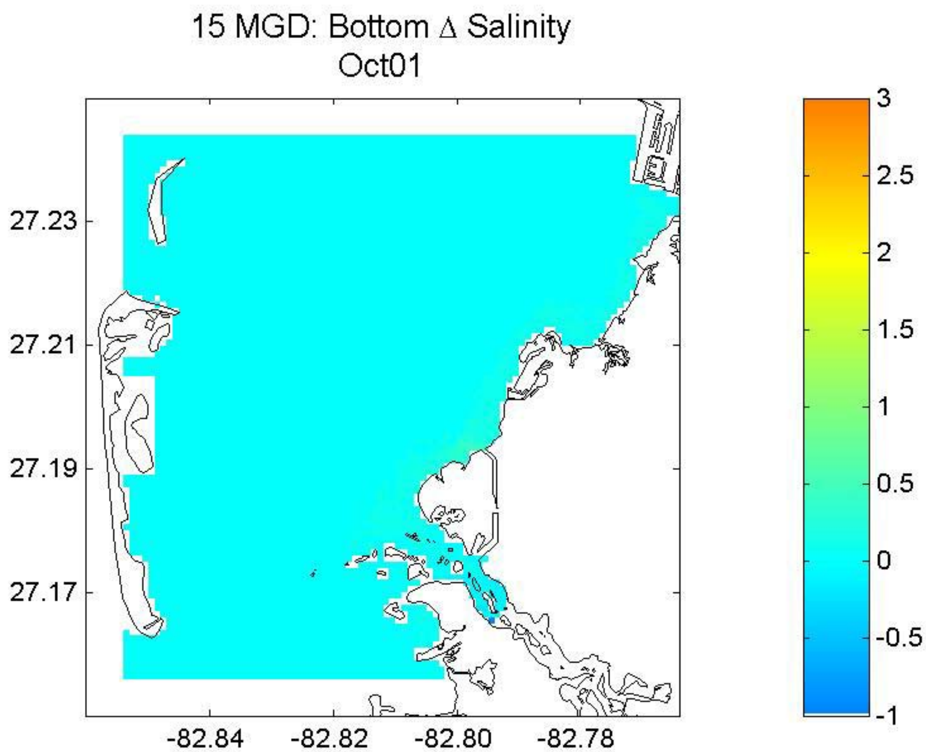
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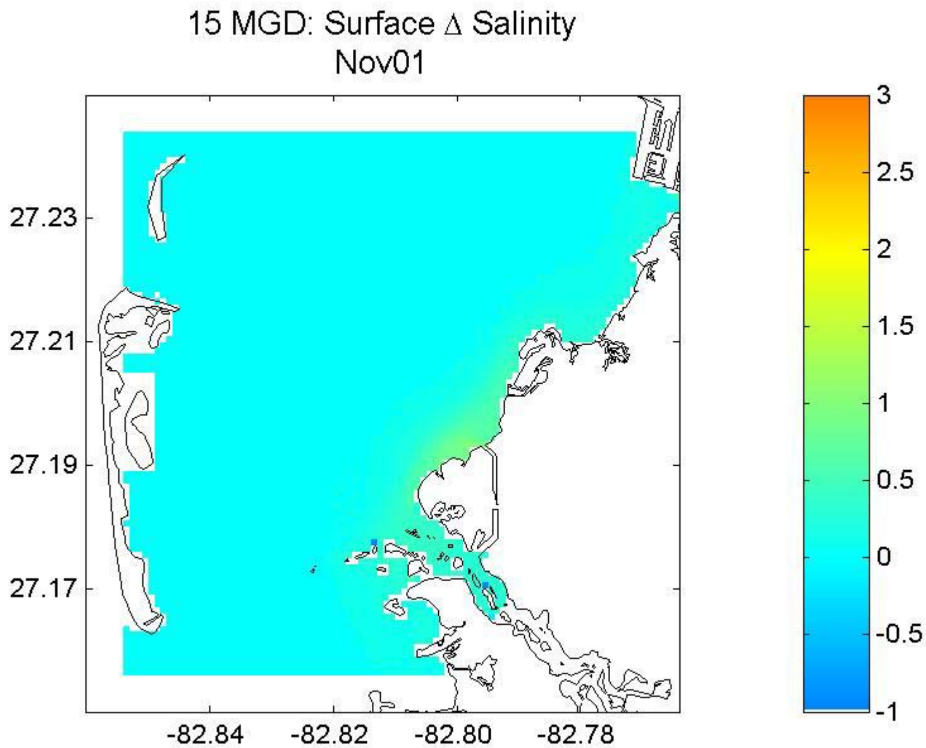
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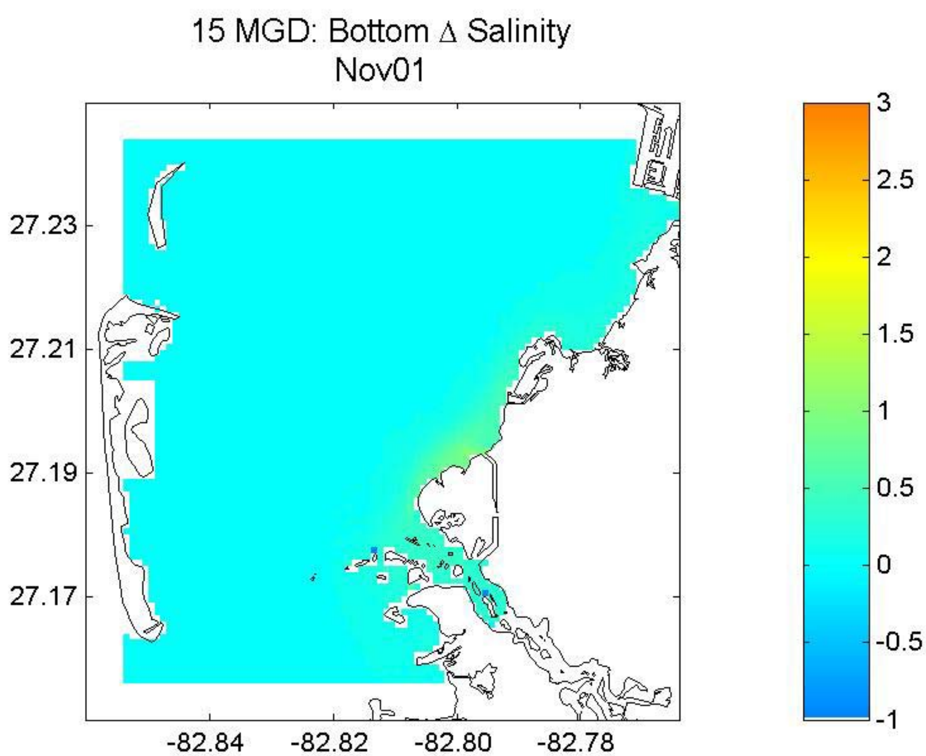
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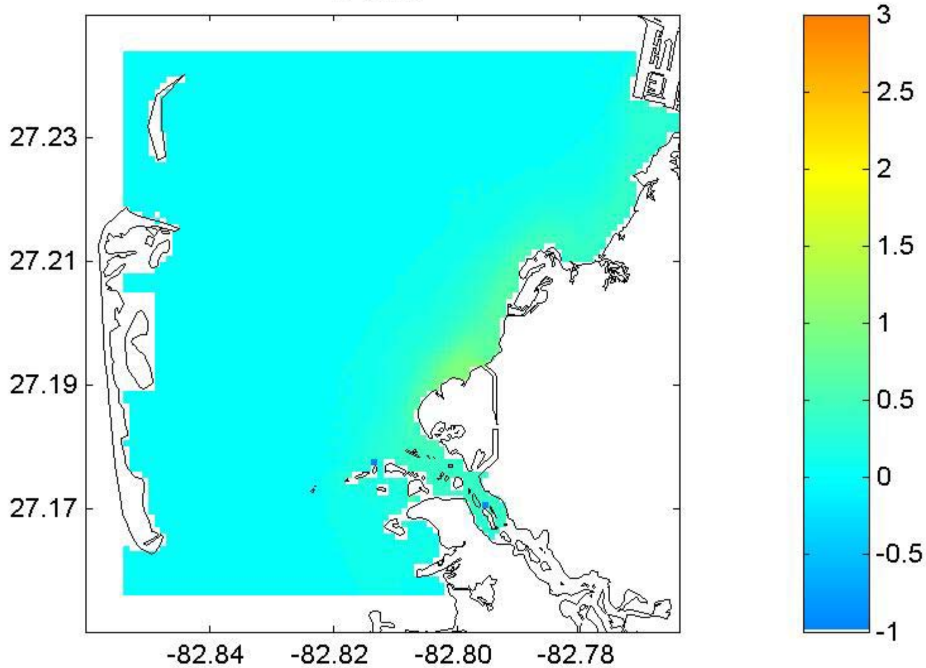

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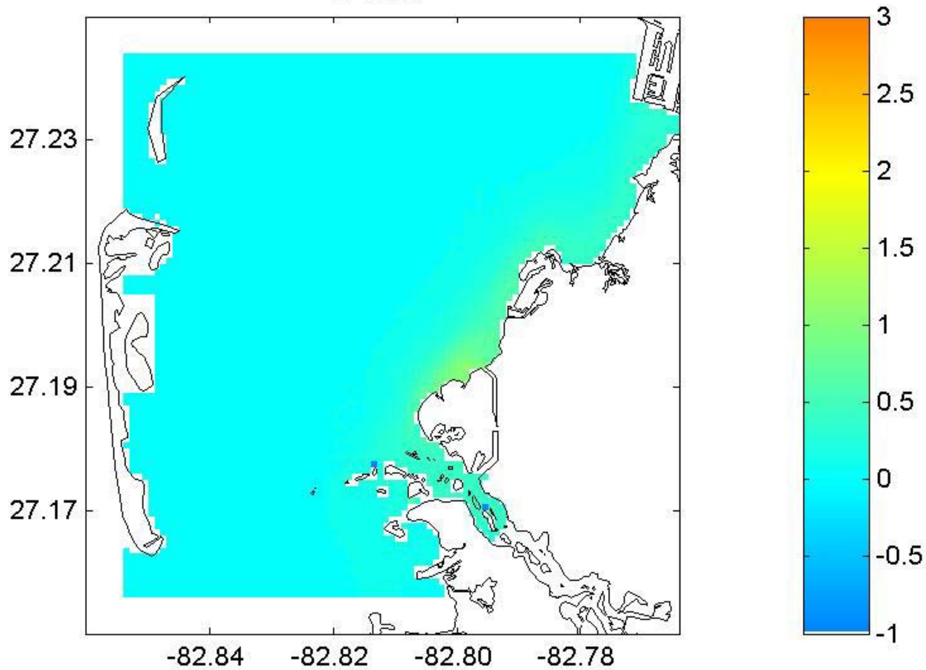

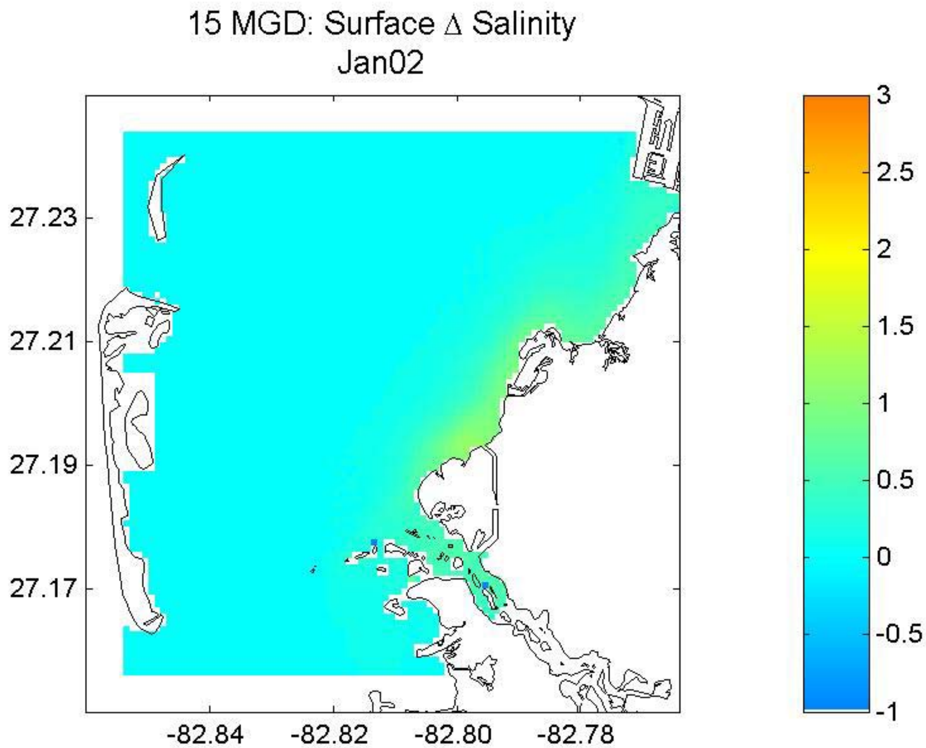
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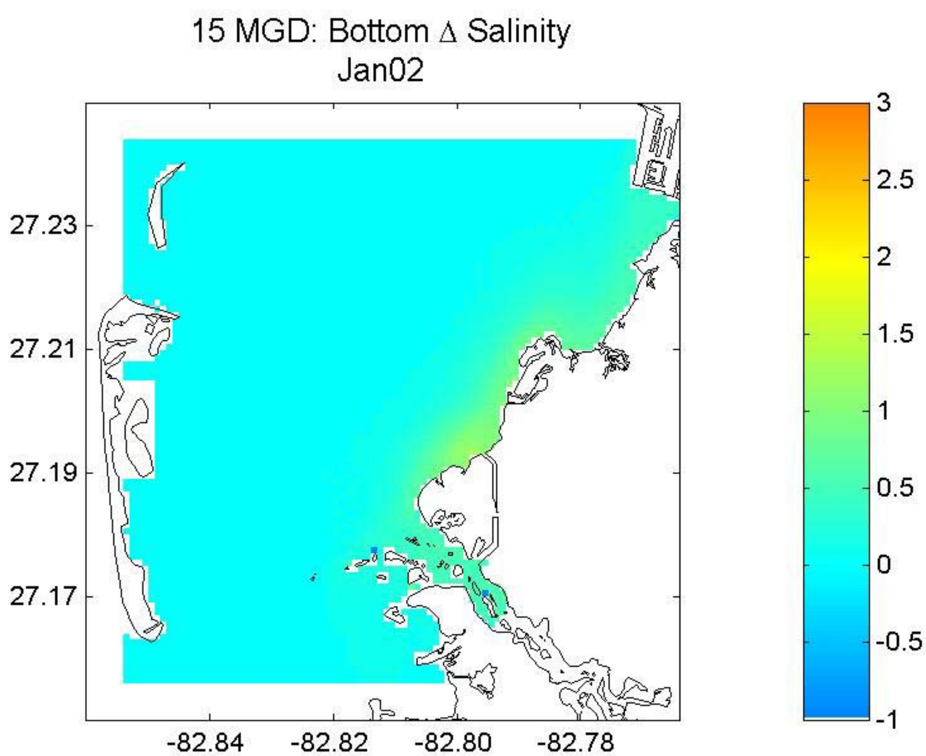
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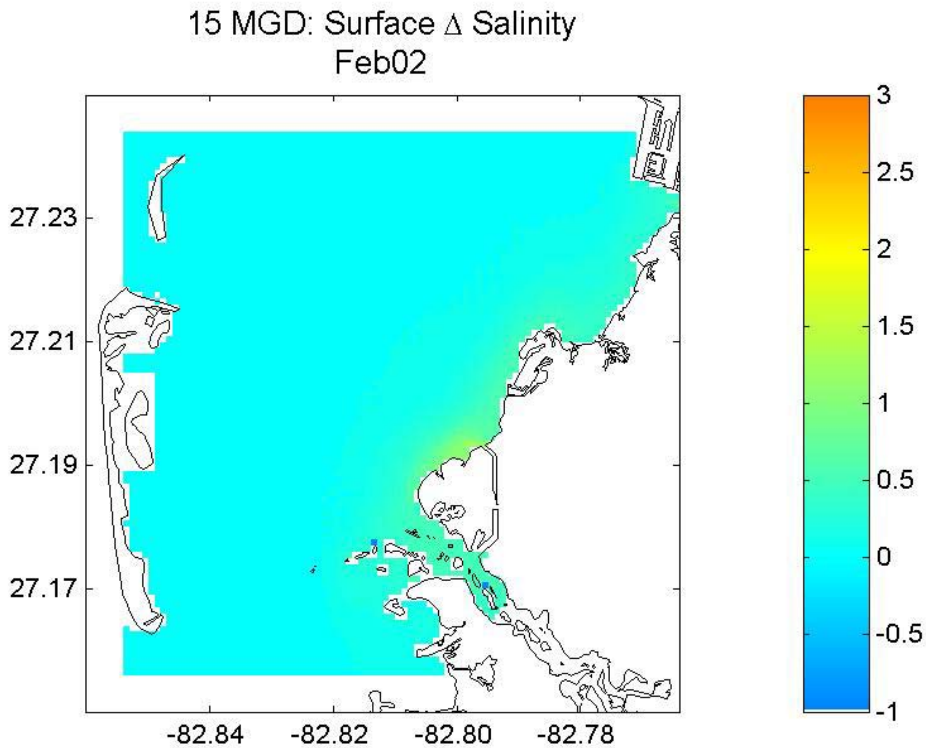
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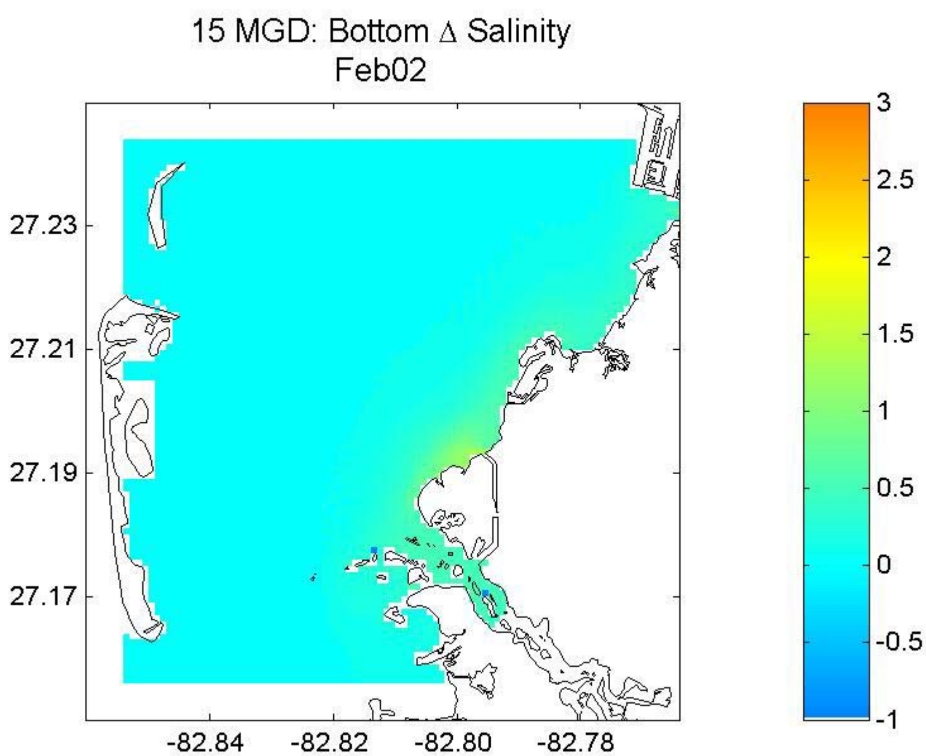
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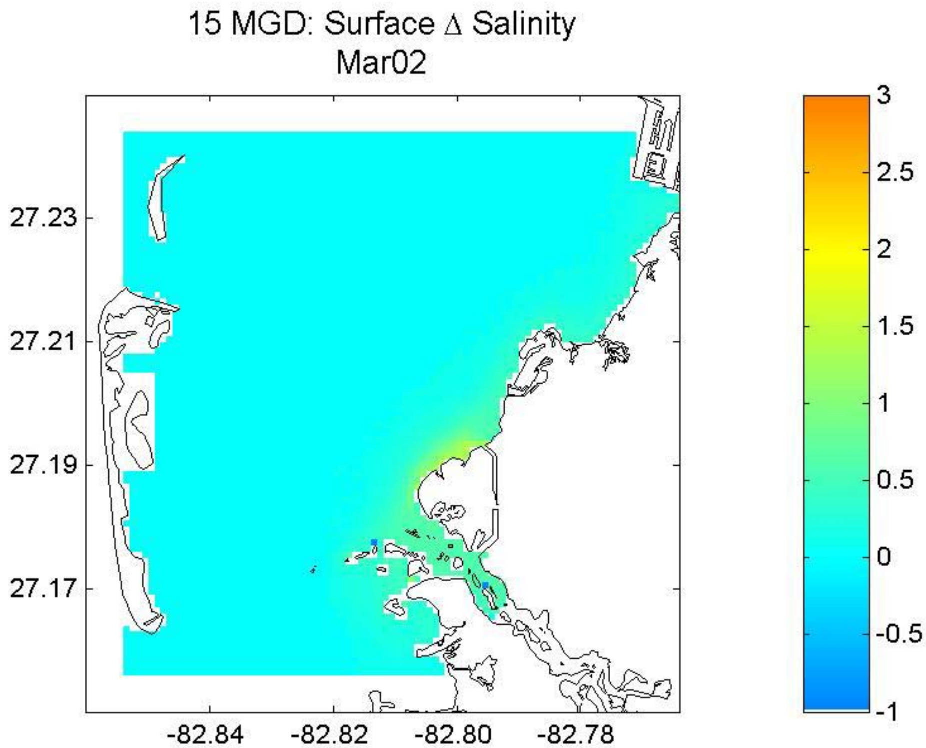
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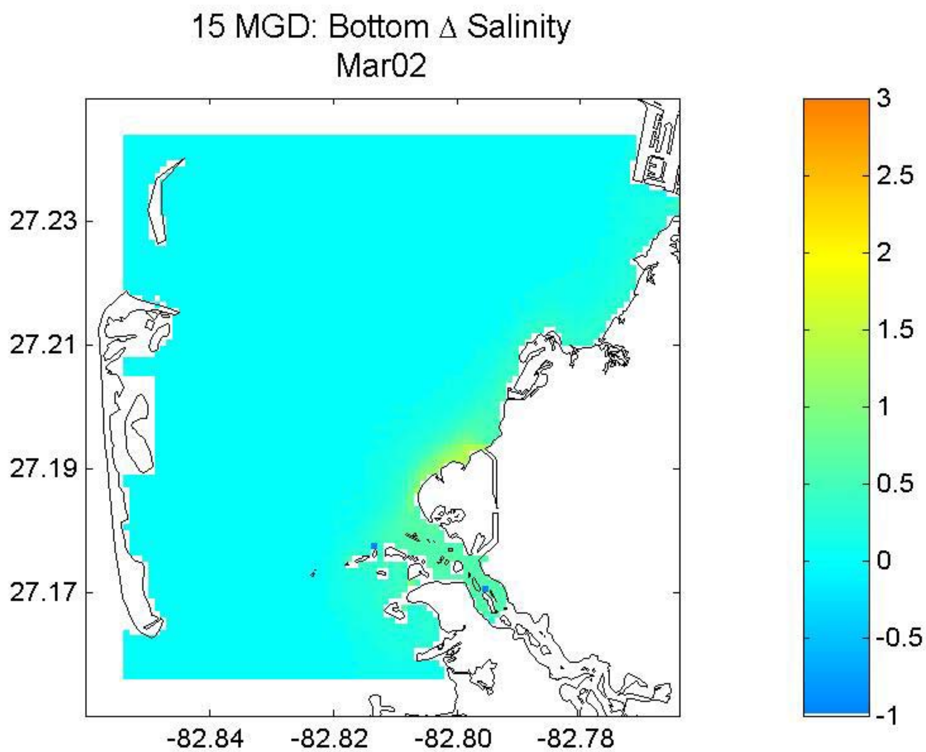
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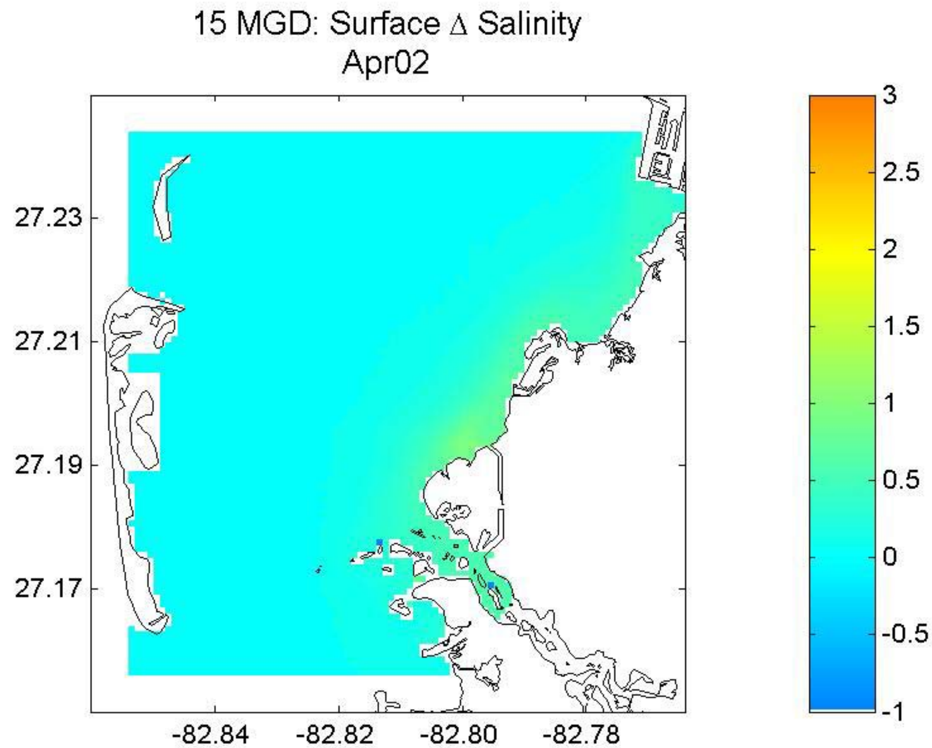
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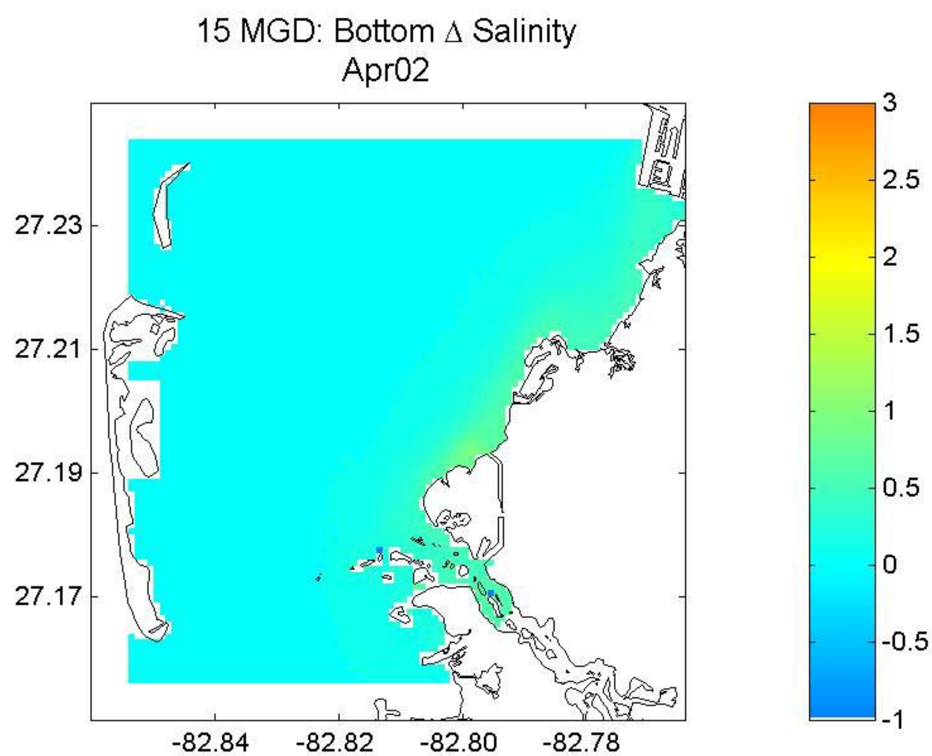
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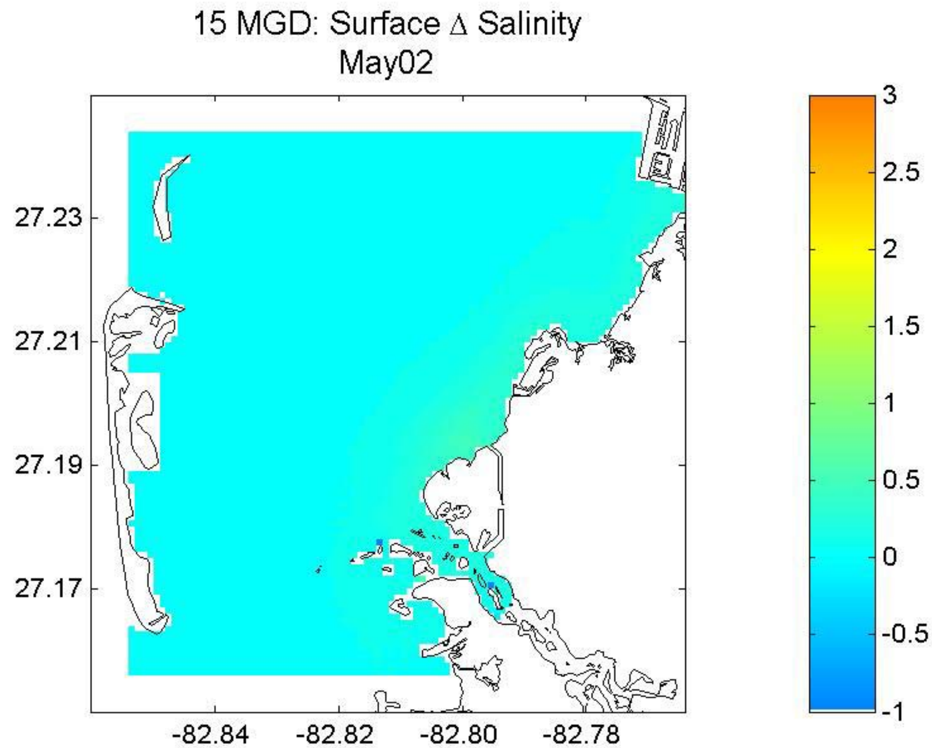
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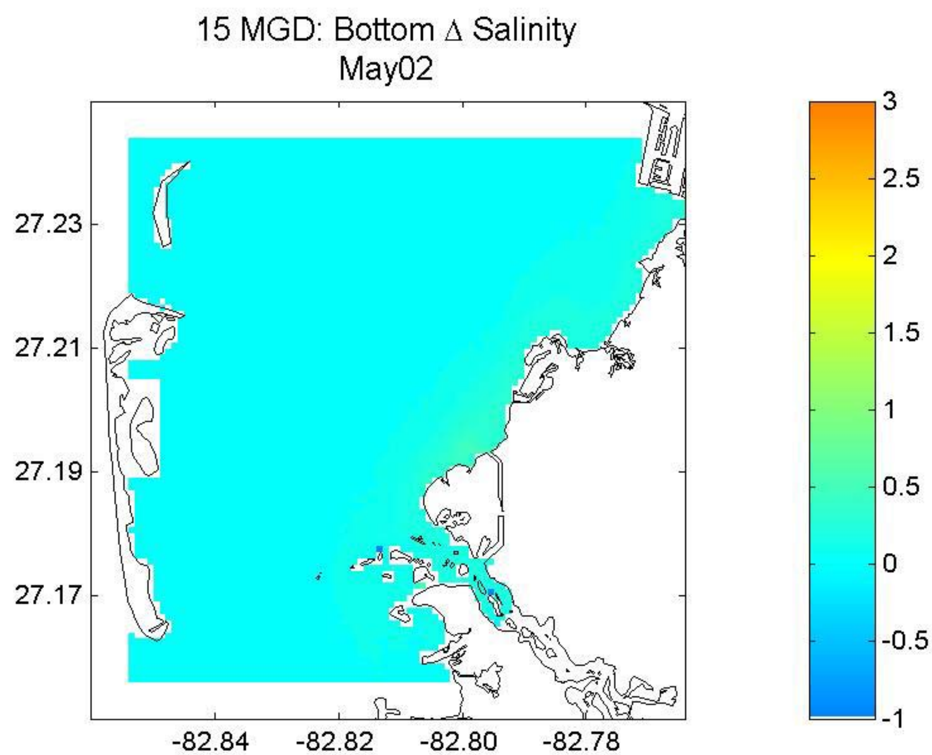
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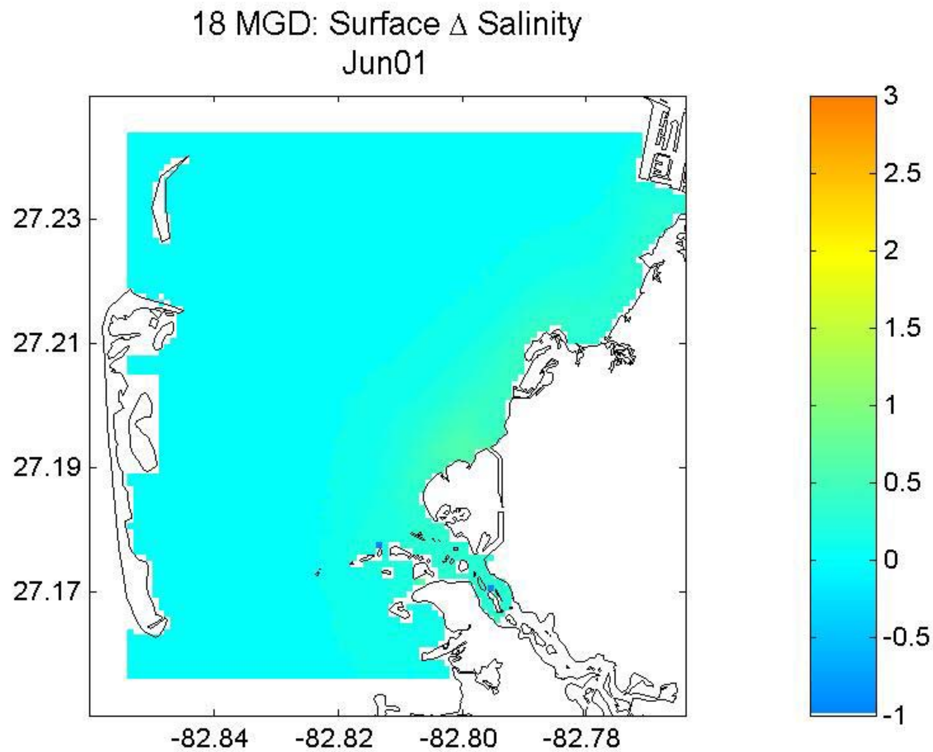
Appendix II

Monthly Change in Nearshore Salinity from 18 MGD Product Water Scenario


18 MGD: Surface Δ Salinity
Jun01
27.23
27.21
27.19
27.17
-82.84
-82.82
-82.80
-82.78
3
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2
1.5
1
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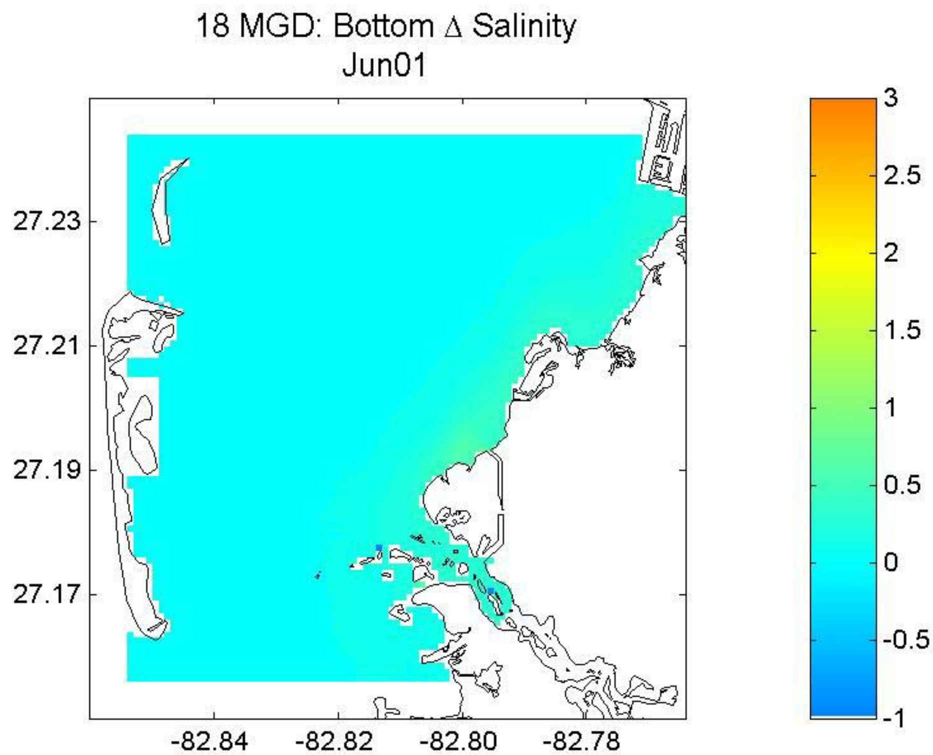
18 MGD: Bottom Δ Salinity
Jun01
27.23
27.21
27.19
27.17
-82.84
-82.82
-82.80
-82.78
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2
1.5
1
0.5
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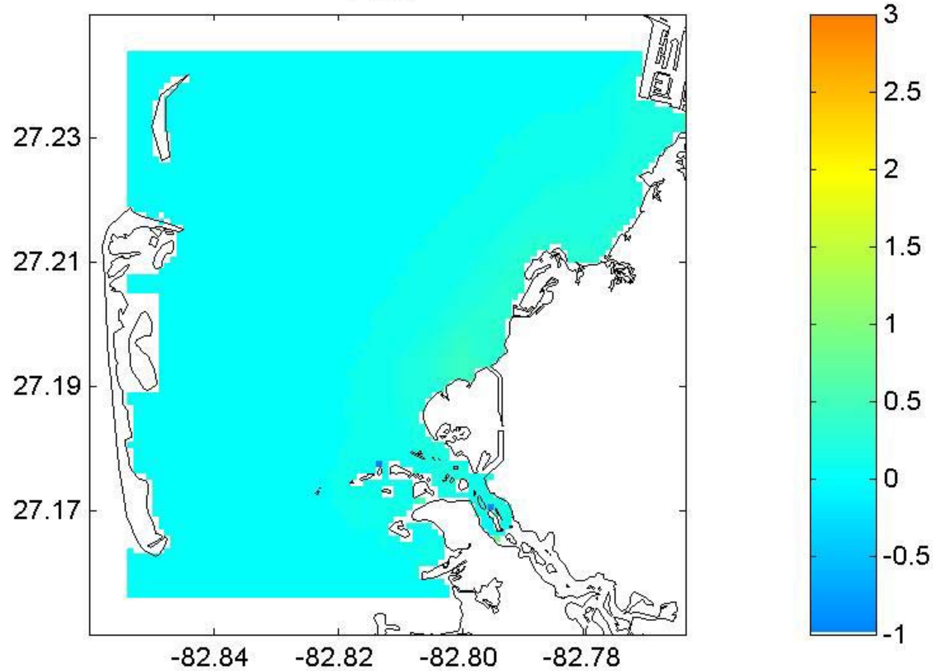
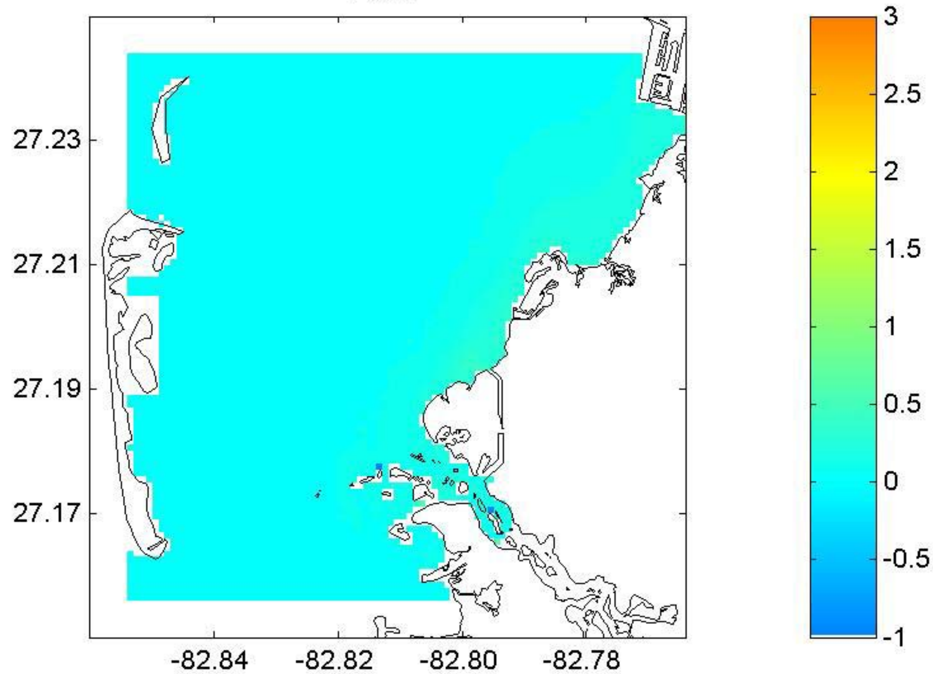
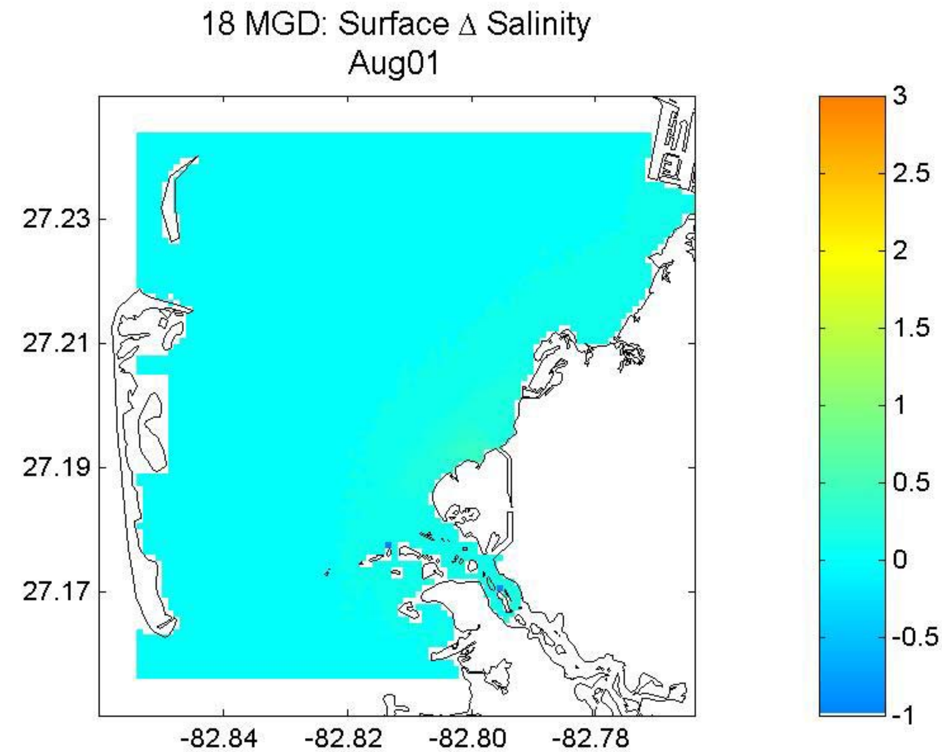
-1

18 MGD: Surface Δ Salinity
Jul01



18 MGD: Bottom Δ Salinity
Jul01




18 MGD: Surface Δ Salinity
Aug01
27.23
27.21
27.19
27.17
-82.84
-82.82
-82.80
-82.78
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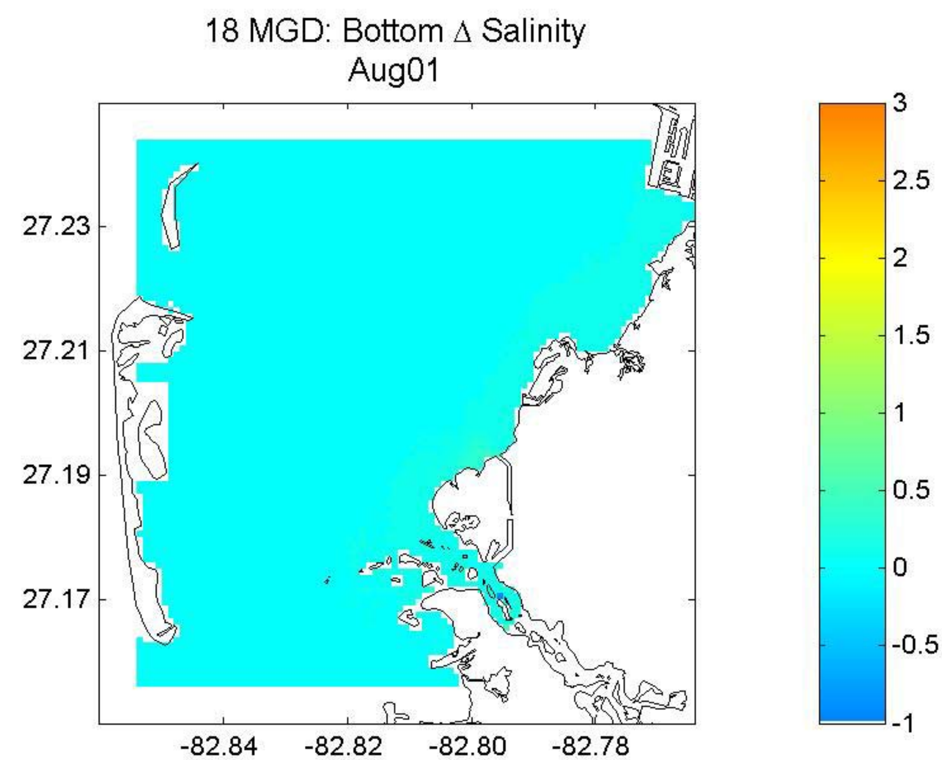
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Aug01
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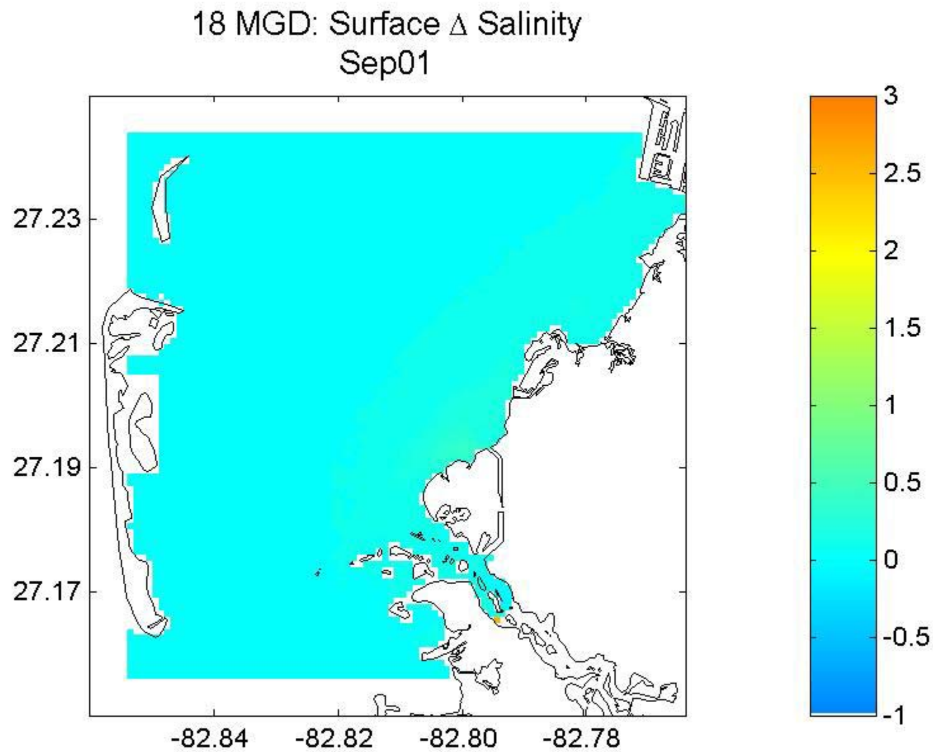
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Sep01
27.23
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27.19
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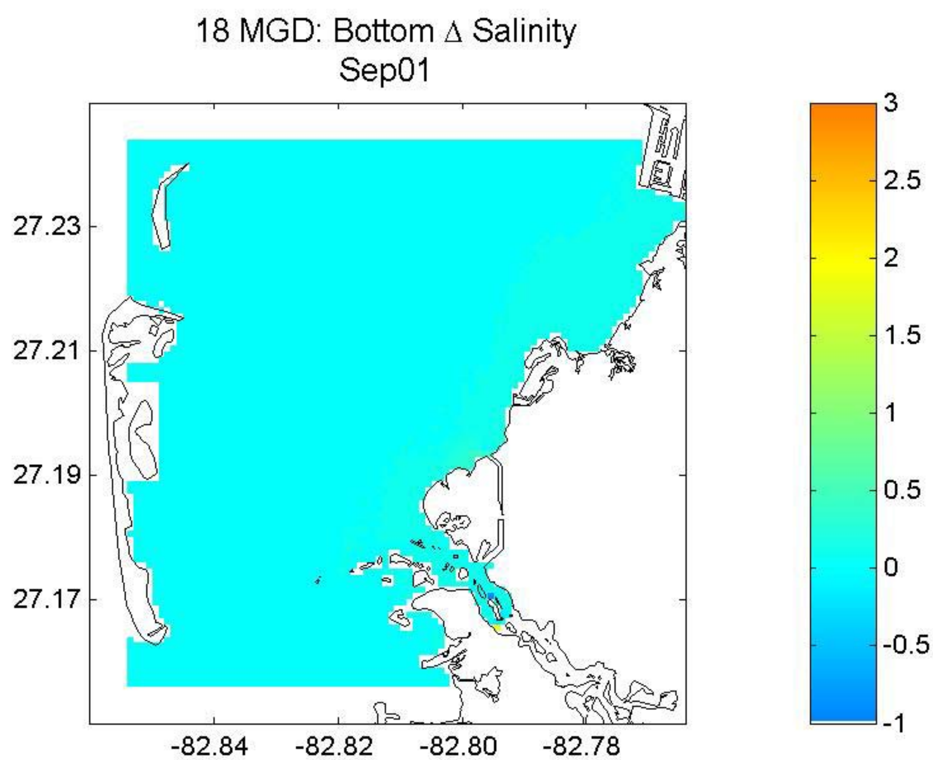
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Sep01
27.23
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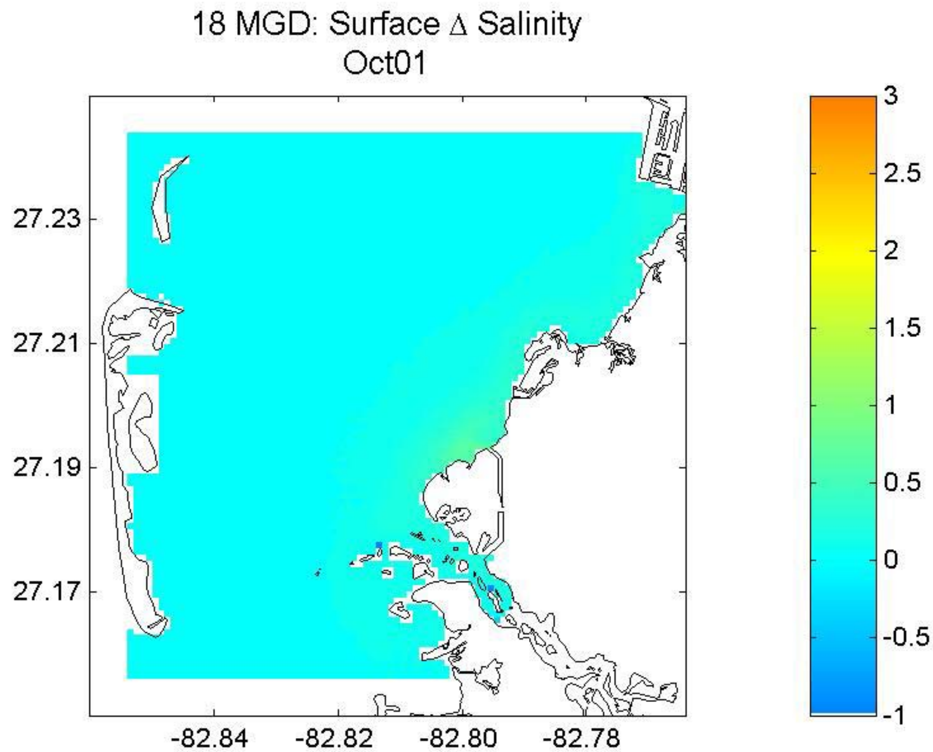
18 MGD: Surface Δ Salinity
Oct01
27.23
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27.19
27.17
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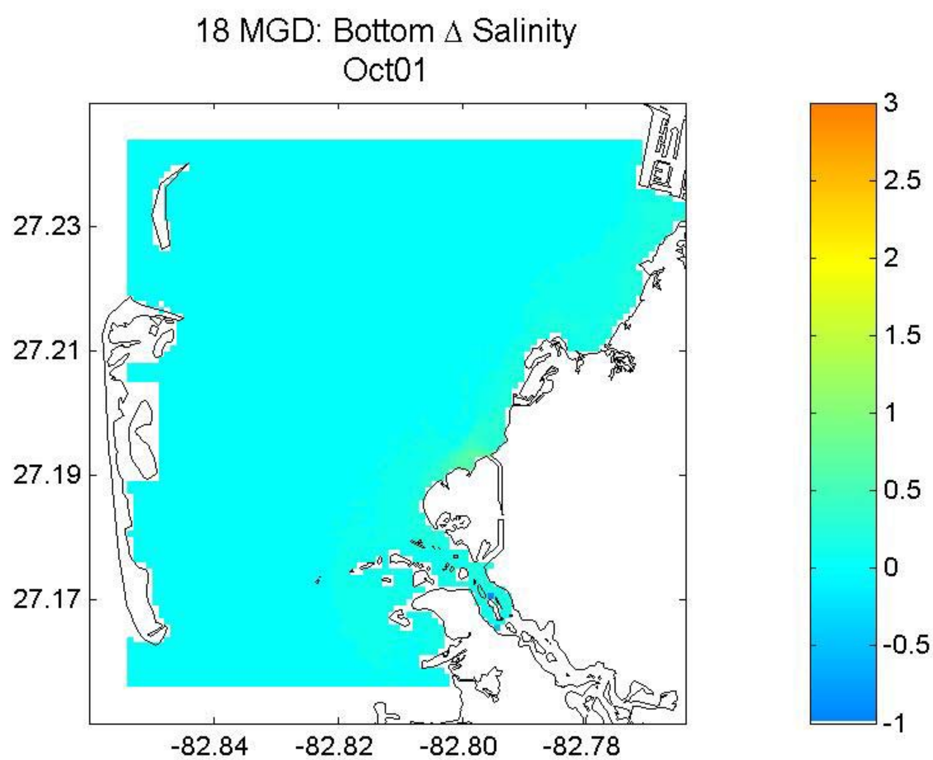
18 MGD: Bottom Δ Salinity
Oct01
27.23
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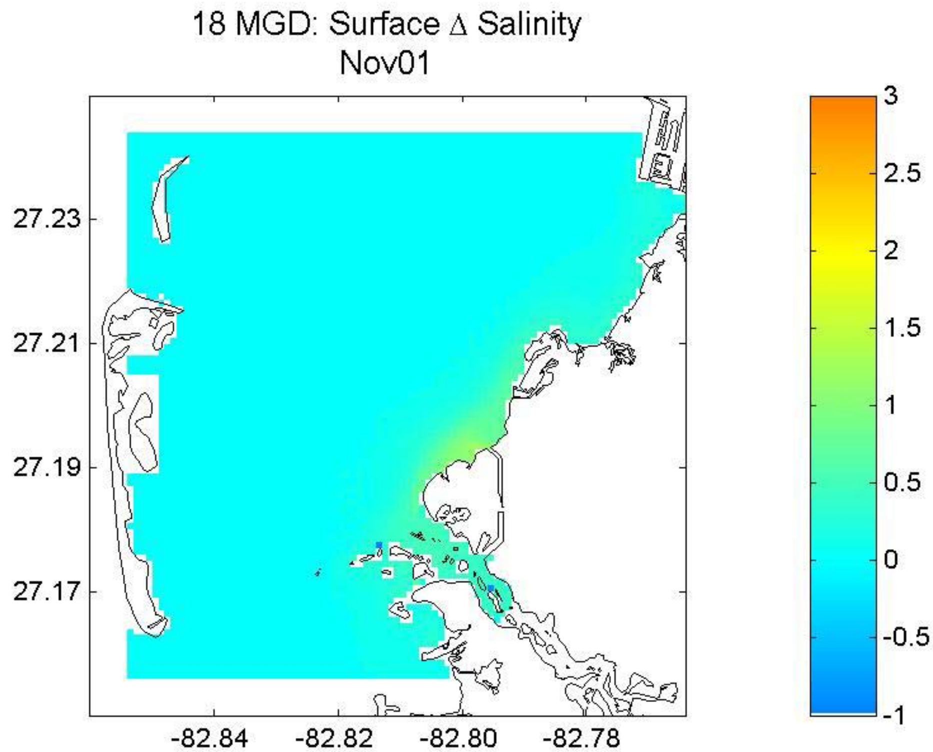
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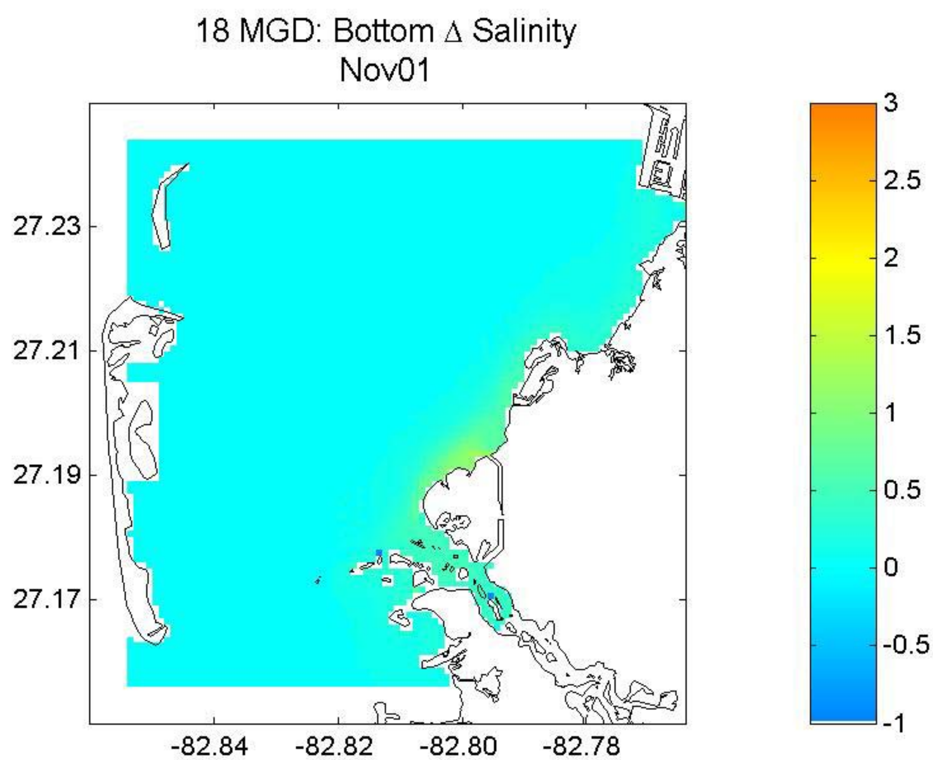
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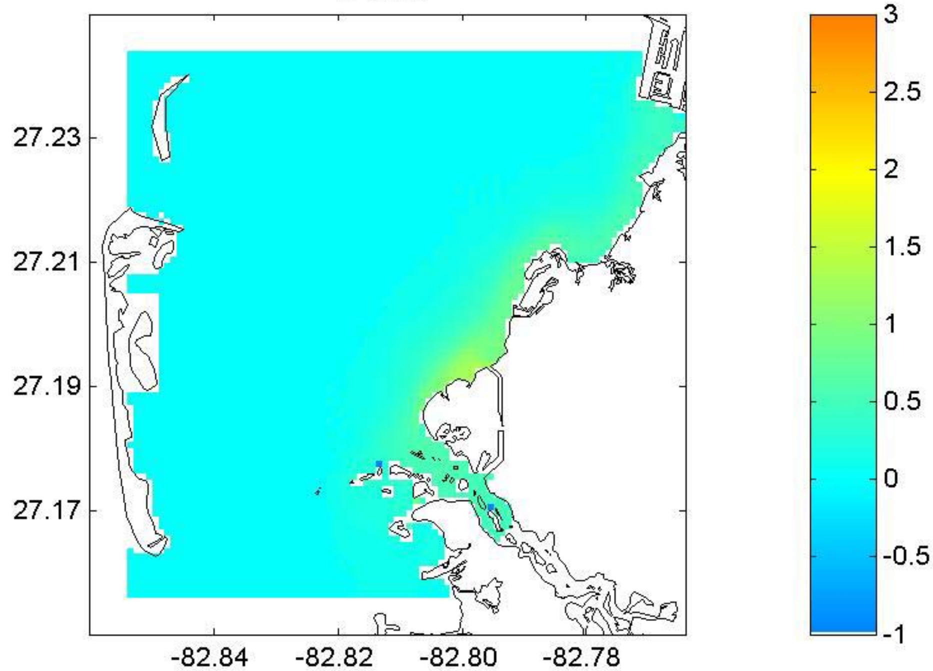
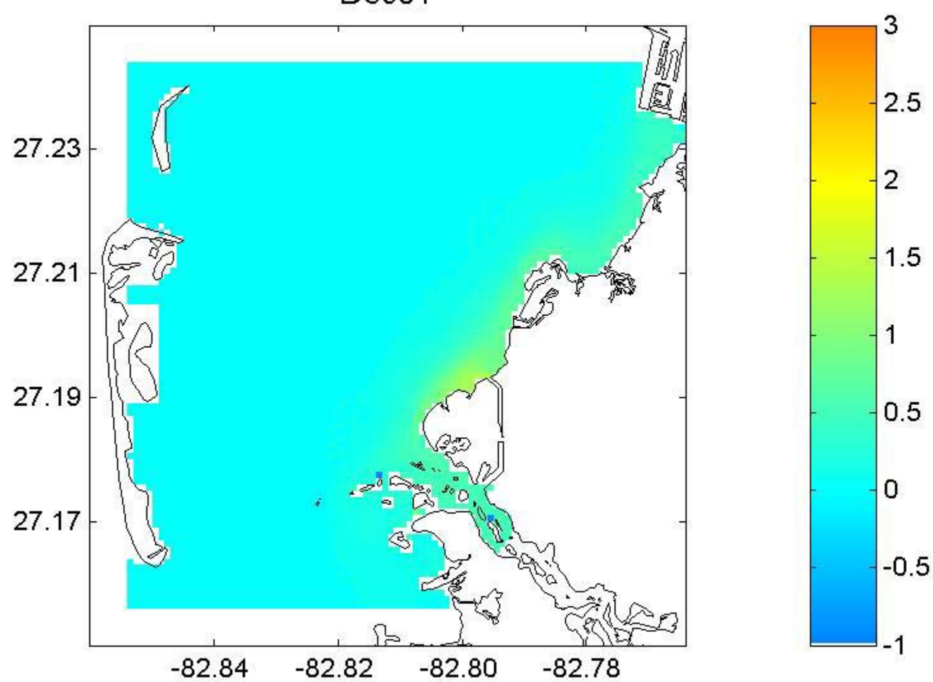
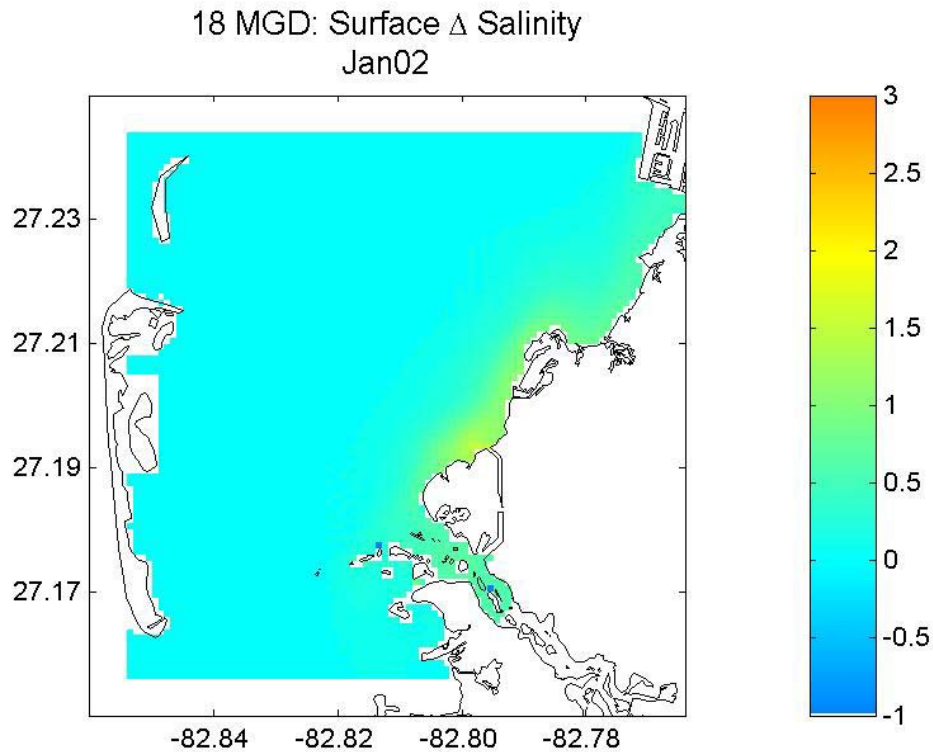
18 MGD: Surface Δ Salinity
Dec01



18 MGD: Bottom Δ Salinity
Dec01

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Jan02
27.23
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27.19
27.17
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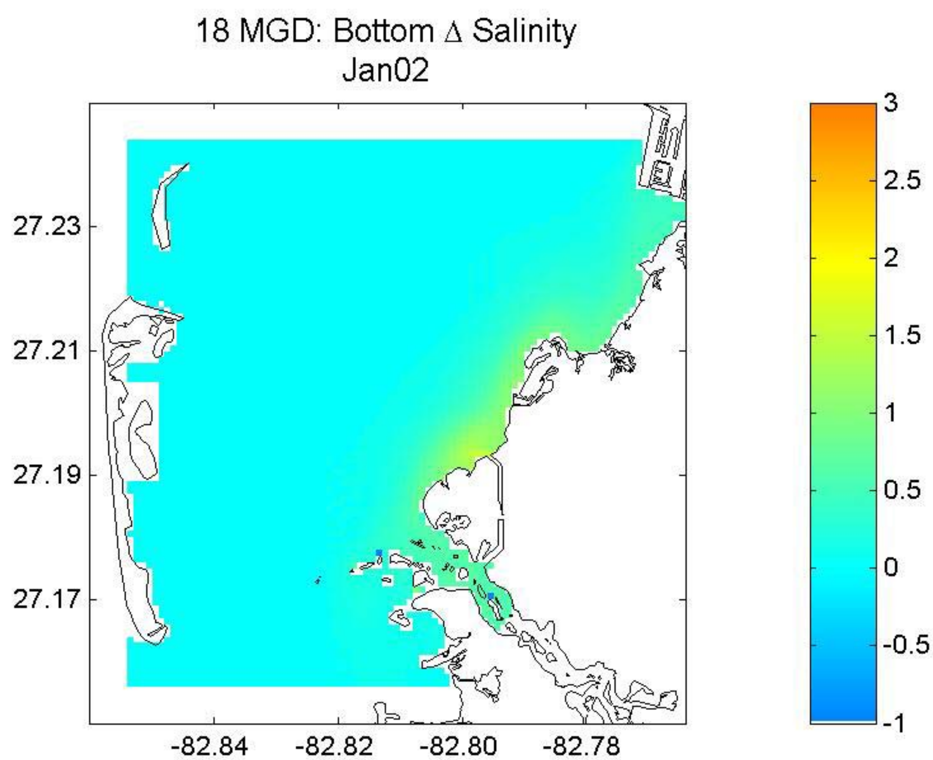
18 MGD: Bottom Δ Salinity
Jan02
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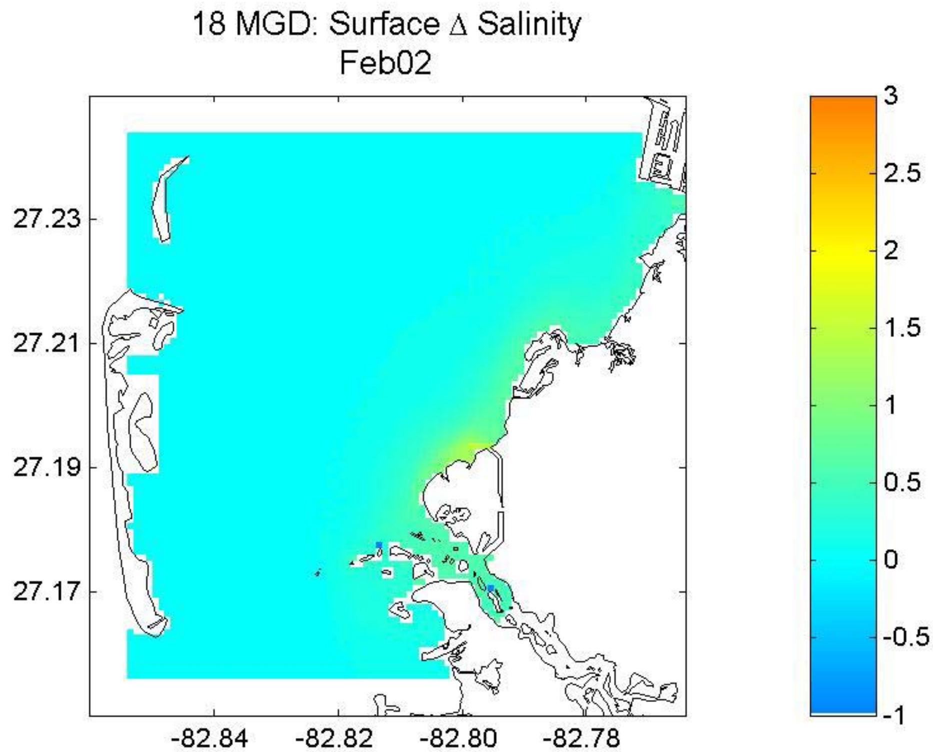
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Feb02
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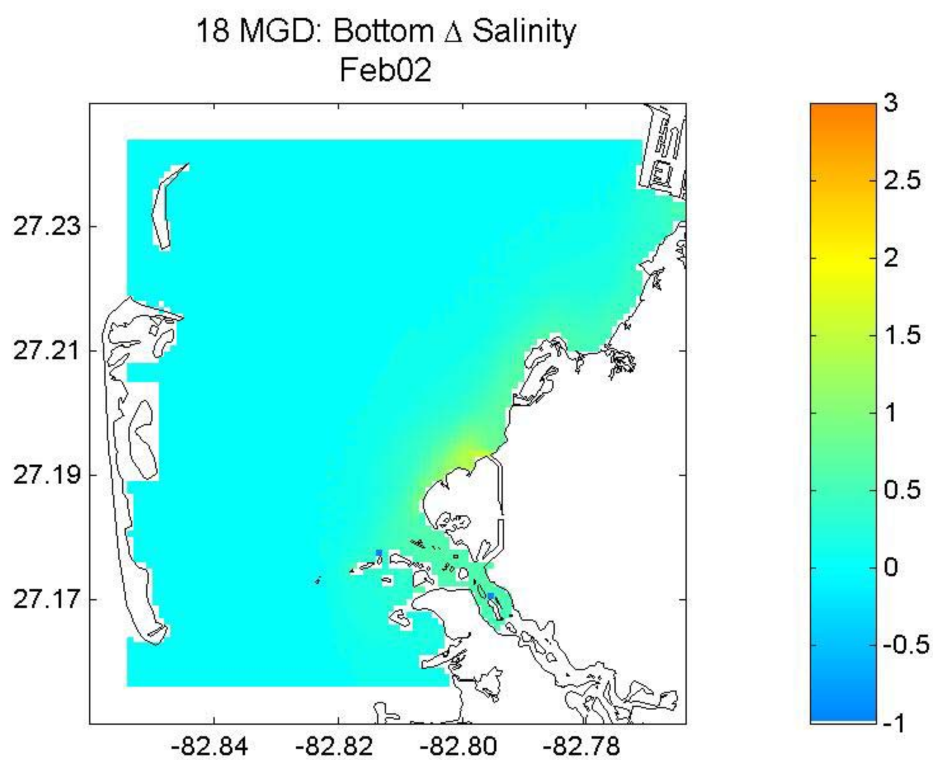
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Feb02
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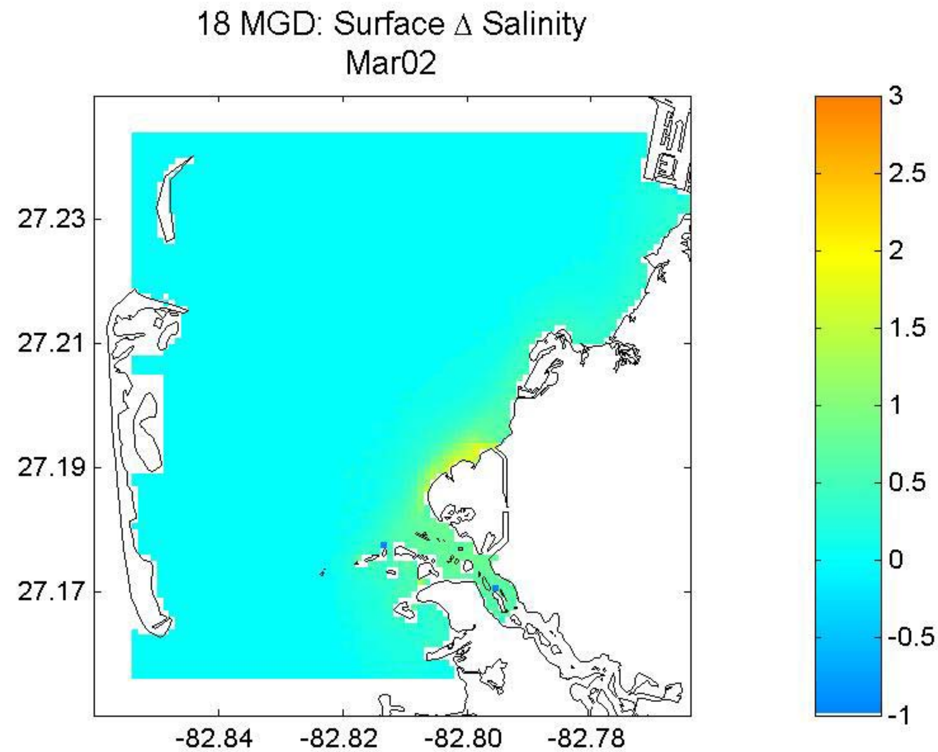
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Mar02
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27.19
27.17
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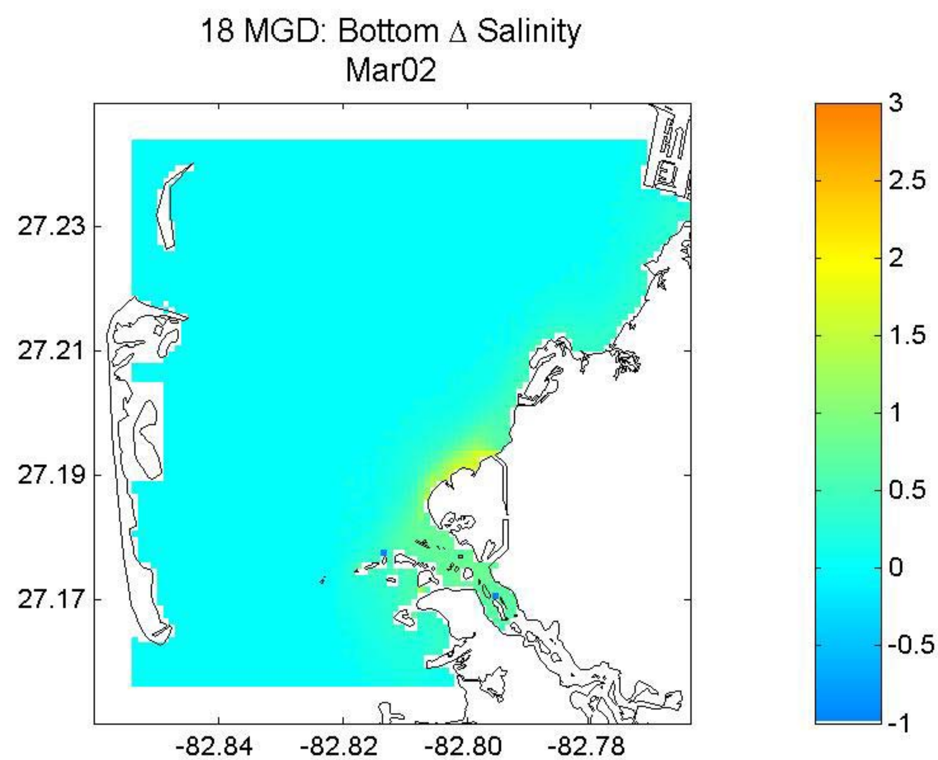
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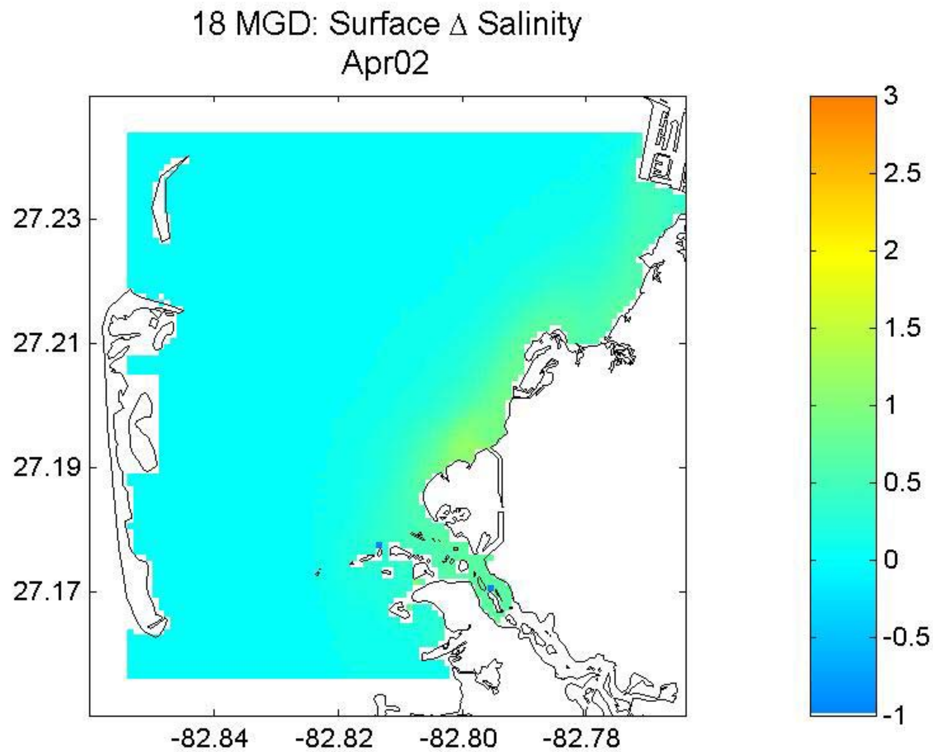
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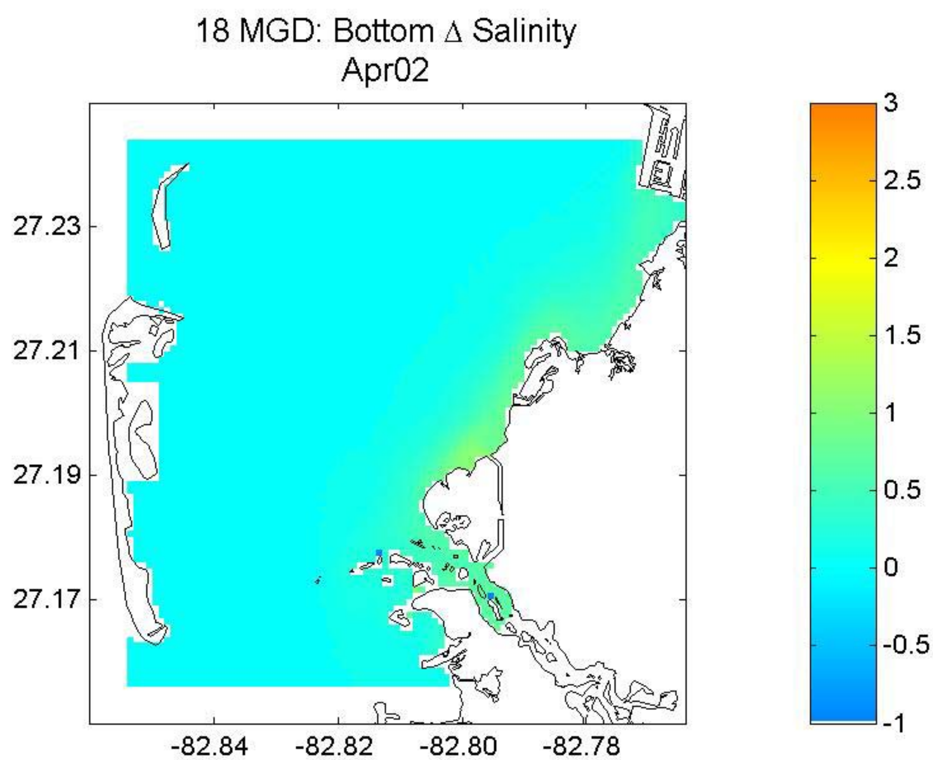
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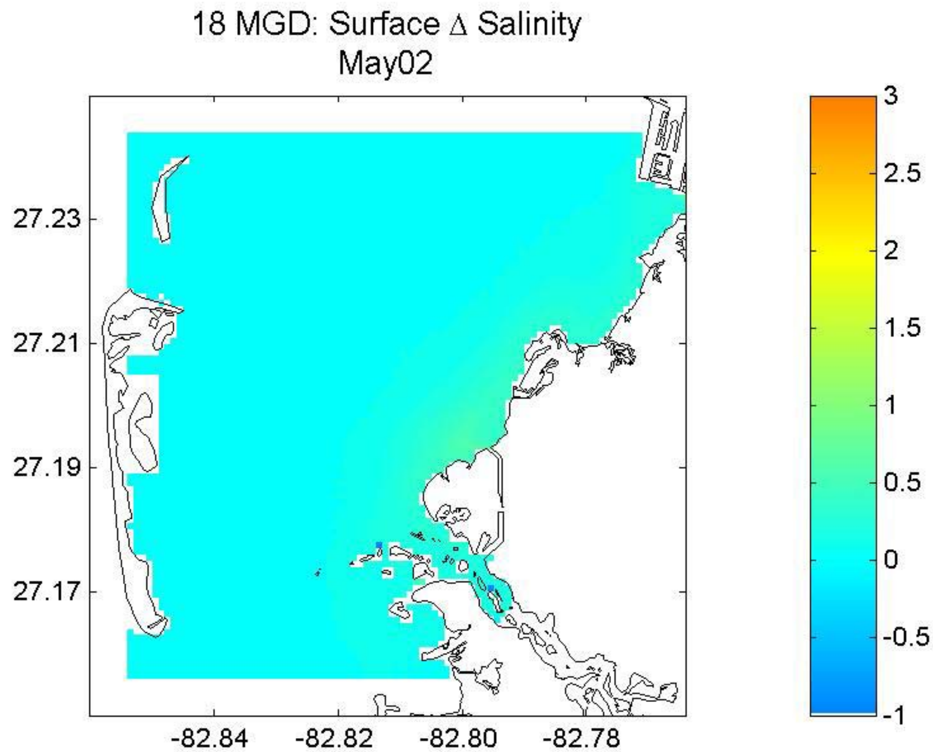
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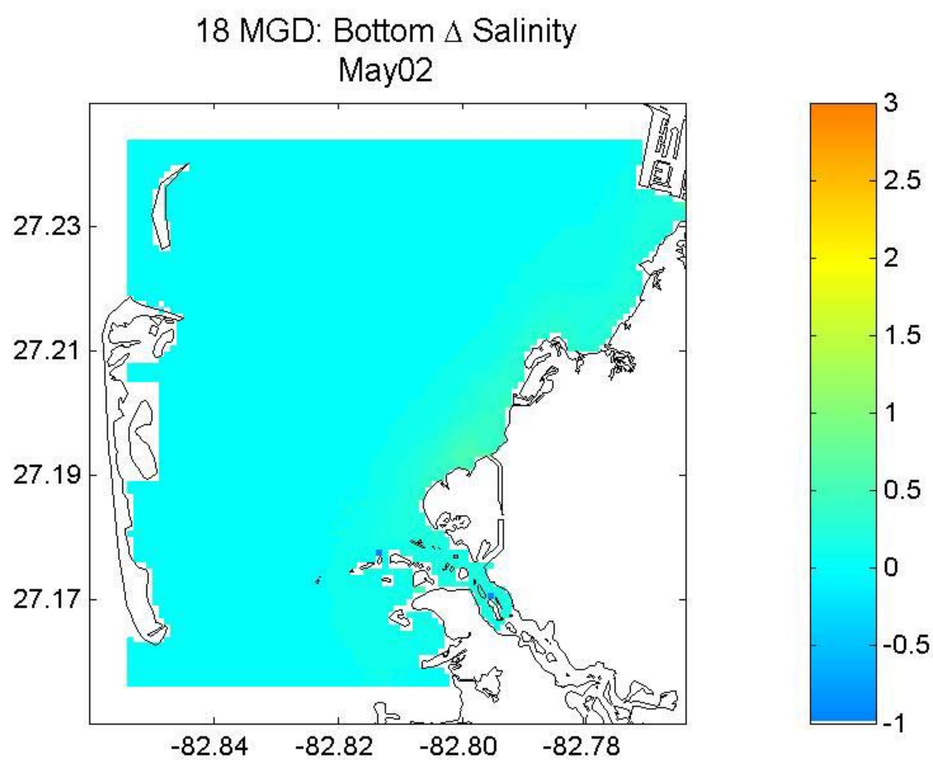
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May02
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-82.80
-82.78
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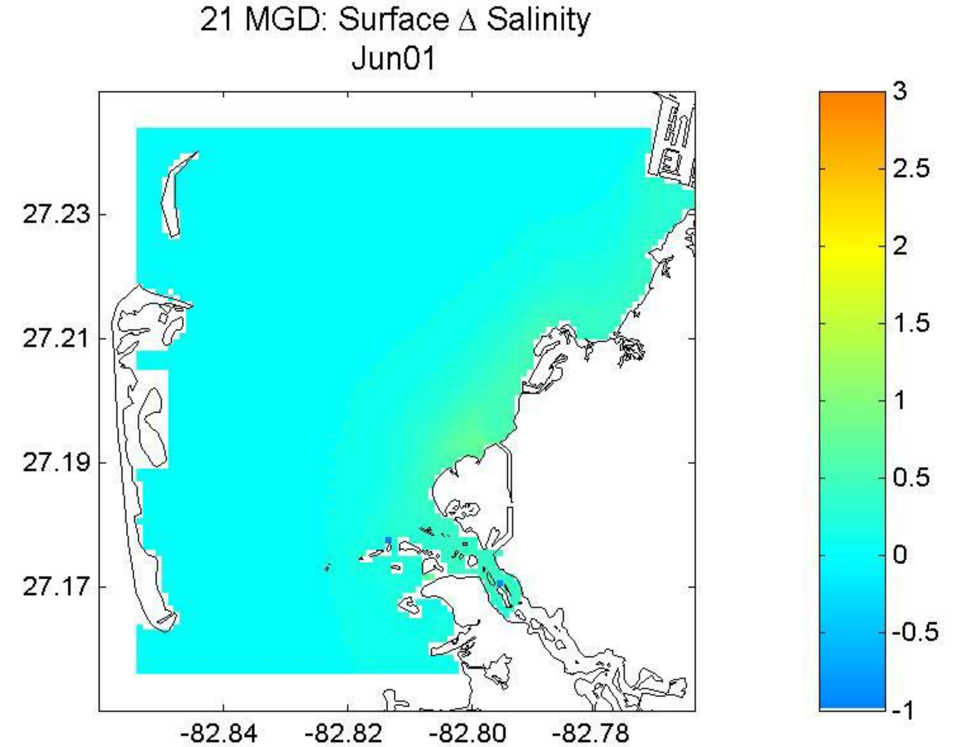
-1

Appendix III

Monthly Change in Nearshore Salinity from 21 MGD Product Water Scenario


21 MGD: Surface Δ Salinity
Jun01
27.23
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27.17
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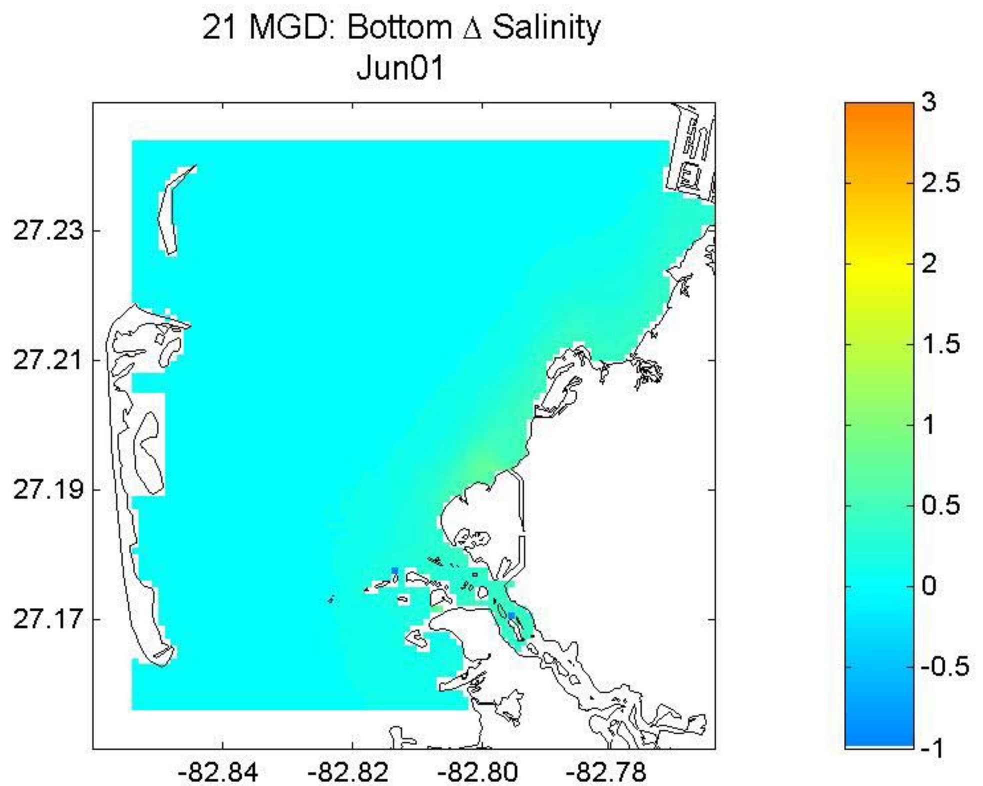
21 MGD: Bottom Δ Salinity
Jun01
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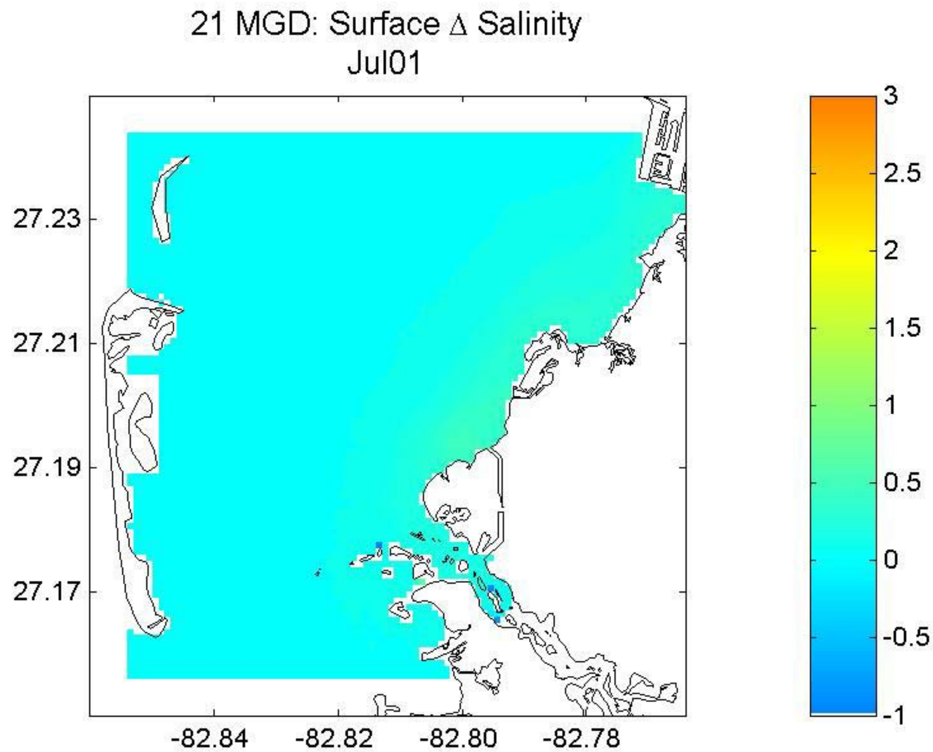
21 MGD: Surface Δ Salinity
Jul01
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27.19
27.17
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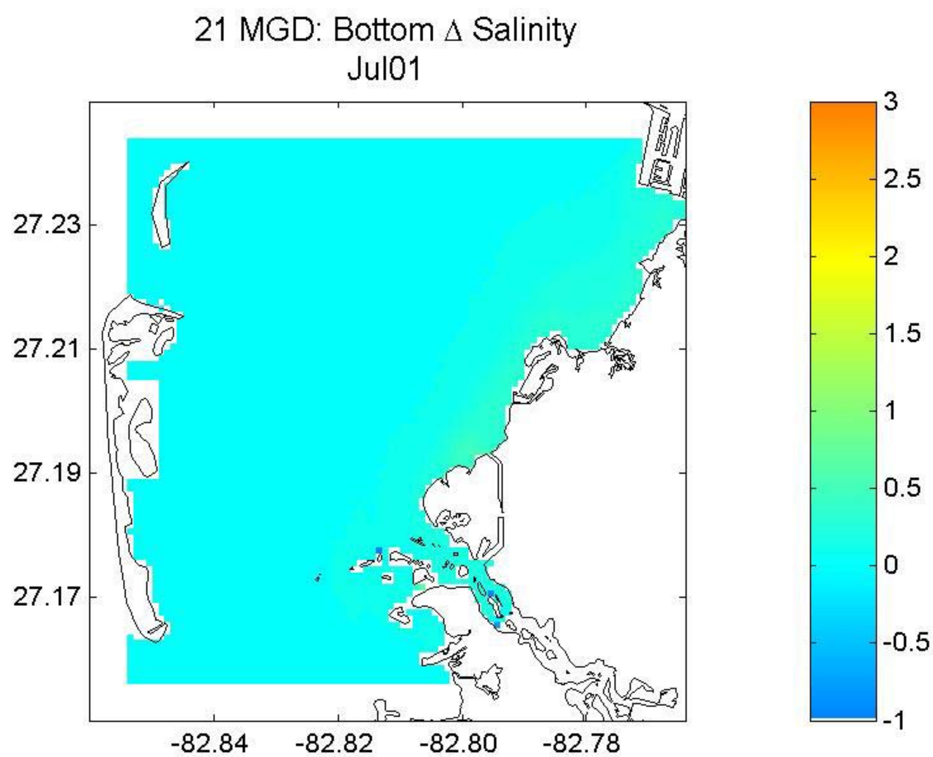
21 MGD: Bottom Δ Salinity
Jul01
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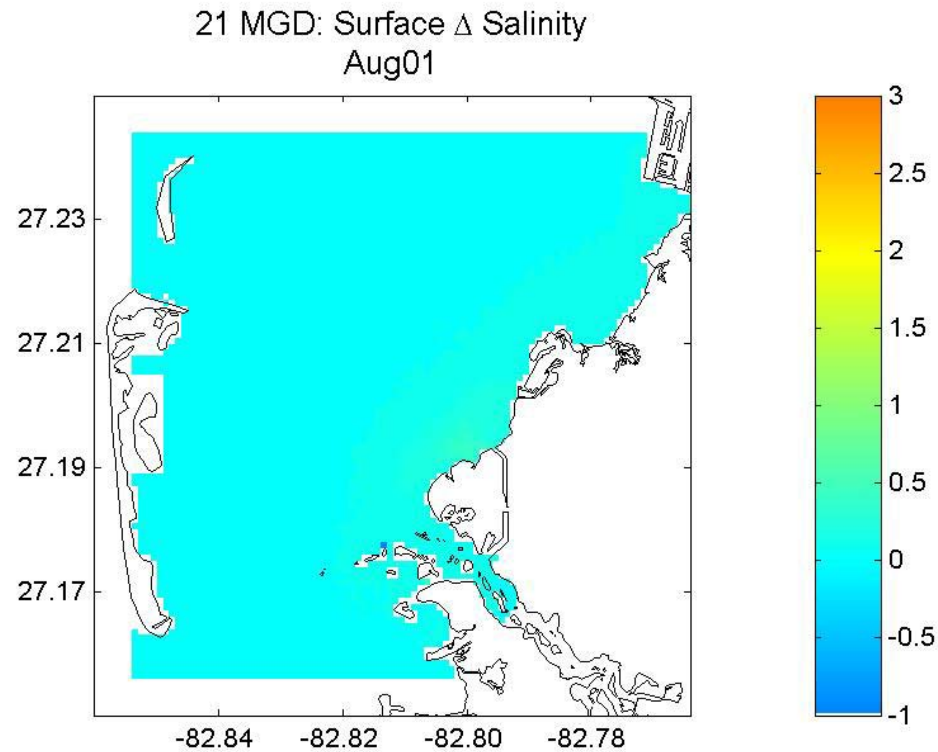
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Aug01
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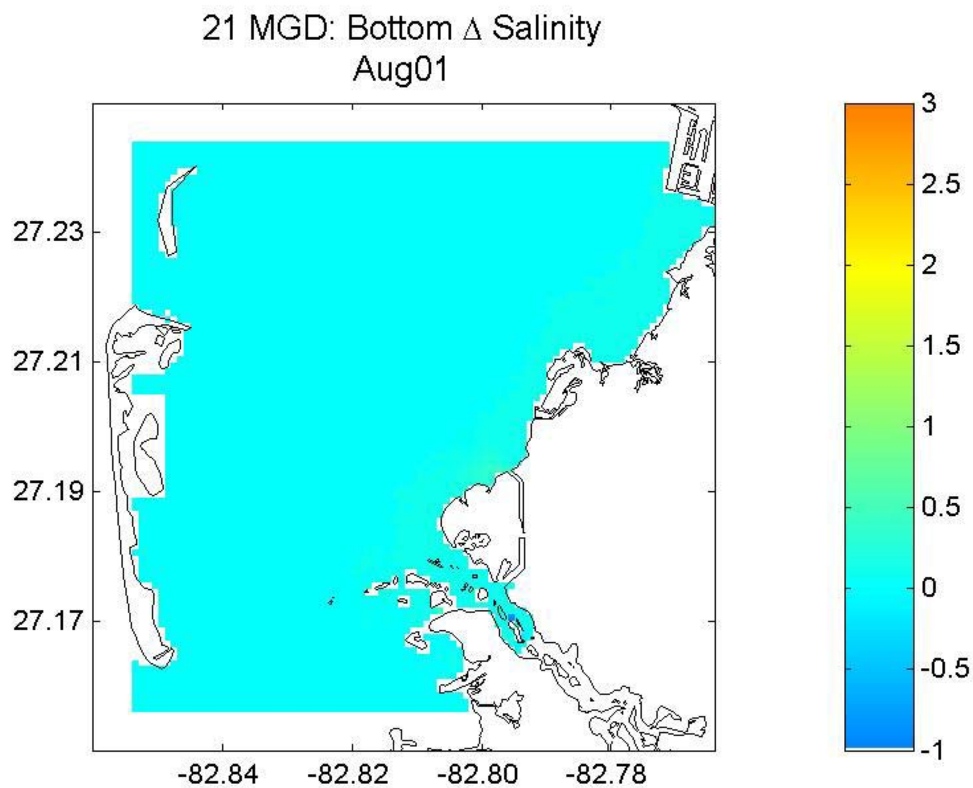
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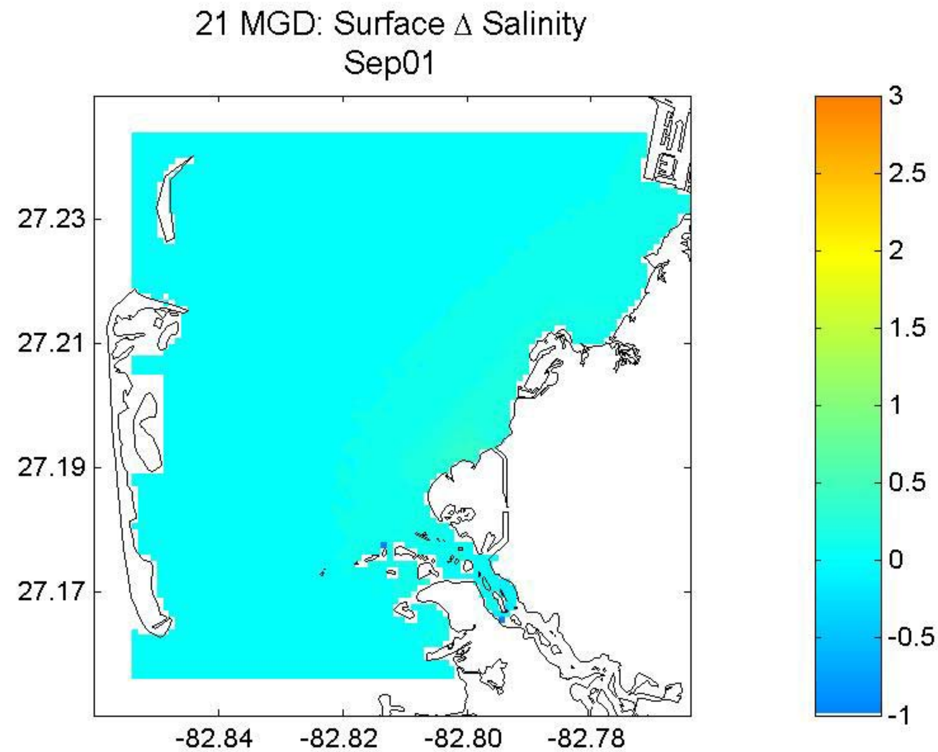
21 MGD: Surface Δ Salinity
Sep01
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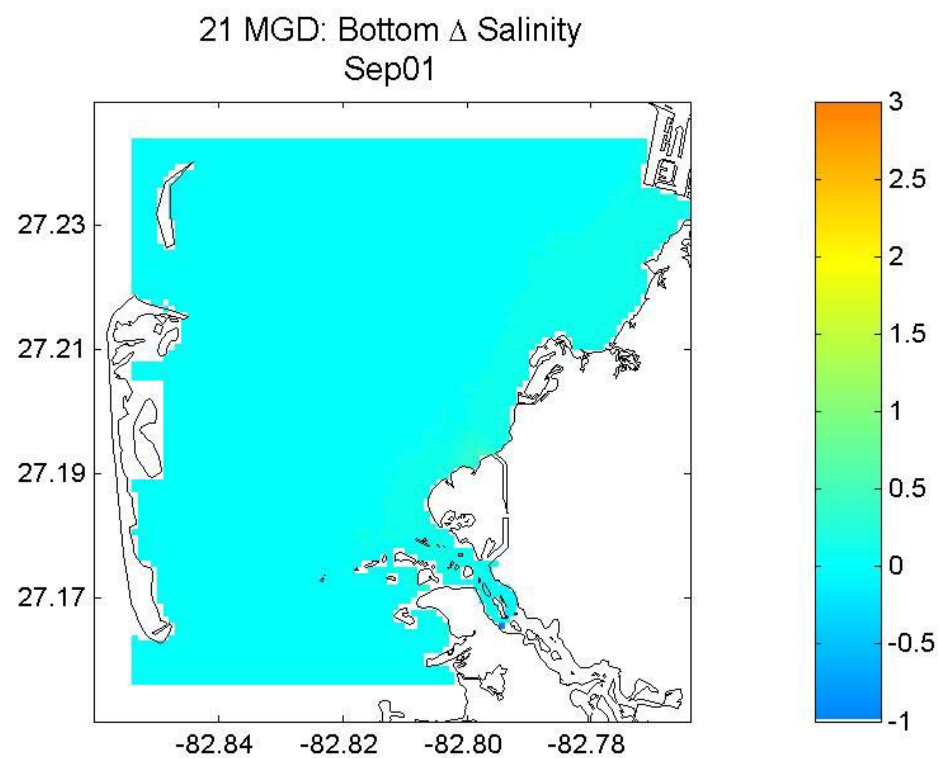
21 MGD: Bottom Δ Salinity
Sep01
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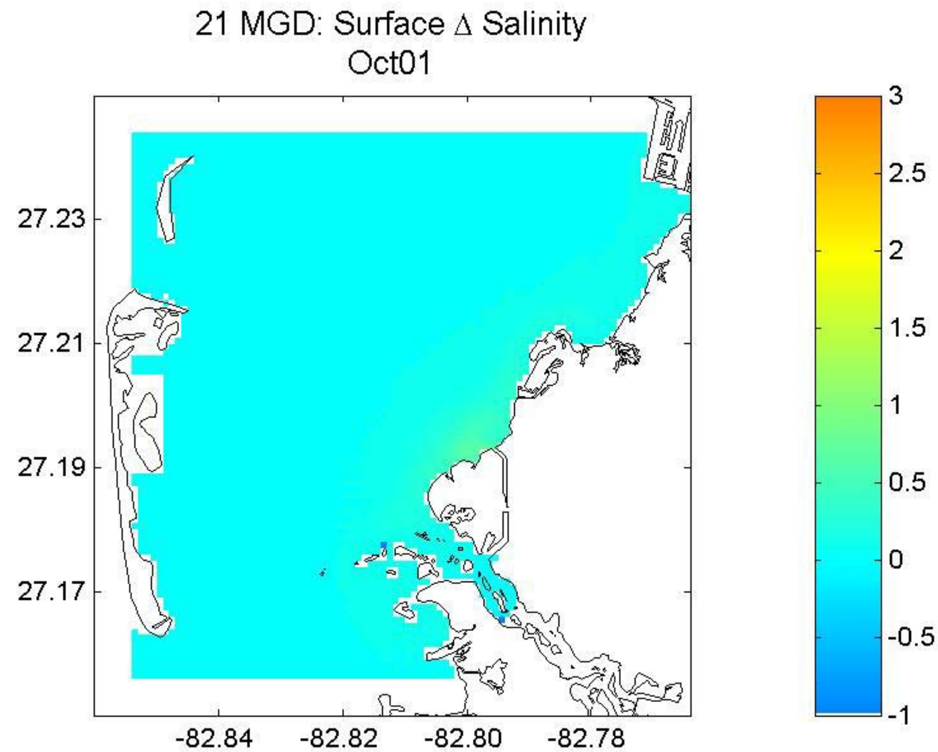
21 MGD: Surface Δ Salinity
Oct01
27.23
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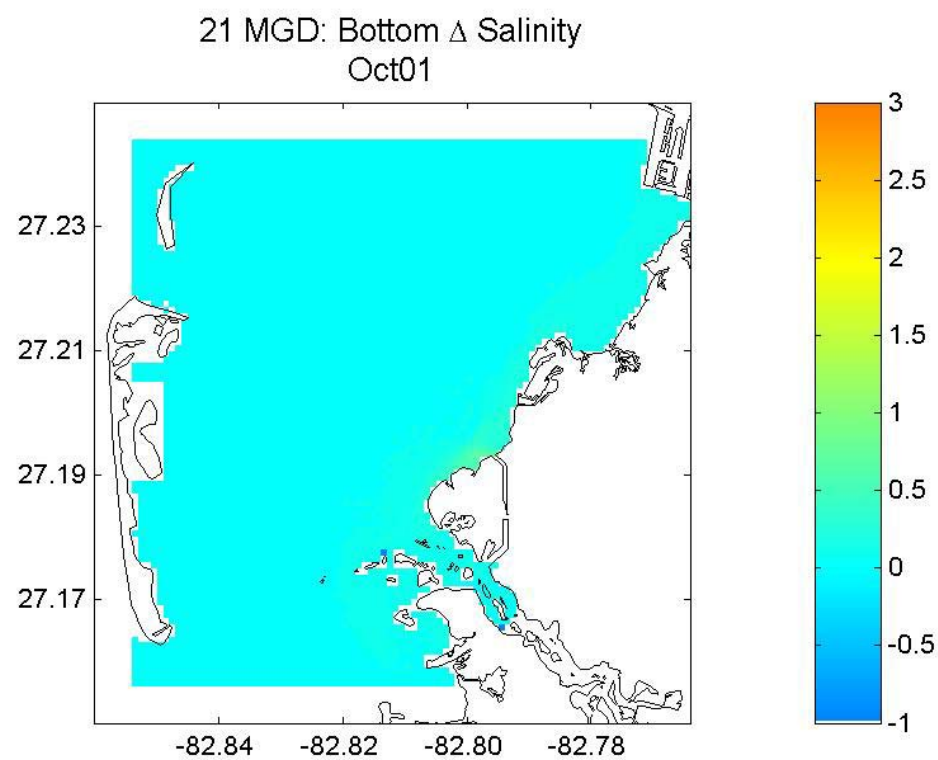
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Oct01
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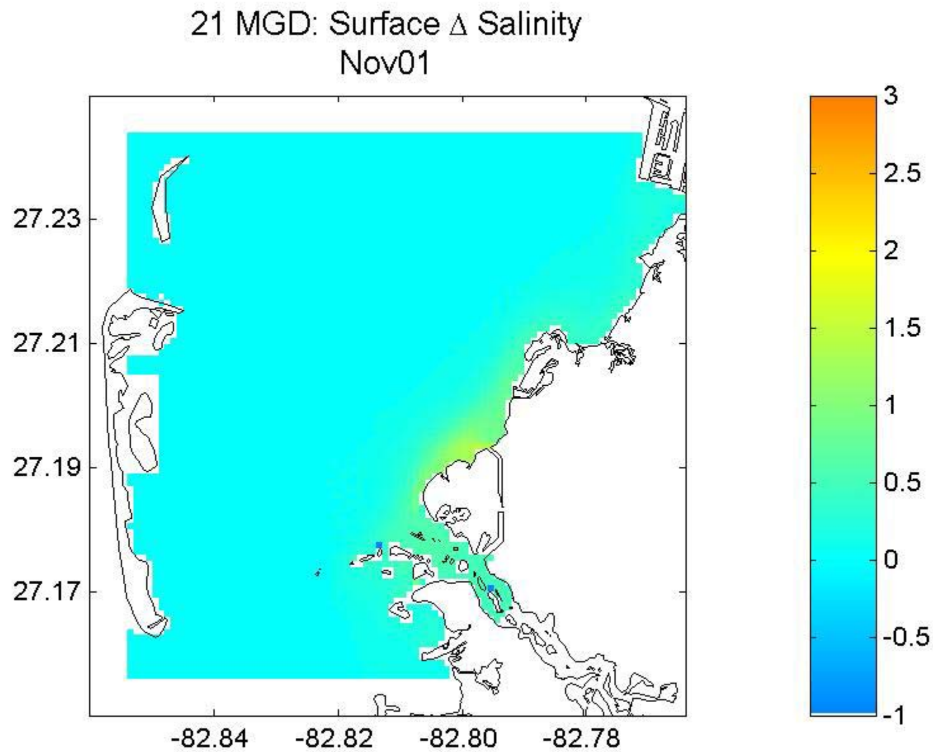
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Nov01
27.23
27.21
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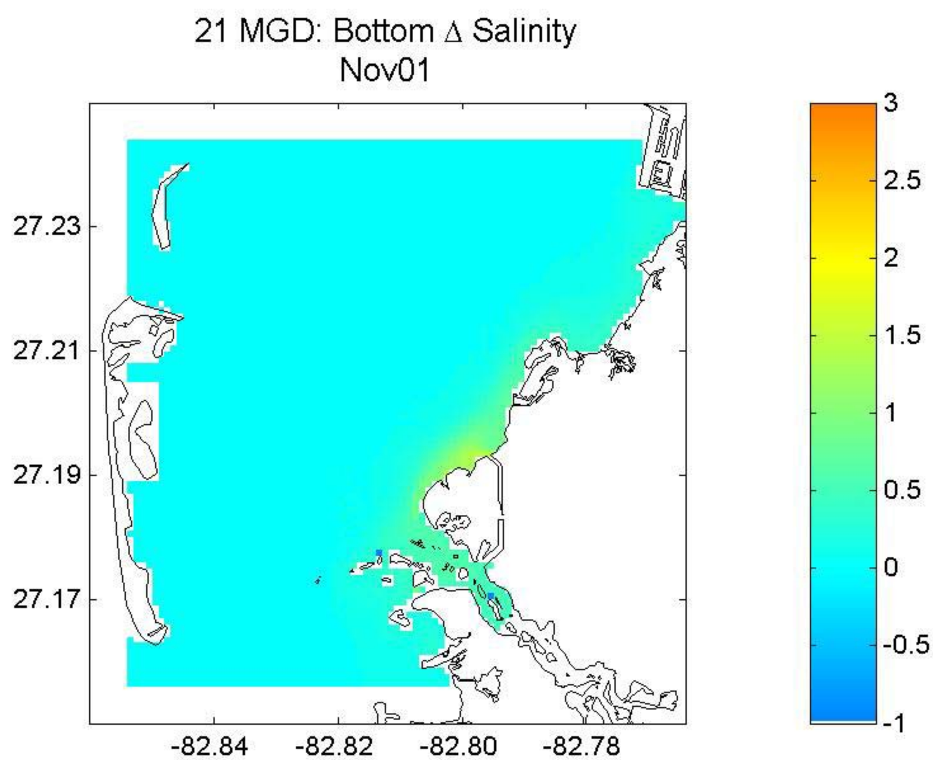
21 MGD: Bottom Δ Salinity
Nov01
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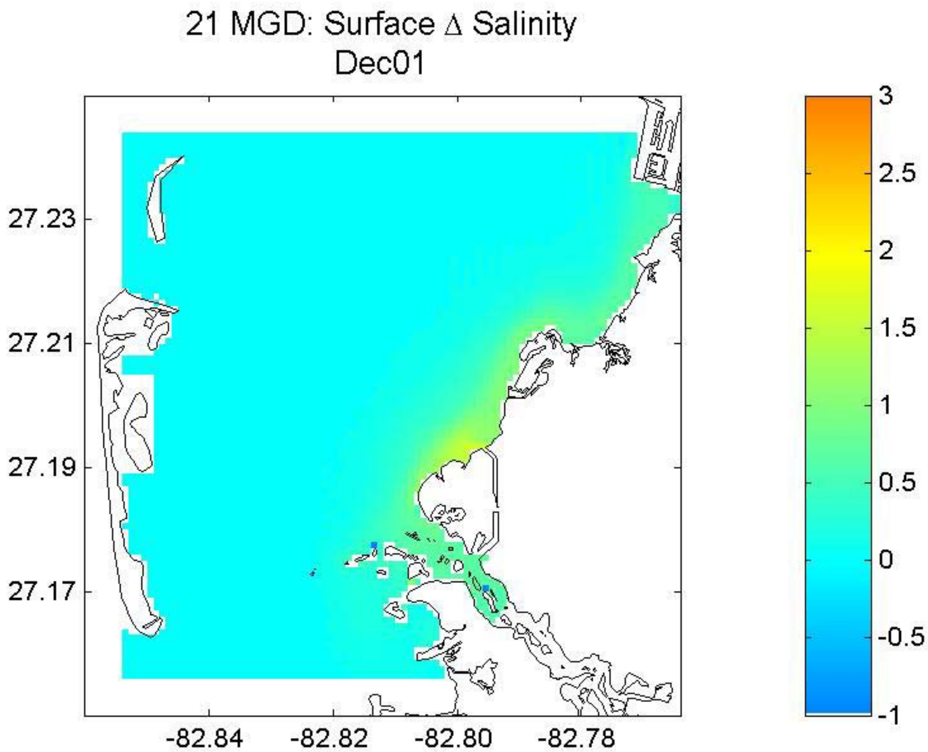

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Dec01
27.23
27.21
27.19
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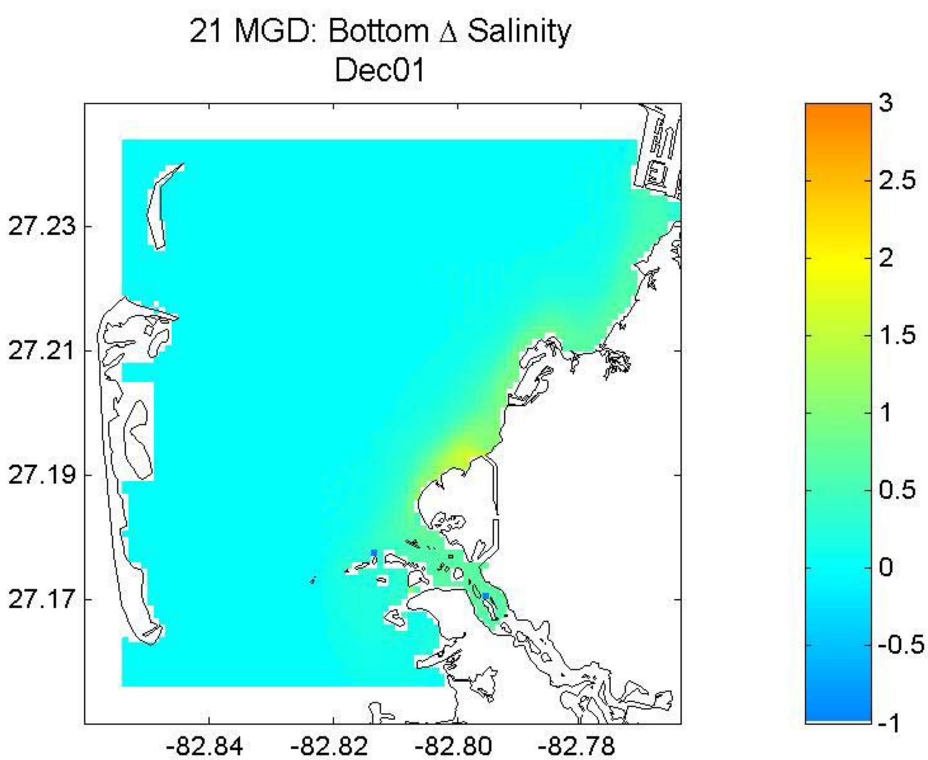

21 MGD: Bottom Δ Salinity
Dec01
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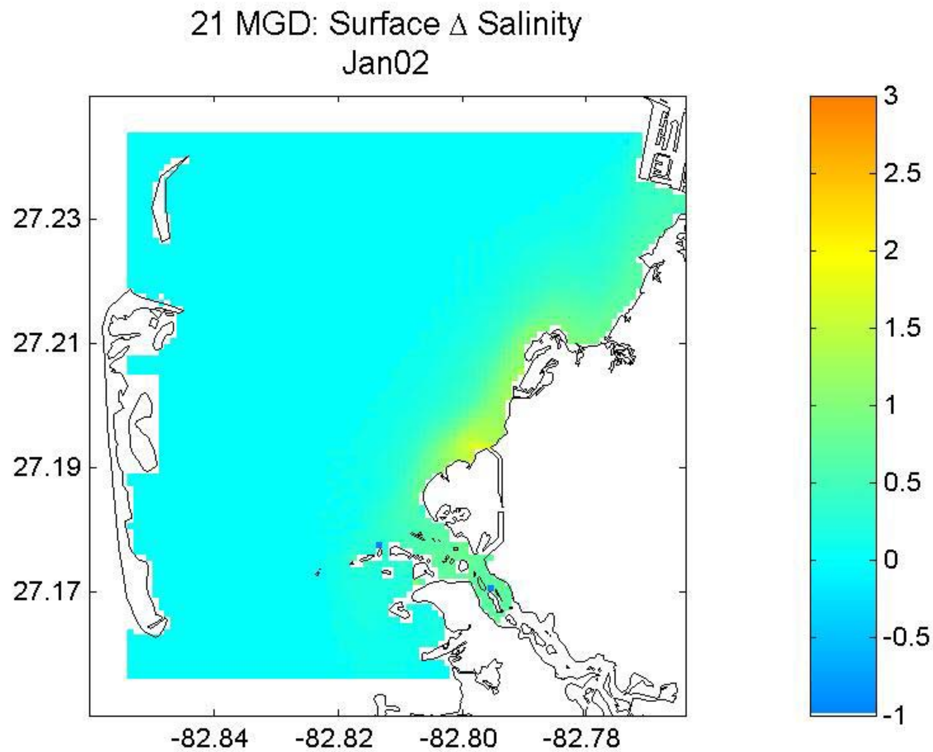
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Jan02
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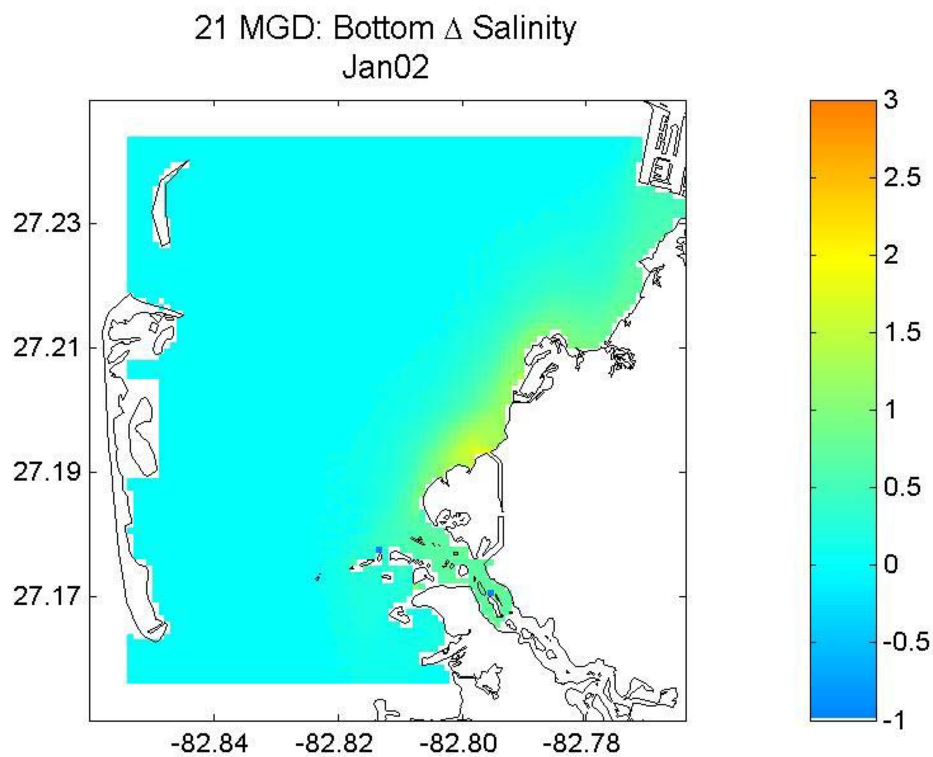
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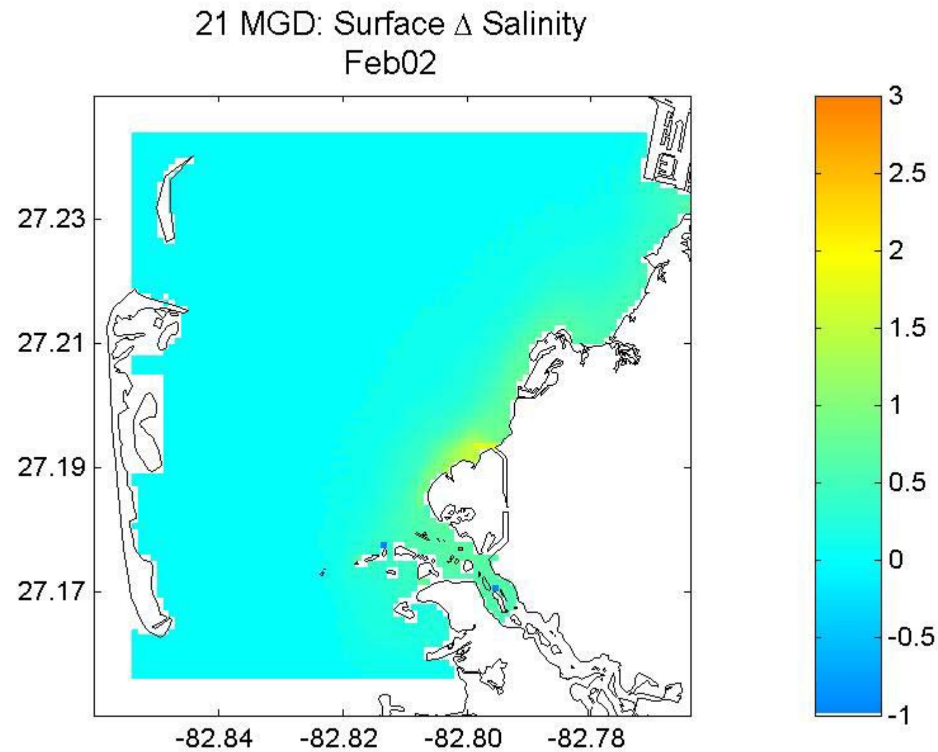
21 MGD: Surface Δ Salinity
Feb02
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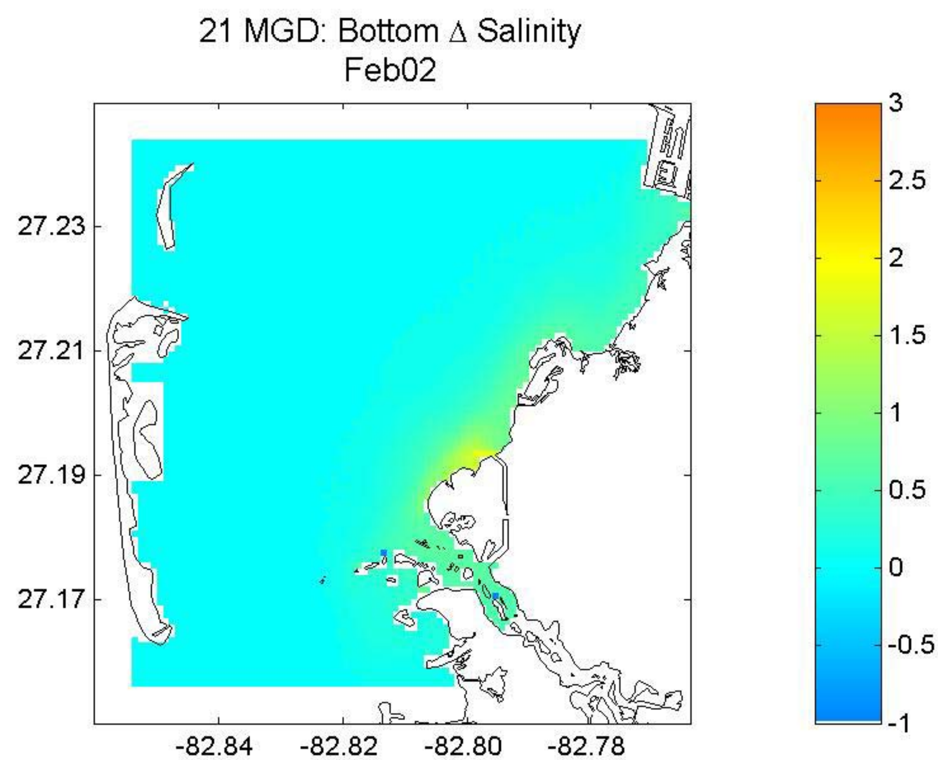
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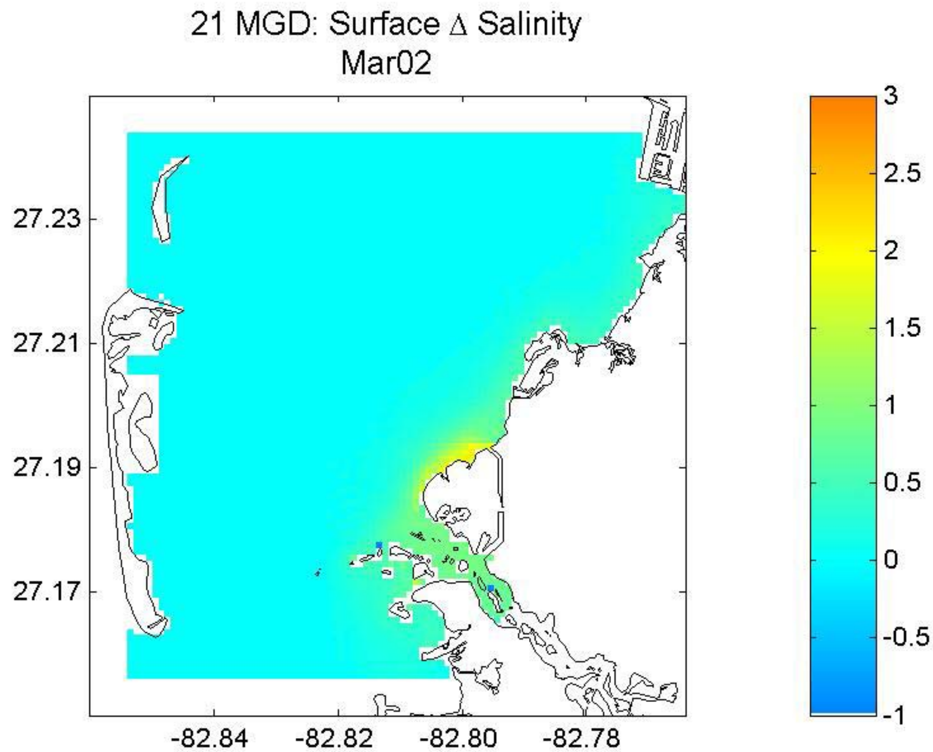
21 MGD: Surface Δ Salinity
Mar02
27.23
27.21
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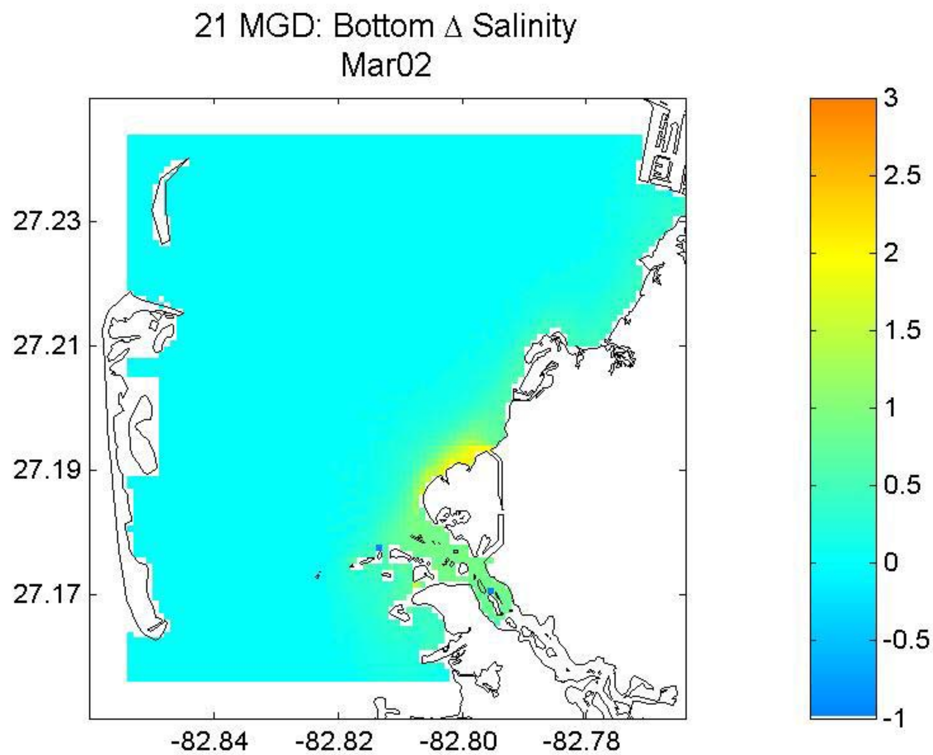
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Mar02
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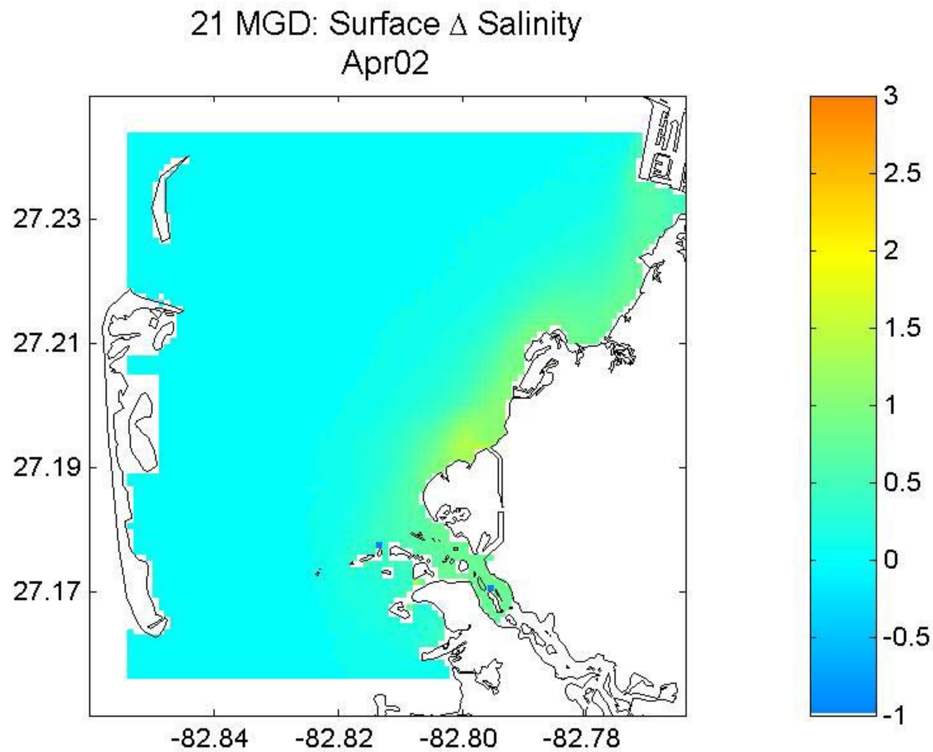
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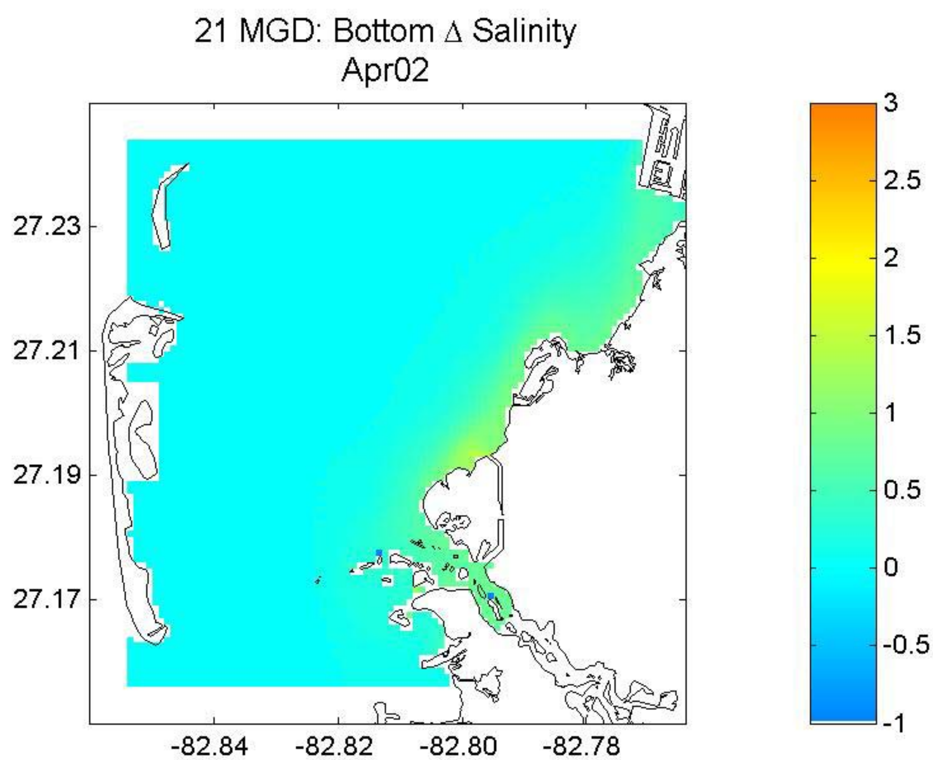
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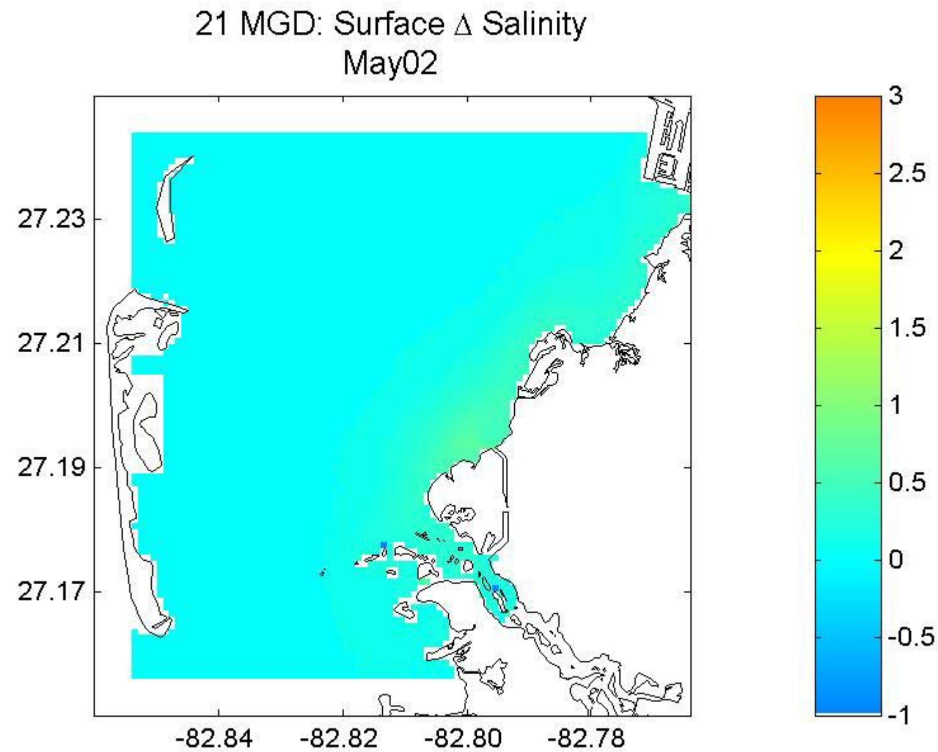
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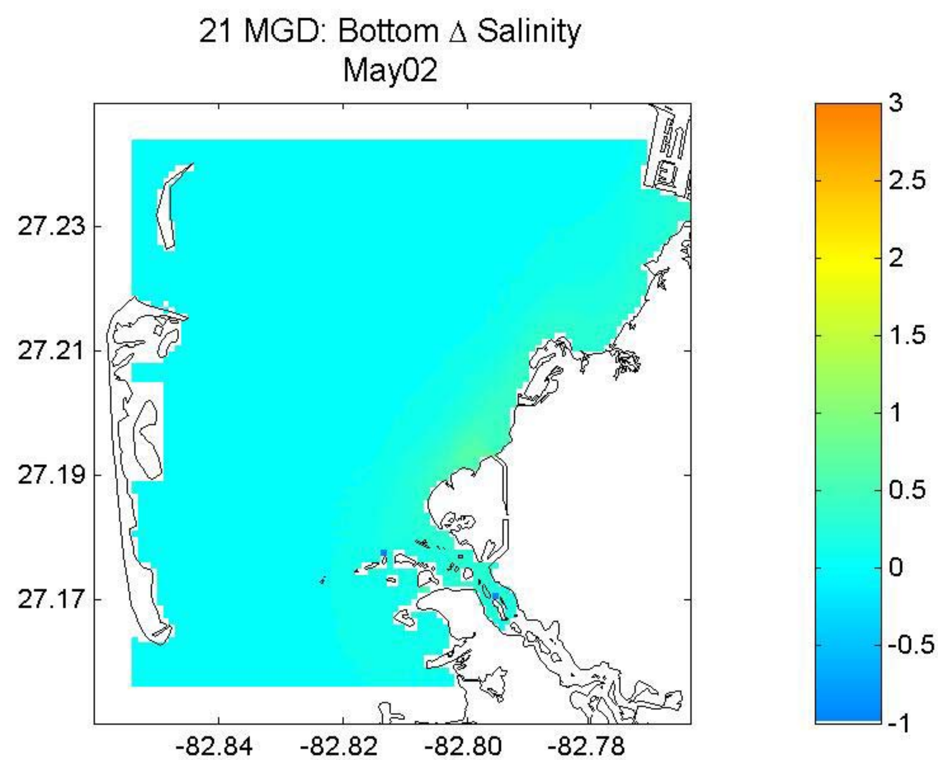
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May02
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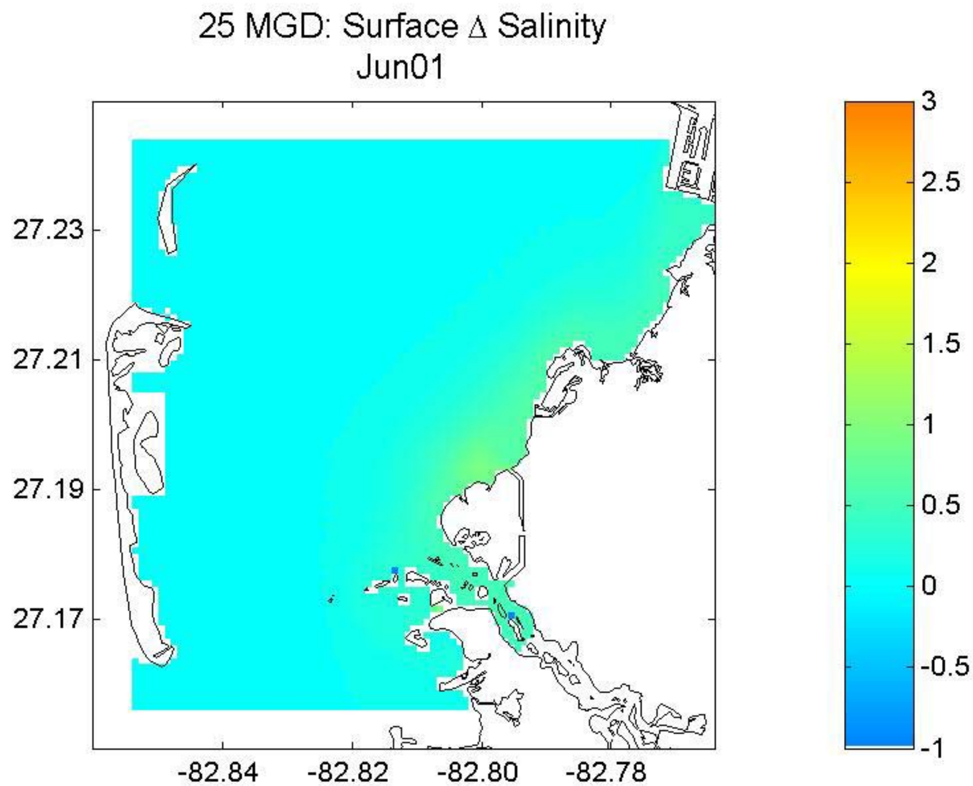
Appendix IV

Monthly Change in Nearshore Salinity from 25 MGD Product Water Scenario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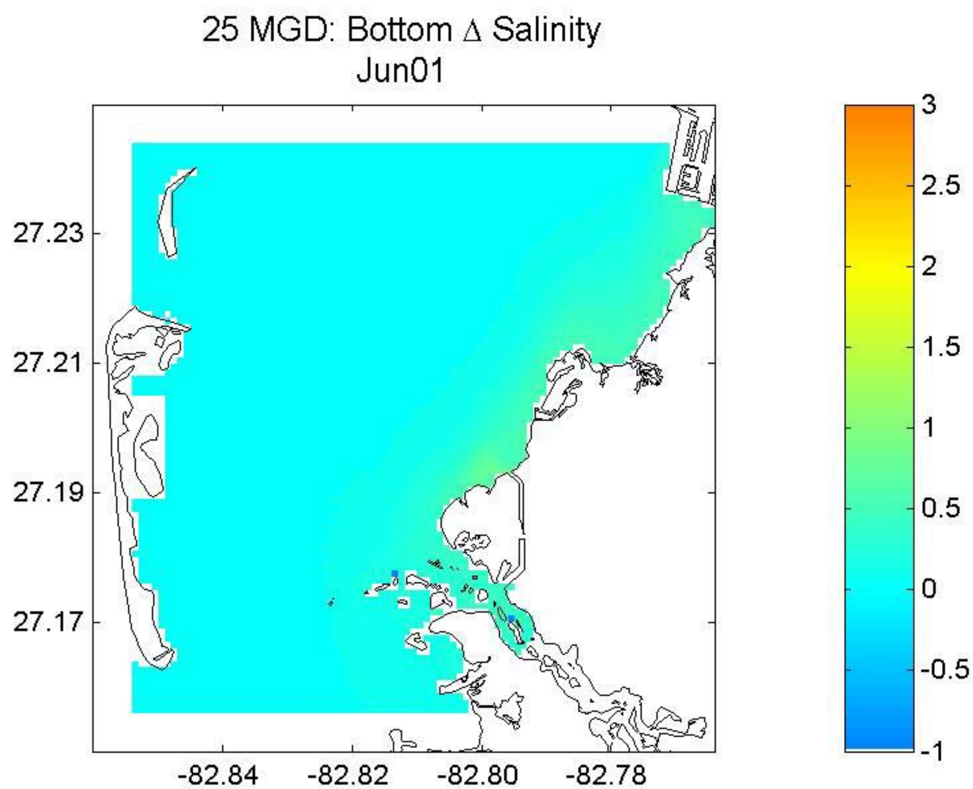
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27.17
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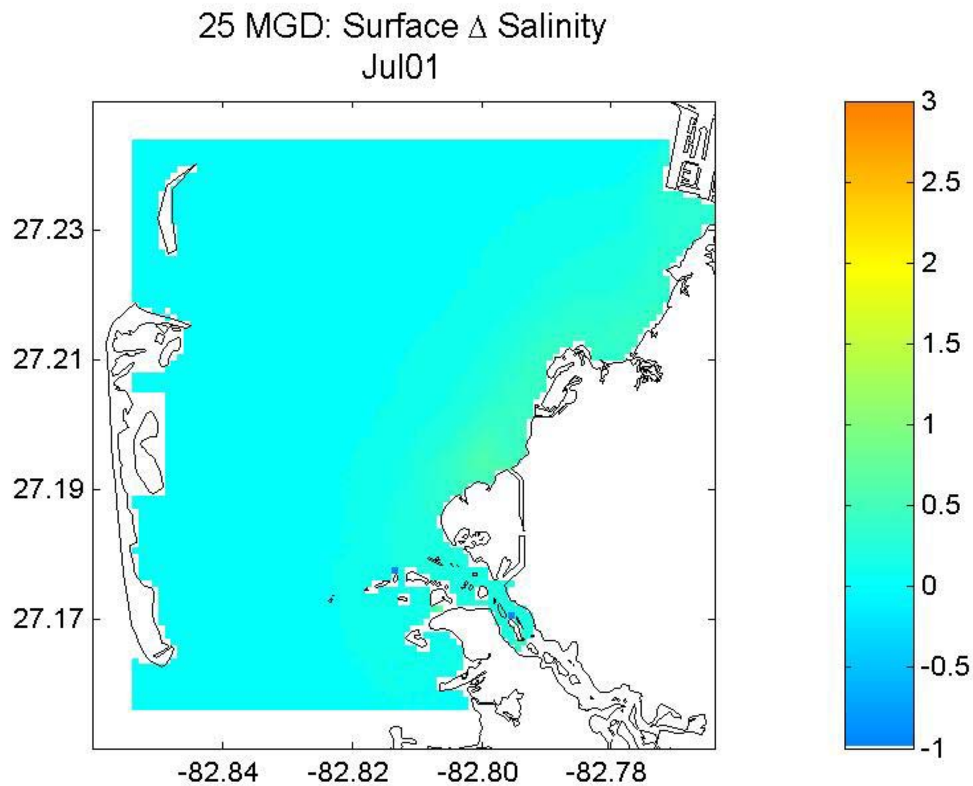
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Jul01
27.23
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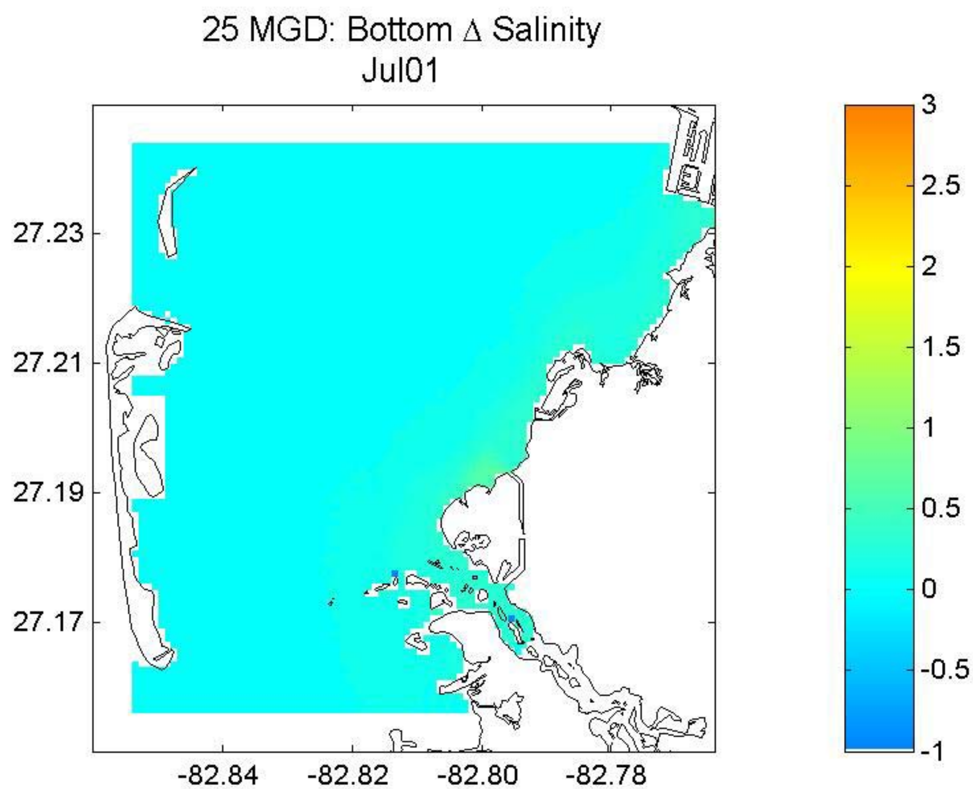
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Jul01
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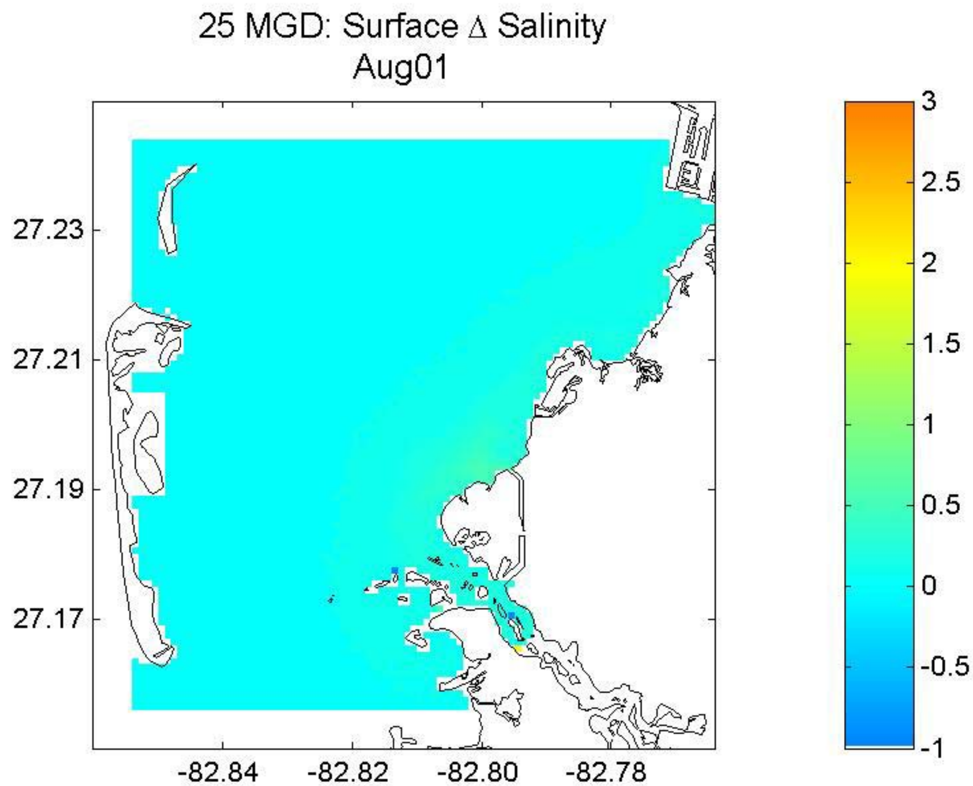
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Aug01
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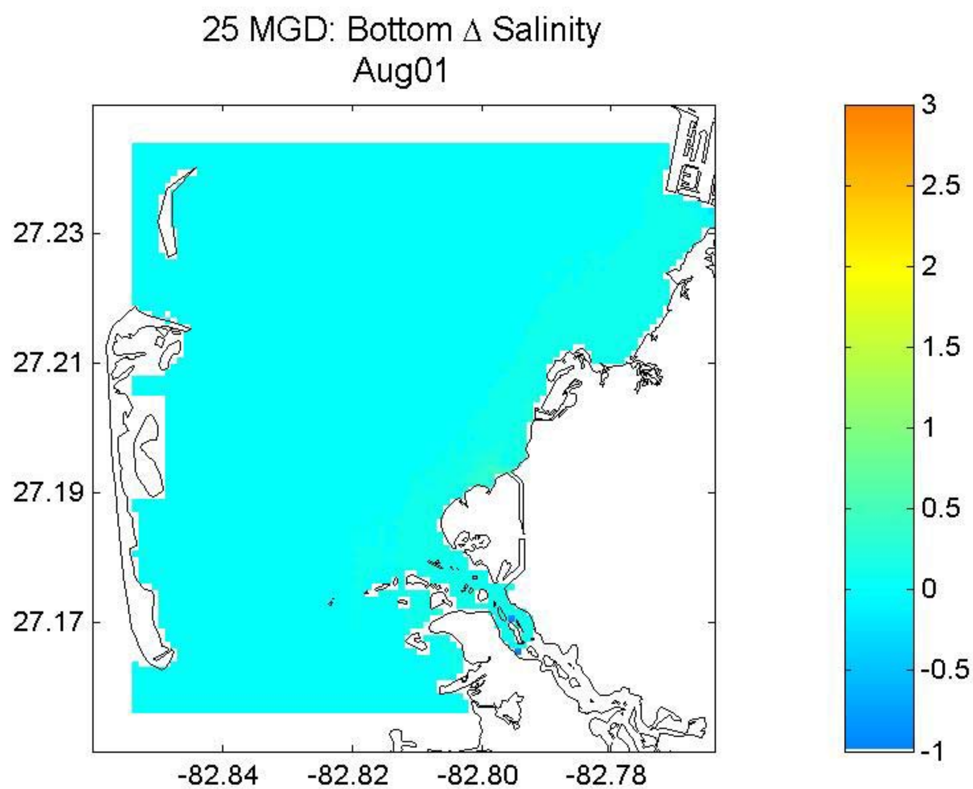
25 MGD: Bottom Δ Salinity
Aug01
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27.21
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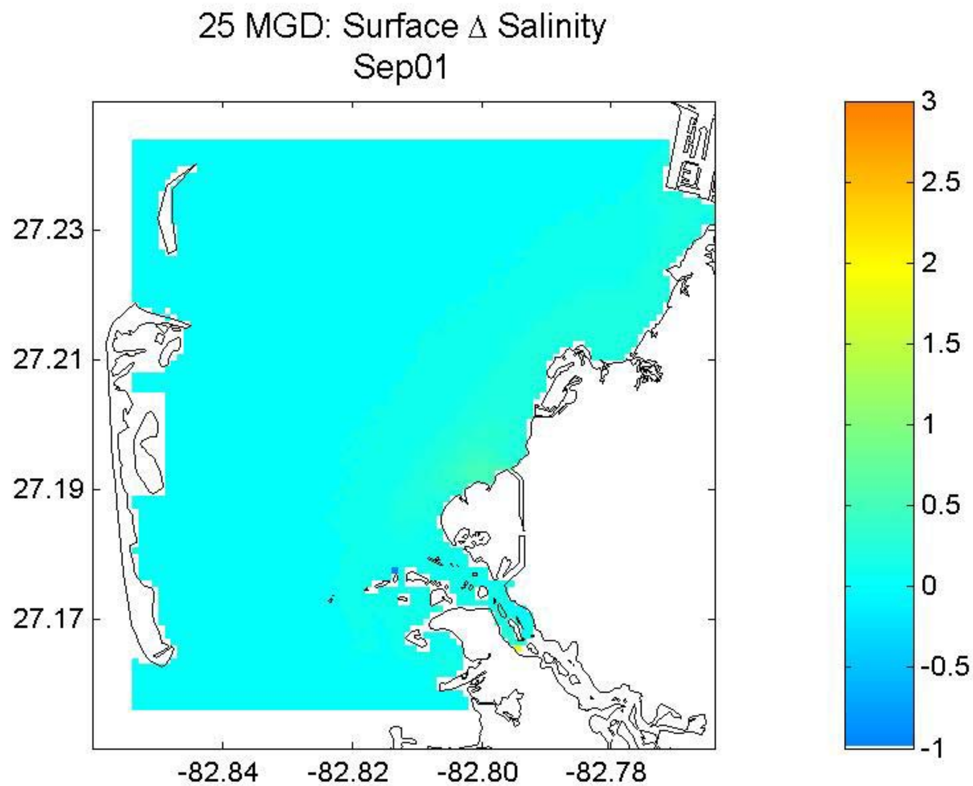
25 MGD: Surface Δ Salinity
Sep01
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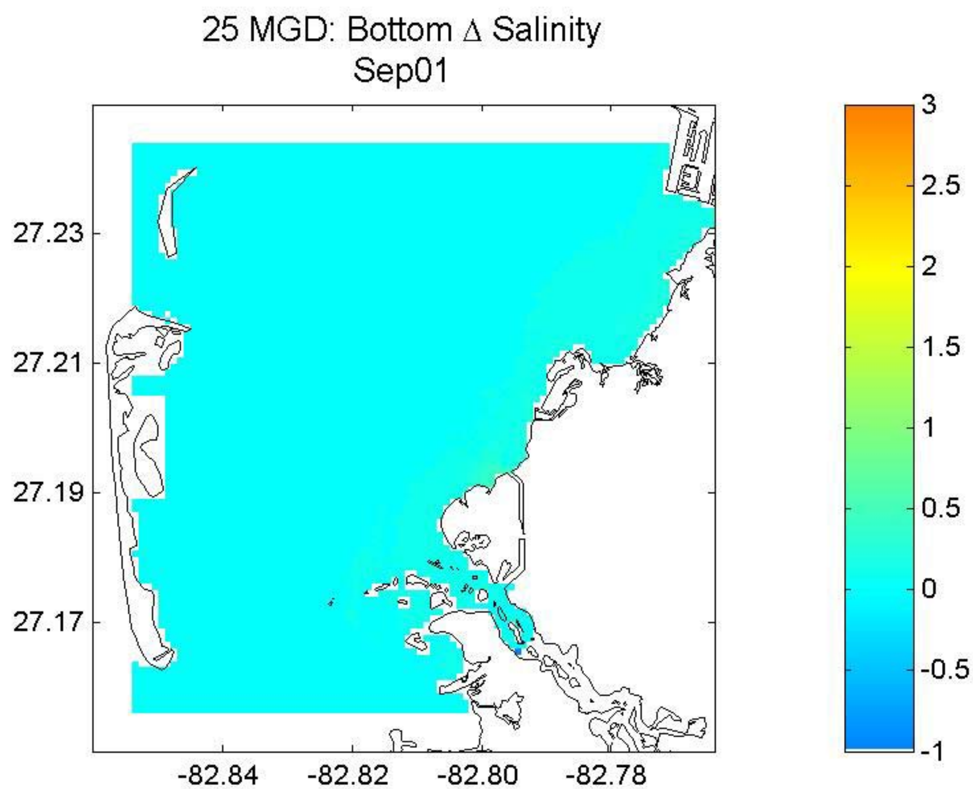
25 MGD: Bottom Δ Salinity
Sep01
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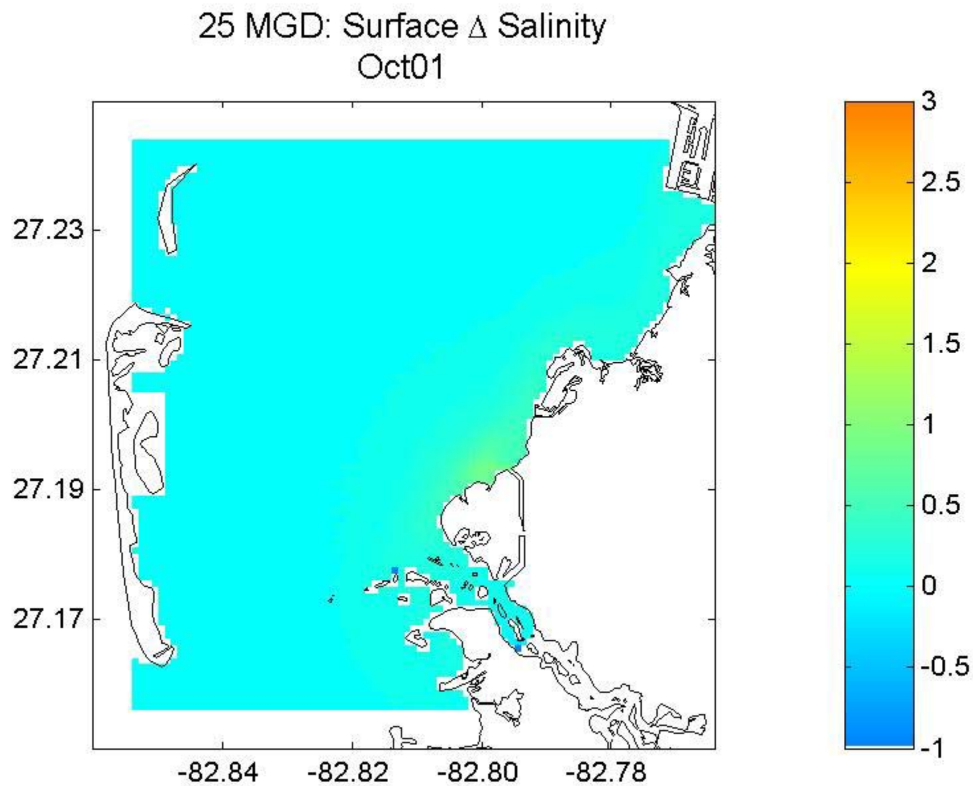
25 MGD: Surface Δ Salinity
Oct01
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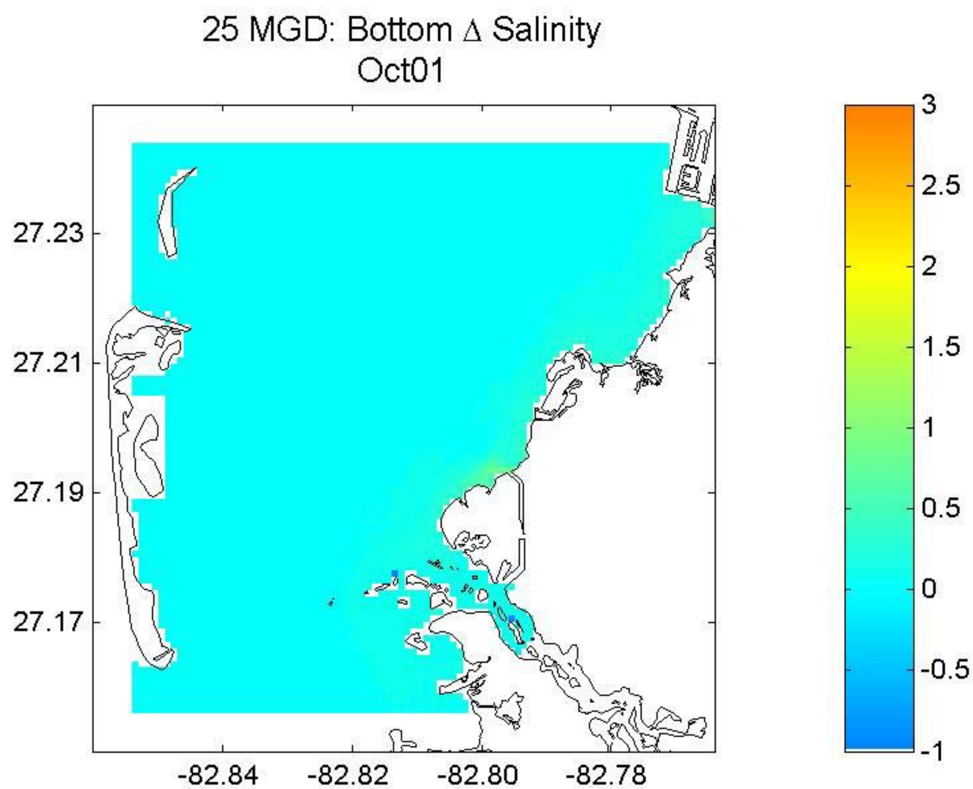
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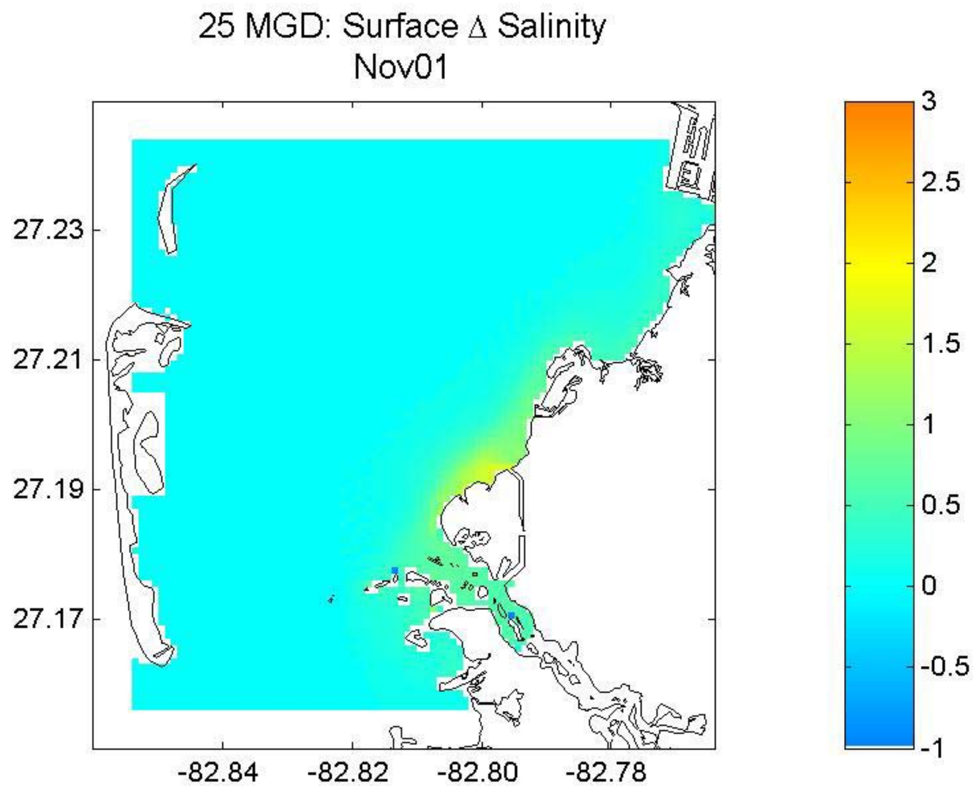
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Nov01
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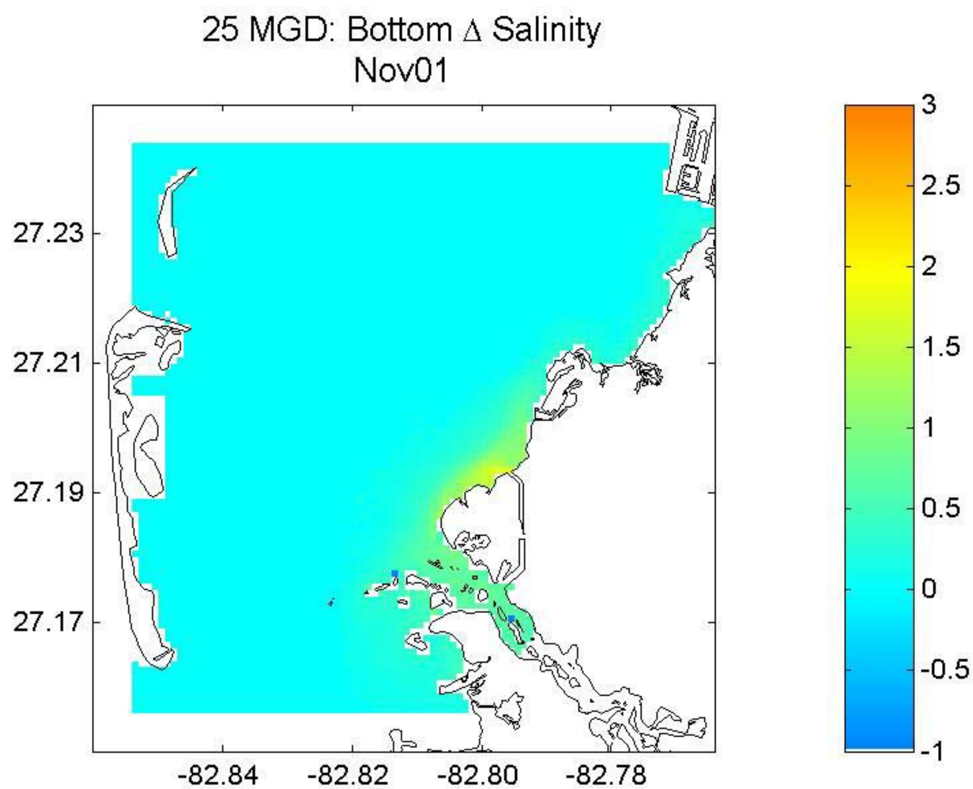
25 MGD: Bottom Δ Salinity
Nov01
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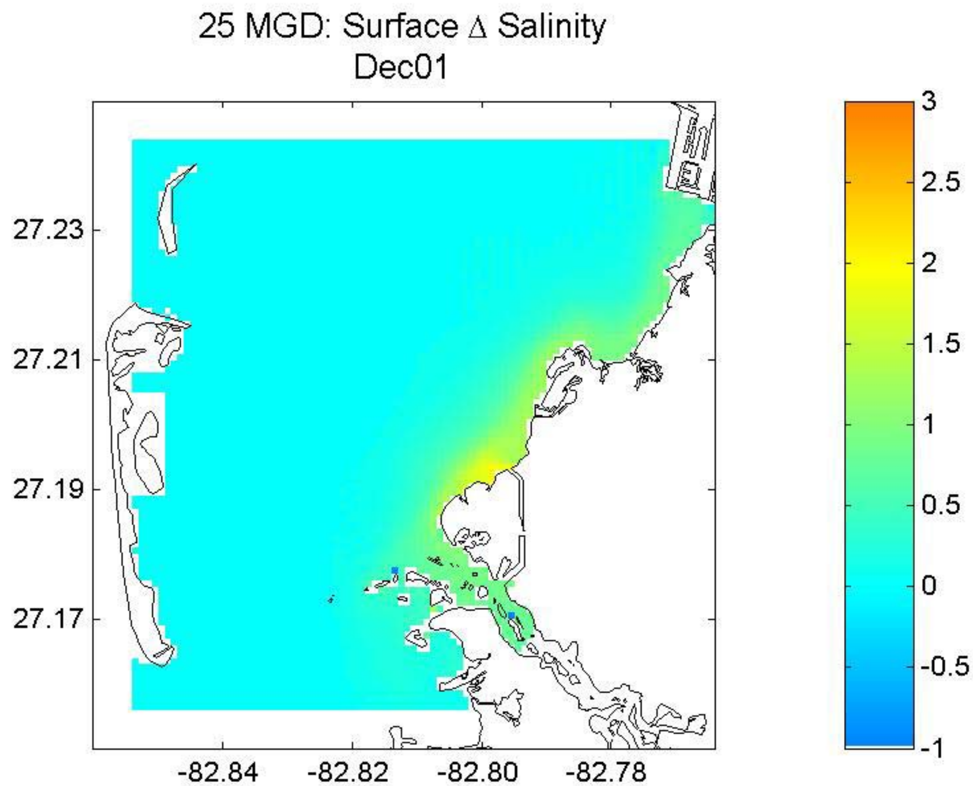
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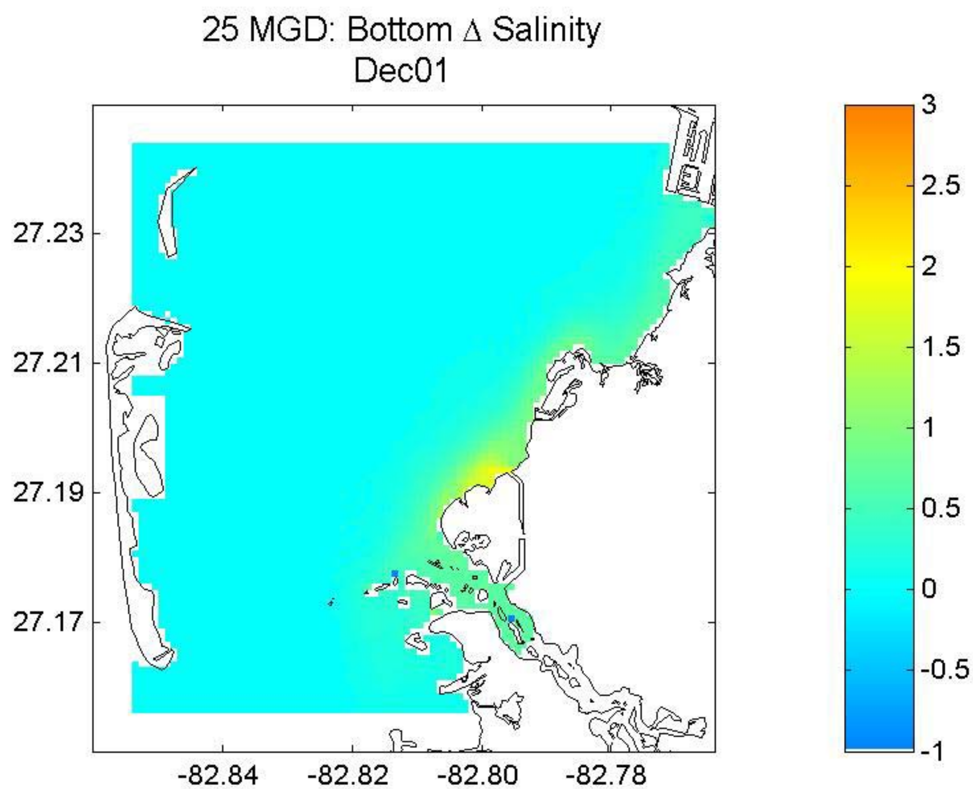
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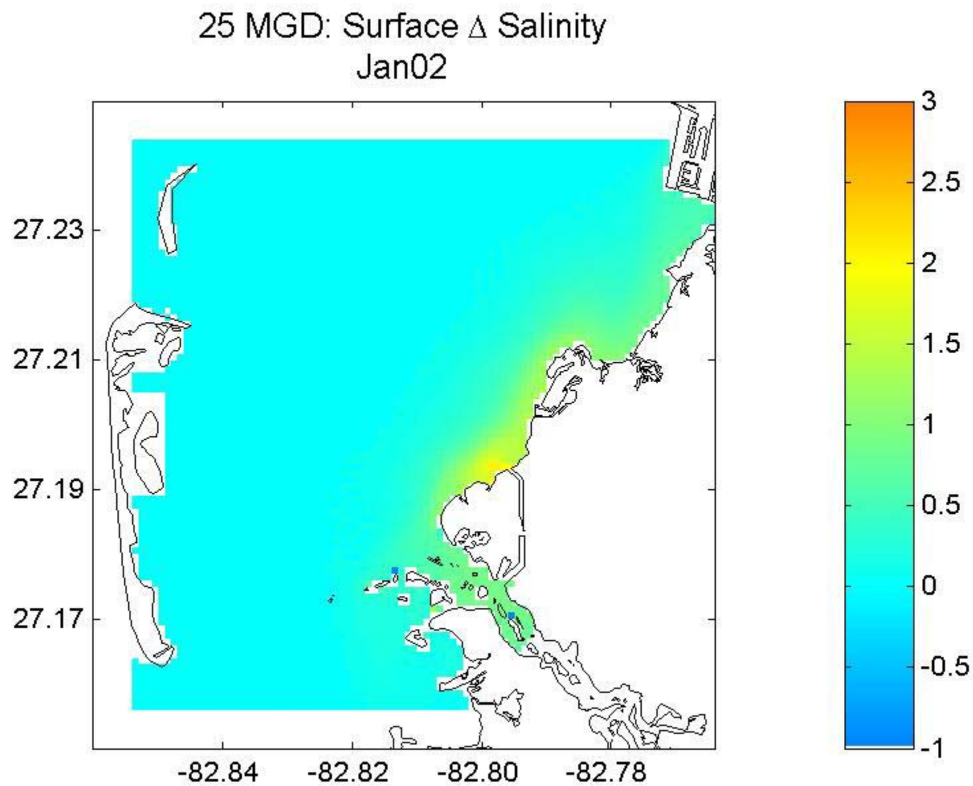
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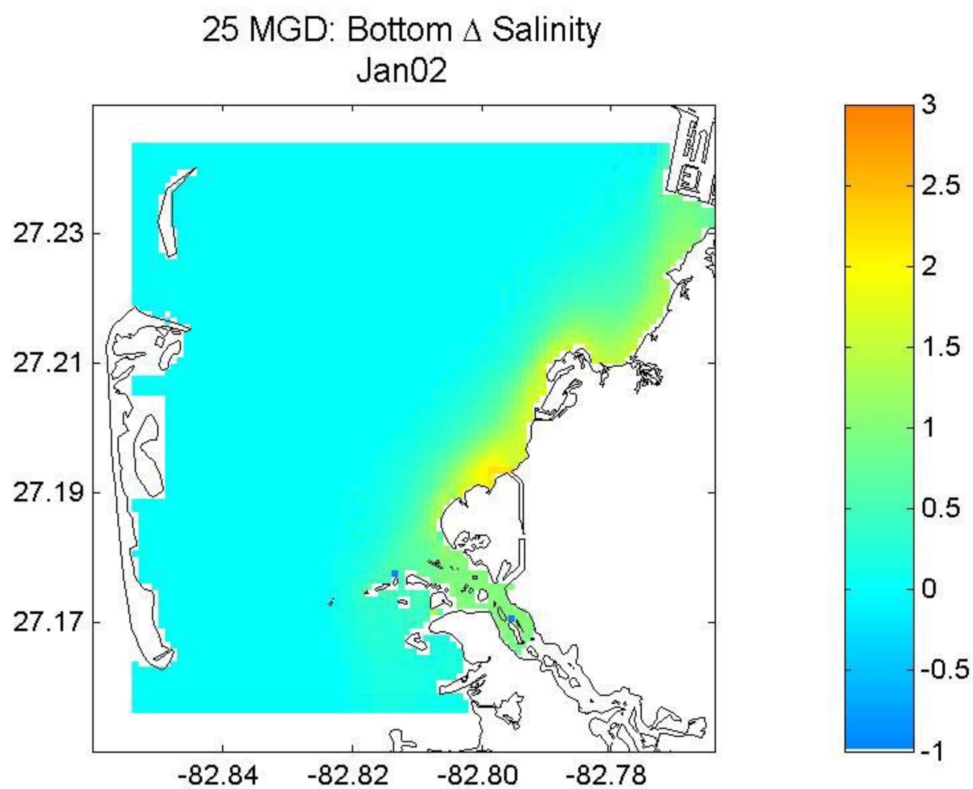
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Jan02
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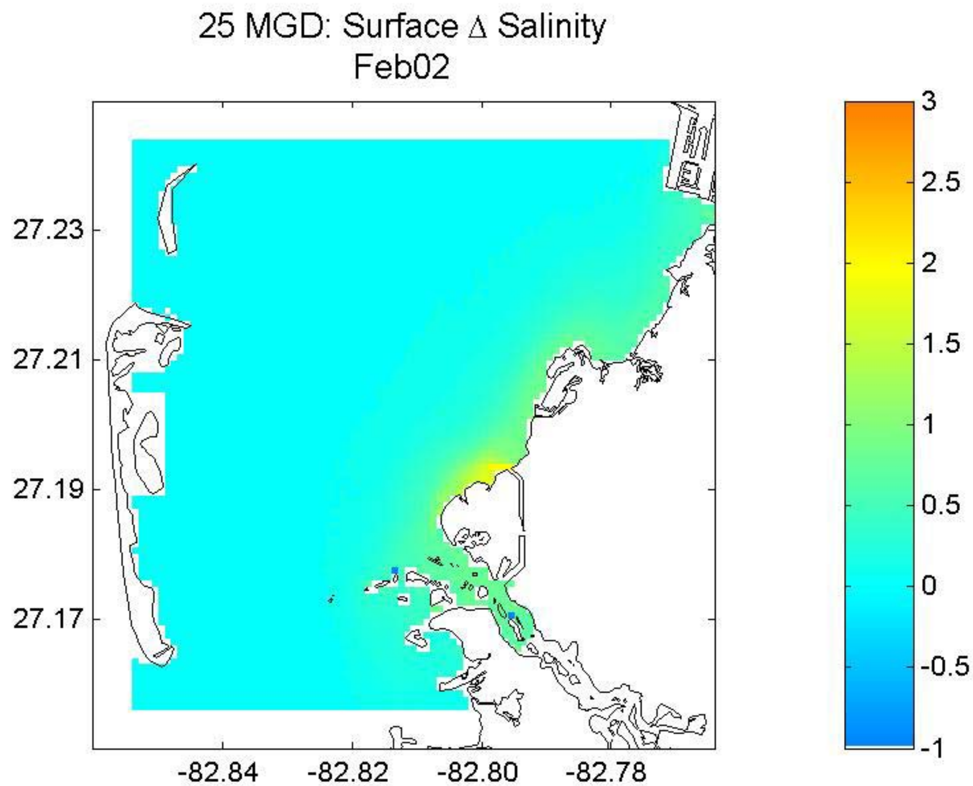
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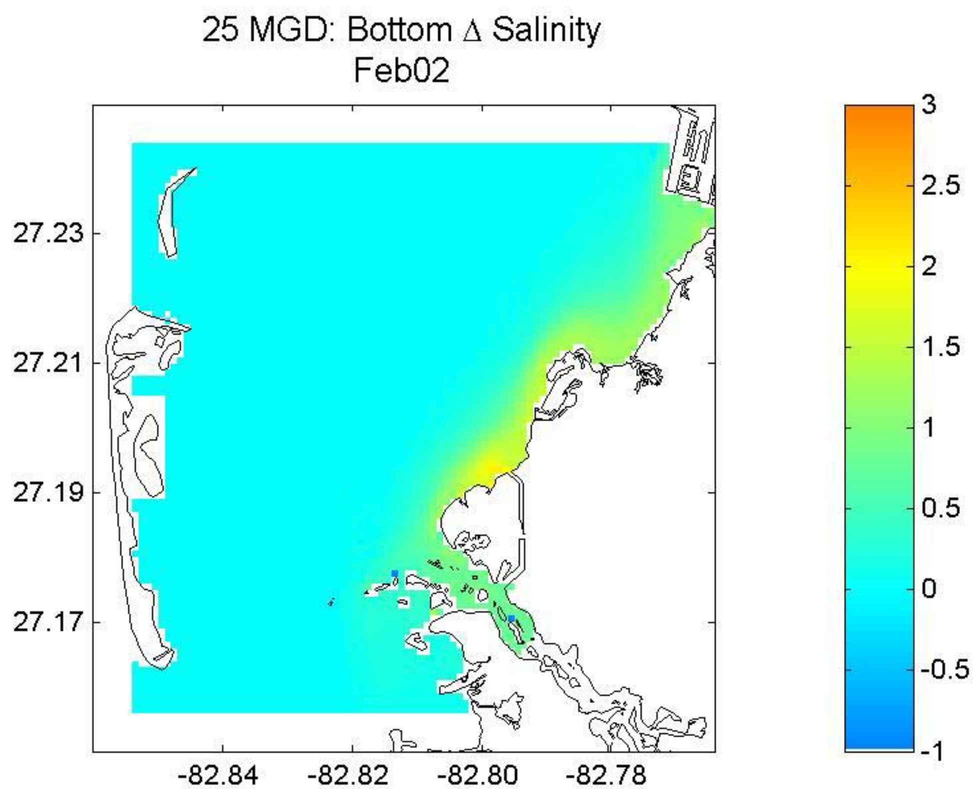
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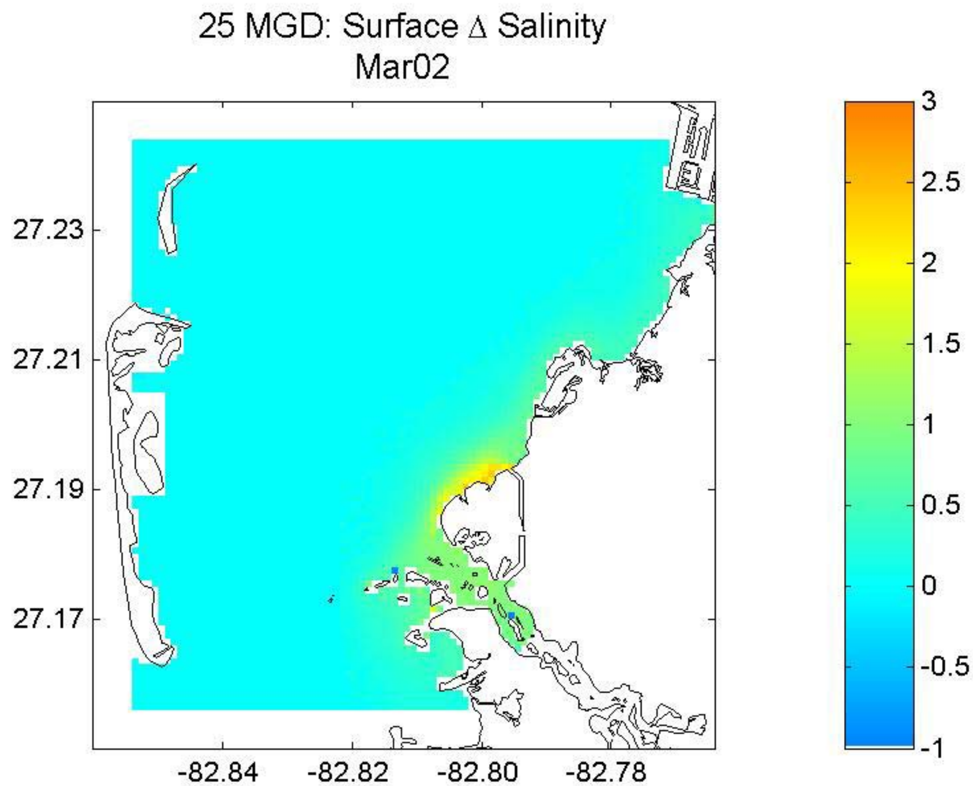
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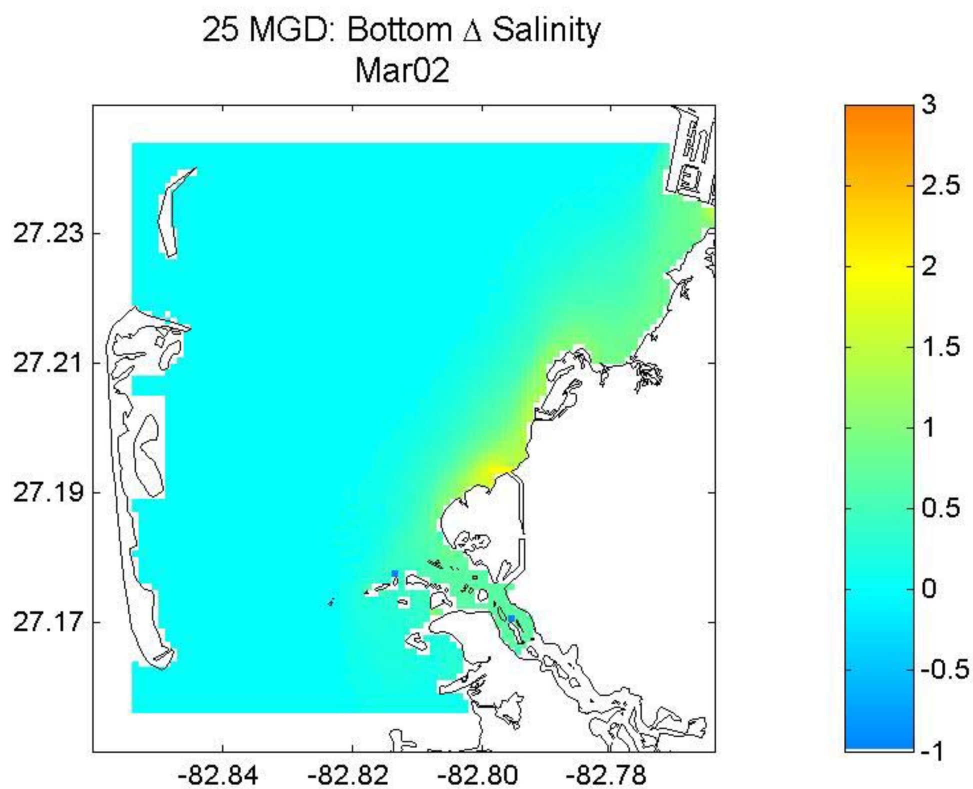
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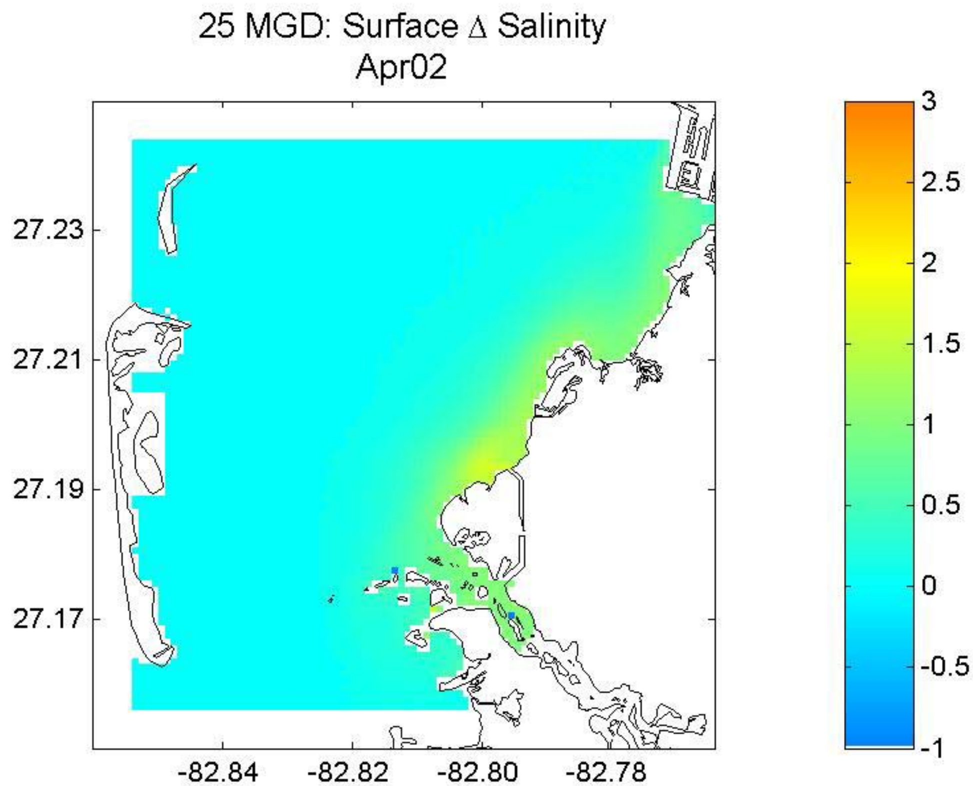
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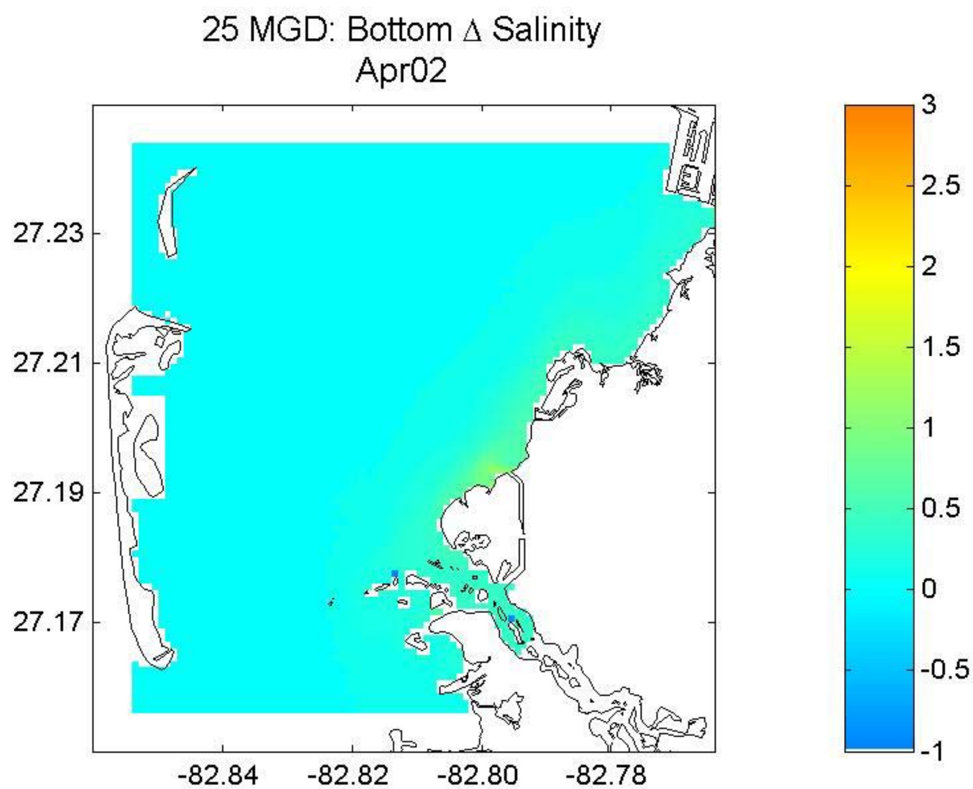
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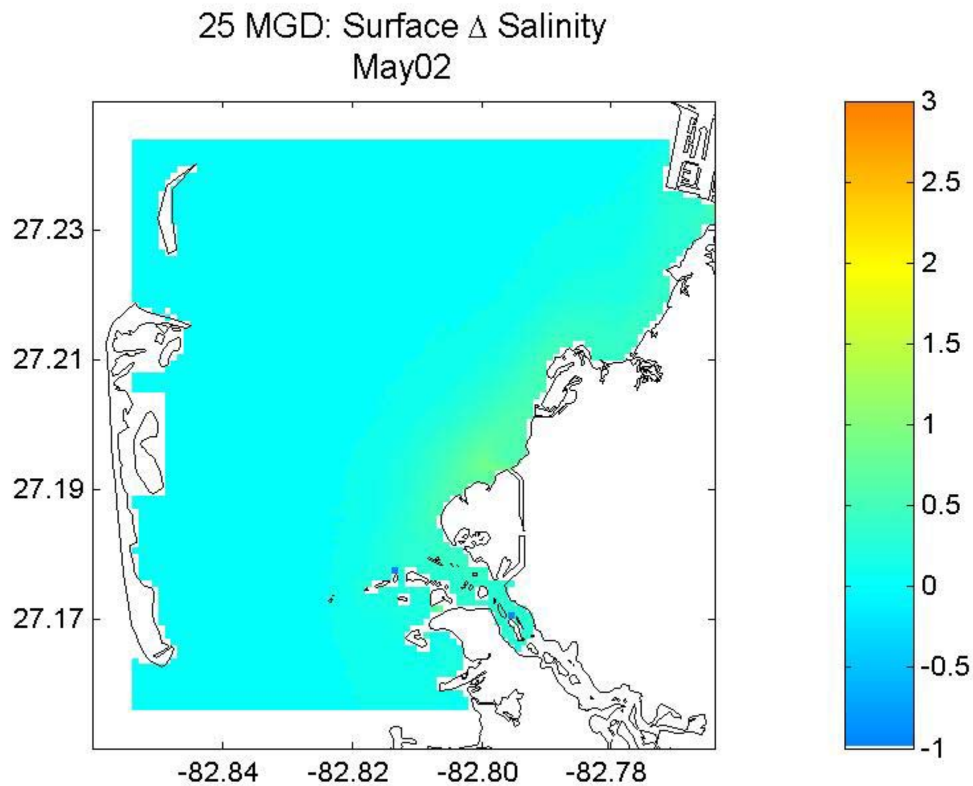
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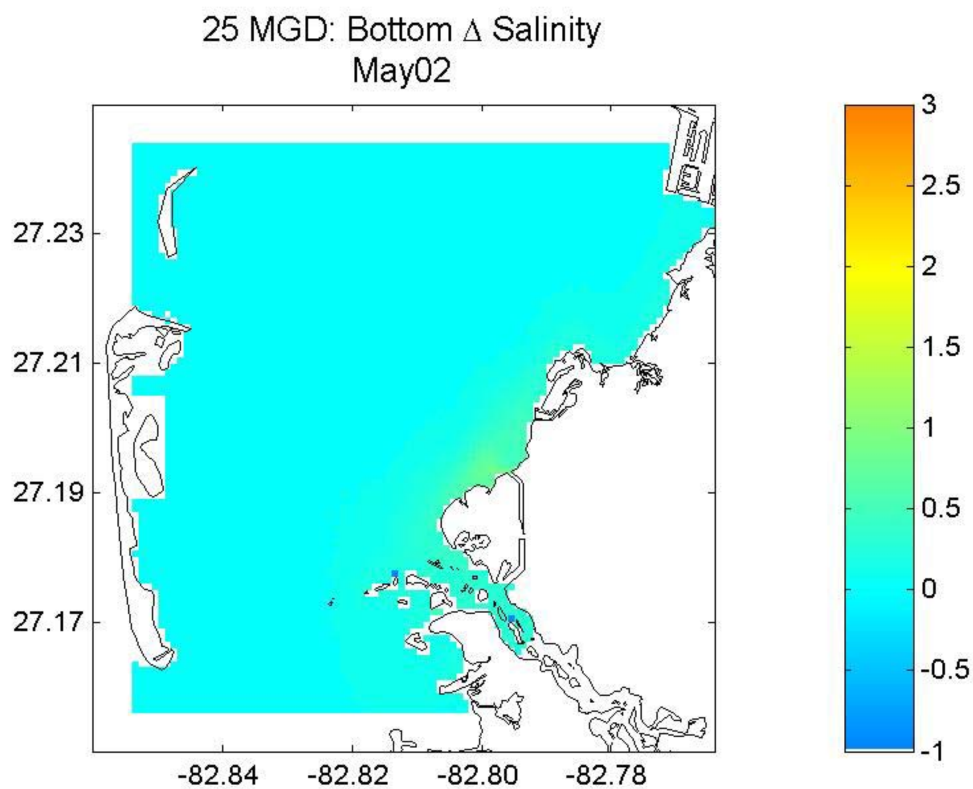
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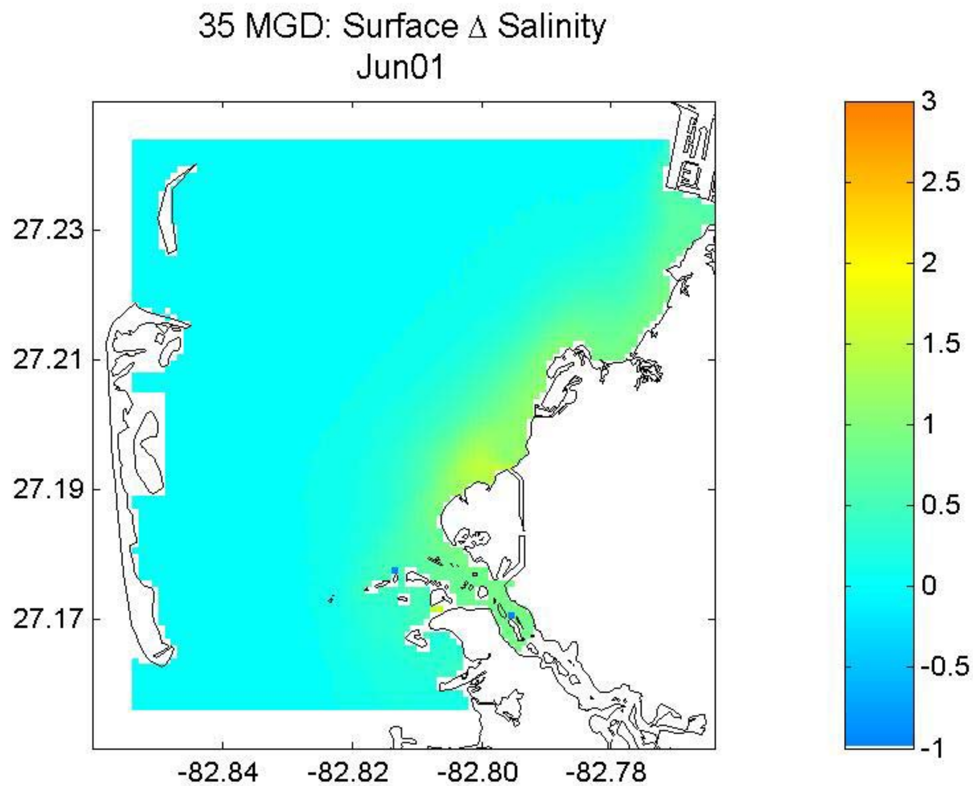
Appendix V

Monthly Change in Nearshore Salinity from 35 MGD Product Water Scenario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27.17
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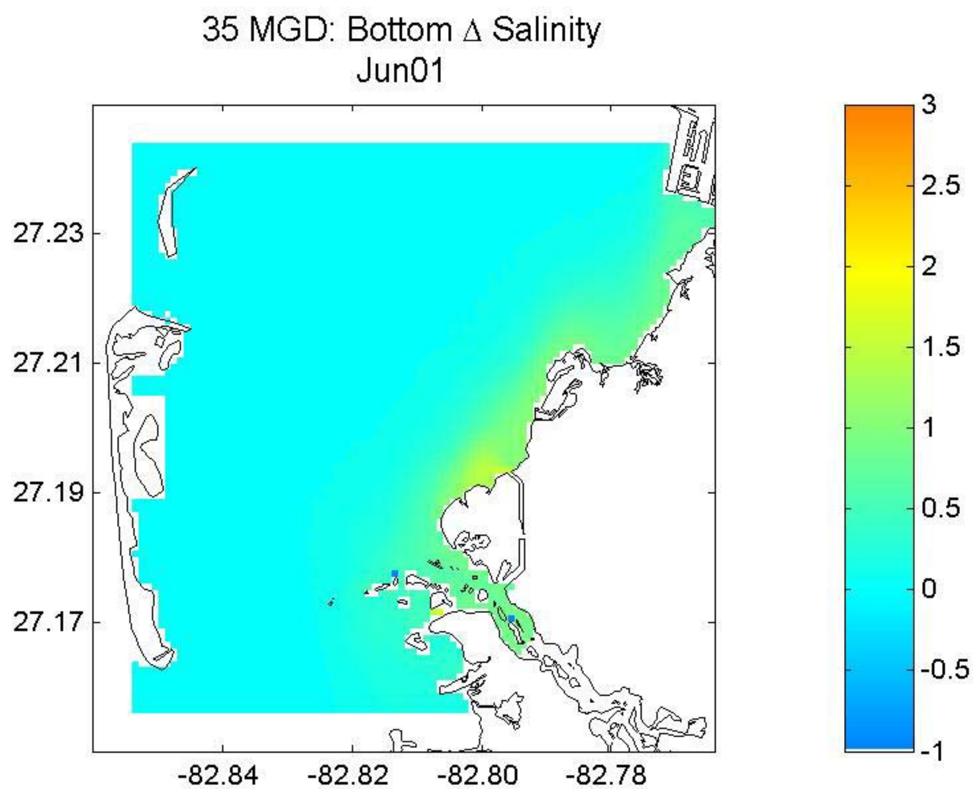
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Jun01
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-82.78
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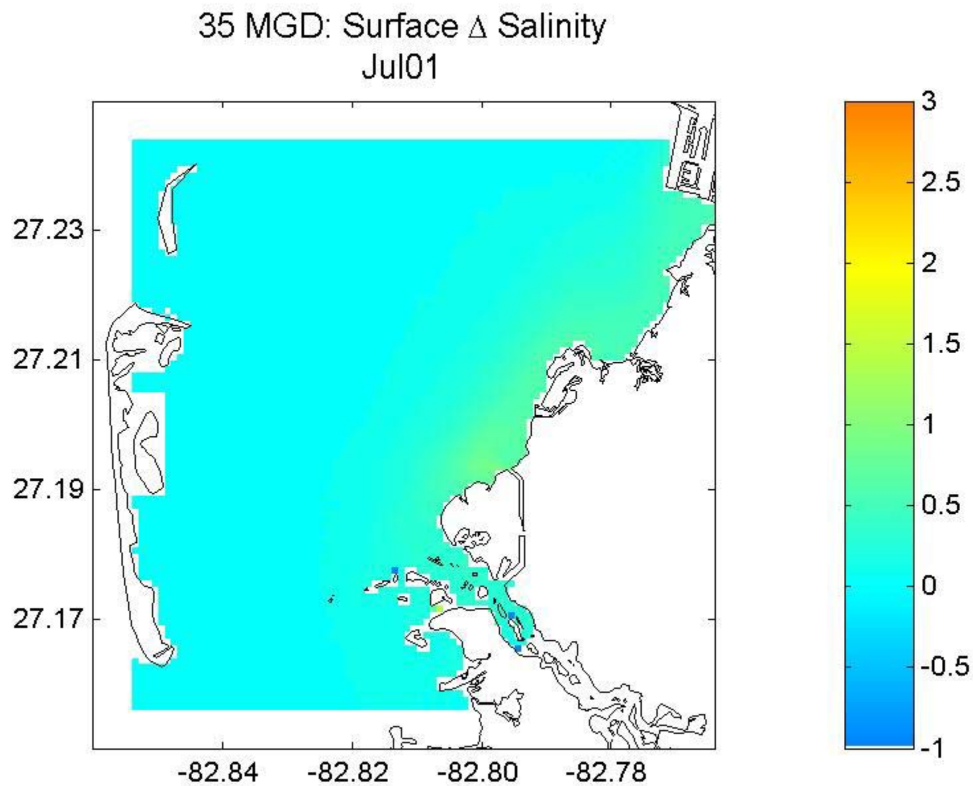
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Jul01
27.23
27.21
27.19
27.17
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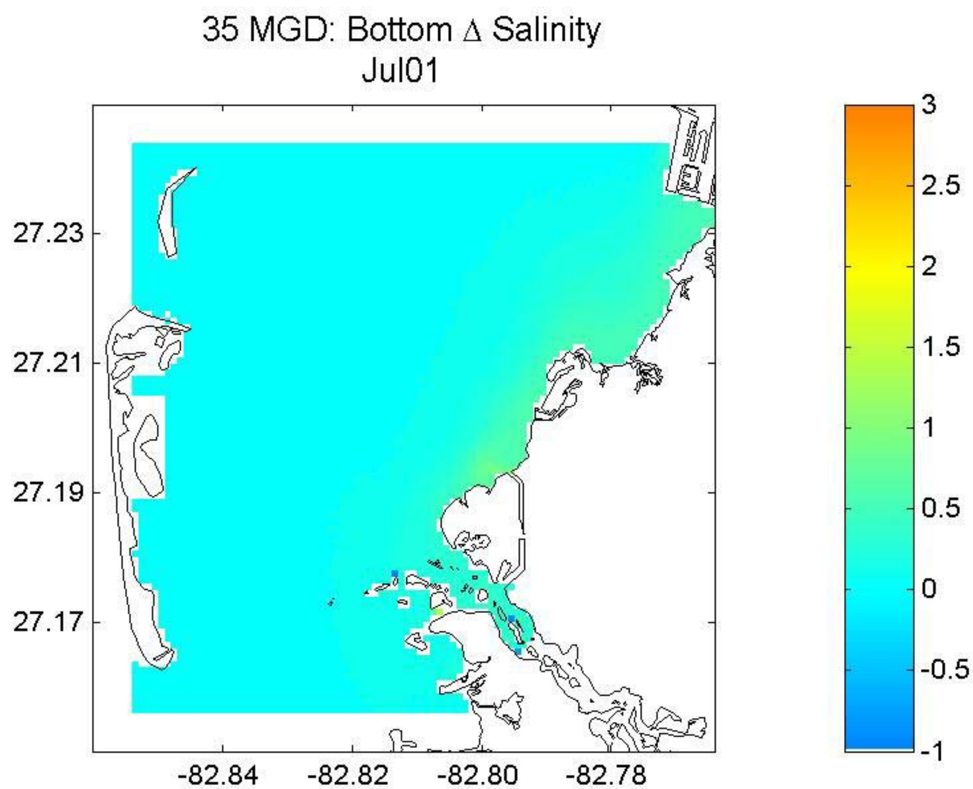
35 MGD: Bottom Δ Salinity
Jul01
27.23
27.21
27.19
27.17
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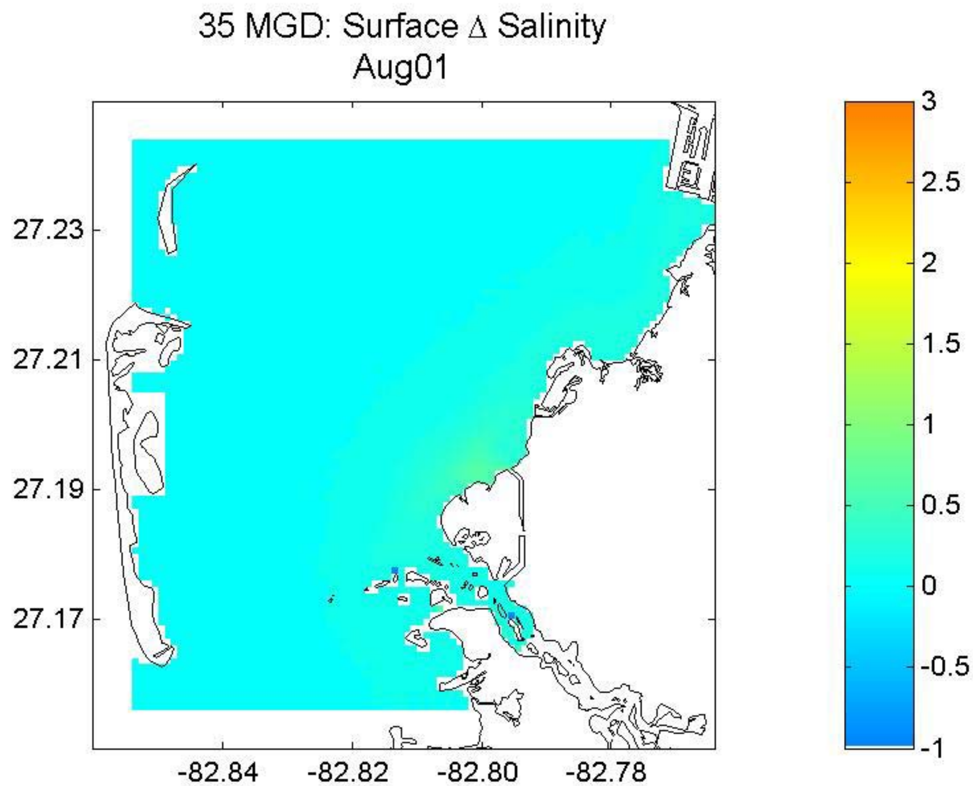
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Aug01
27.23
27.21
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-82.78
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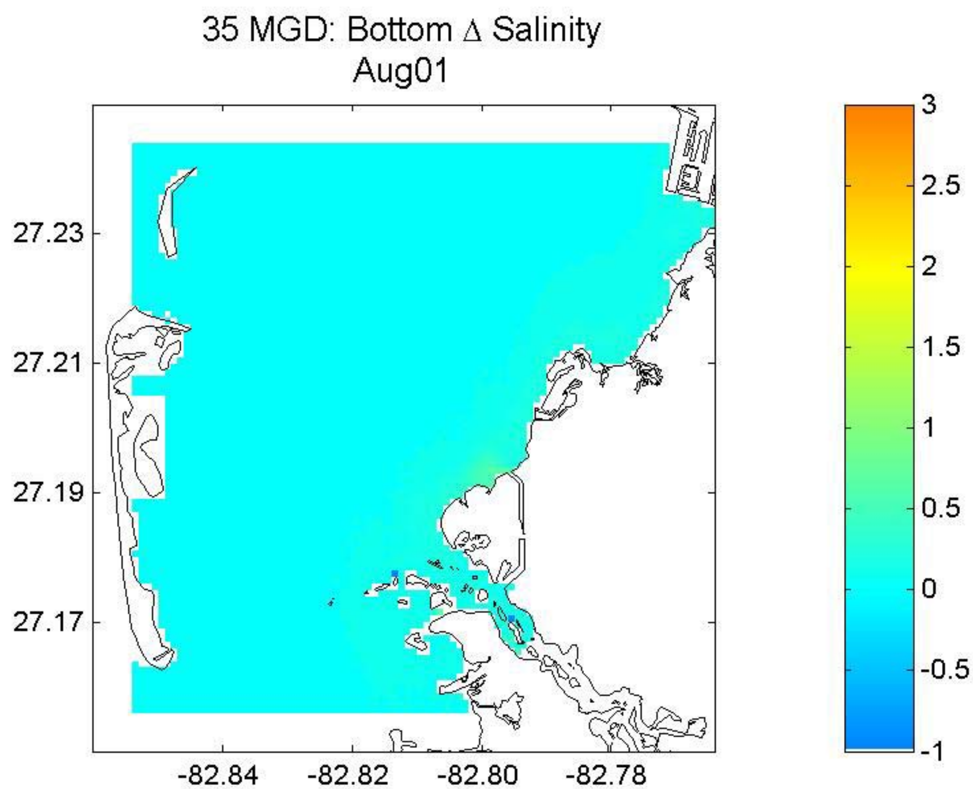
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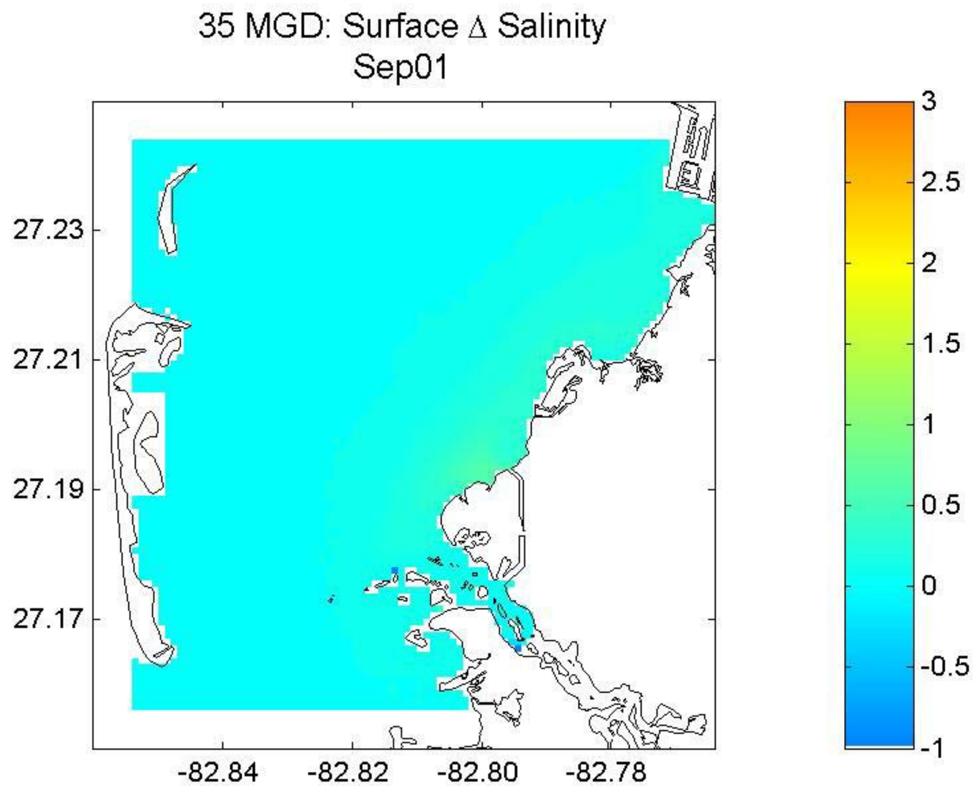
35 MGD: Surface Δ Salinity
Sep01
27.23
27.21
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27.17
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-82.78
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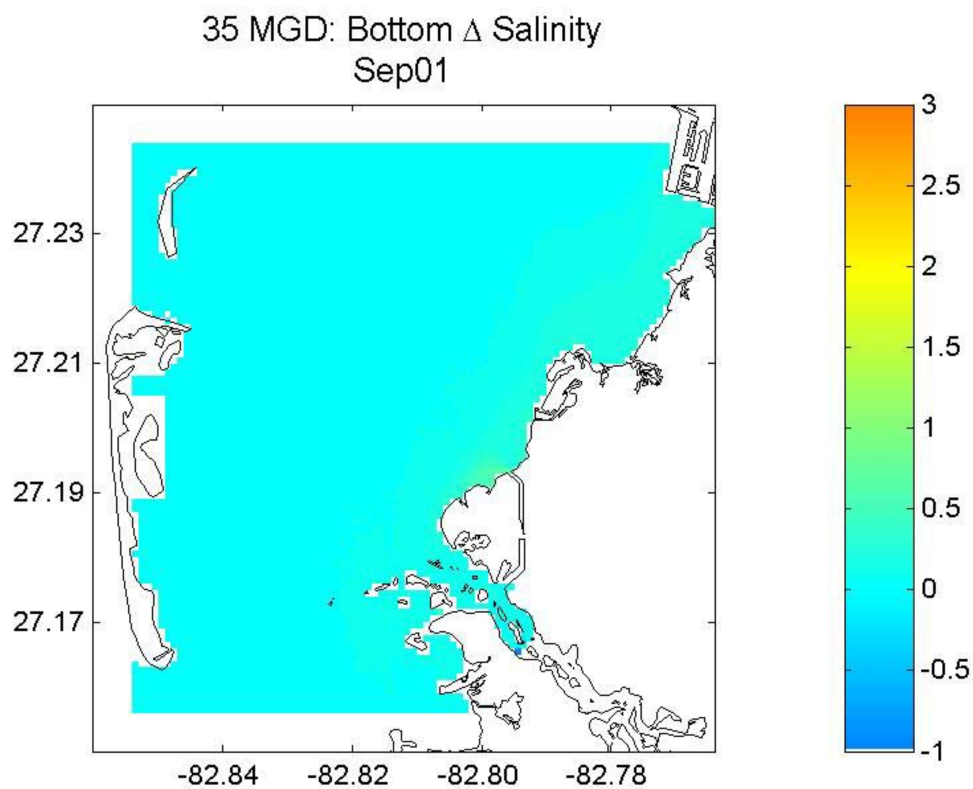
35 MGD: Bottom Δ Salinity
Sep01
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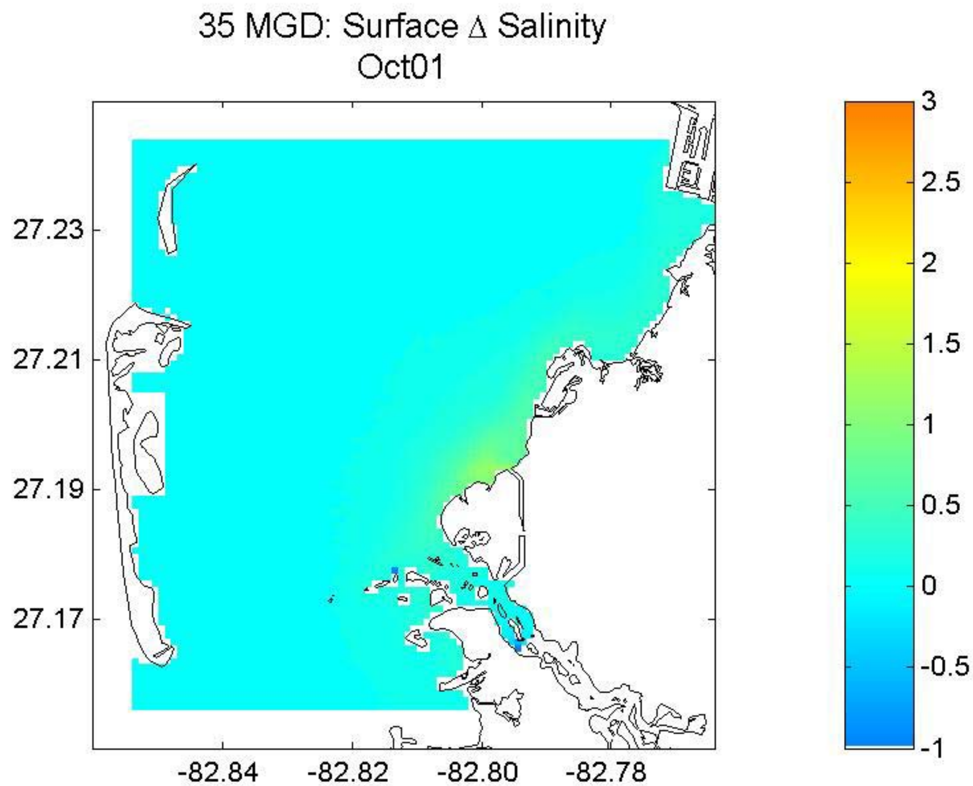
35 MGD: Surface Δ Salinity
Oct01
27.23
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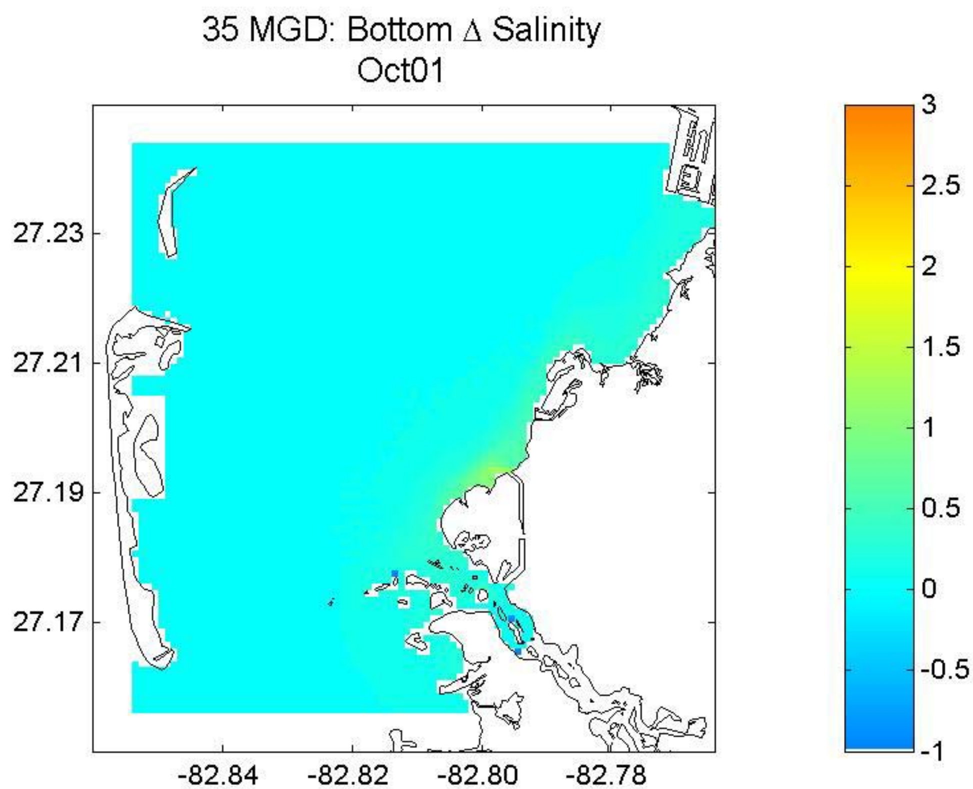
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Oct01
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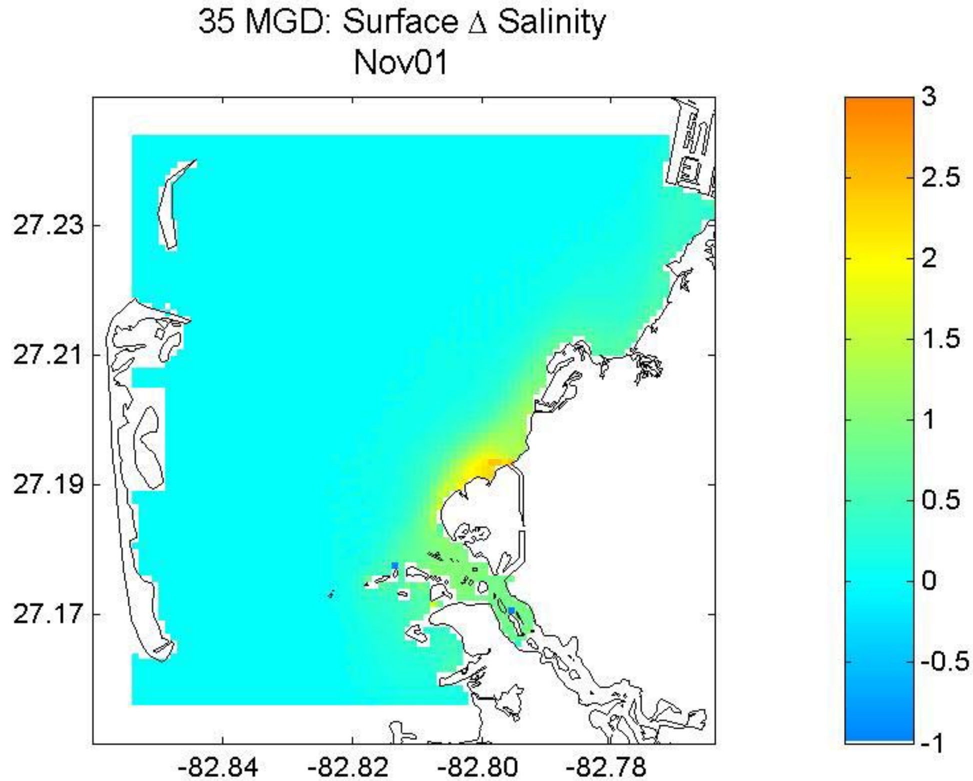
35 MGD: Surface Δ Salinity
Nov01
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3
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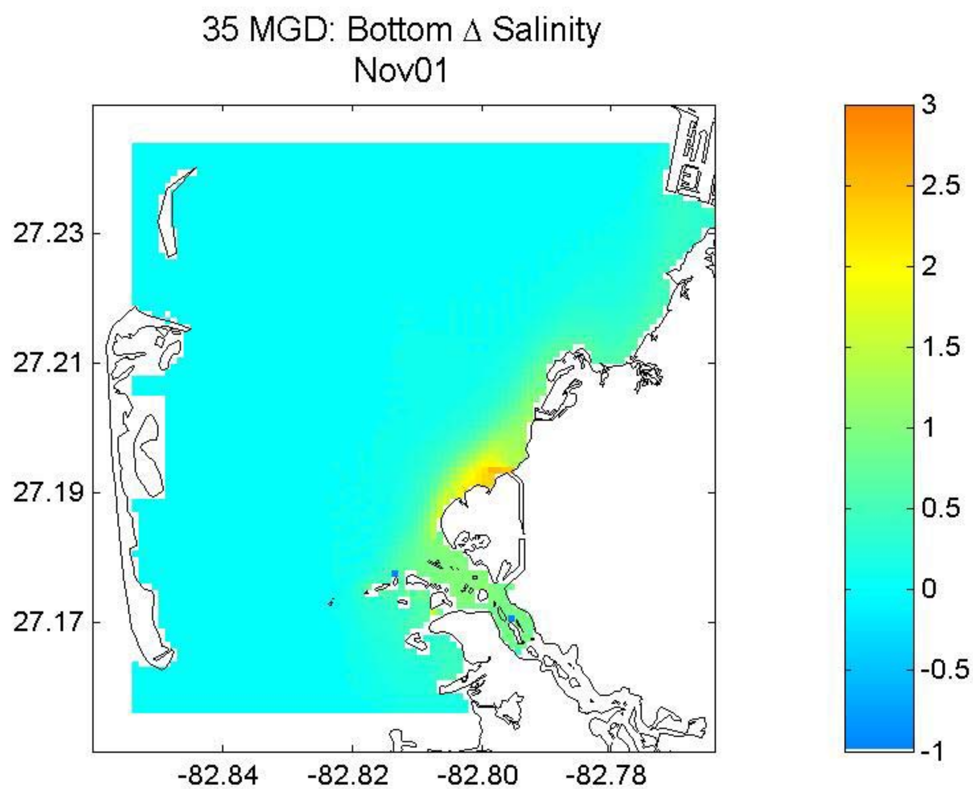
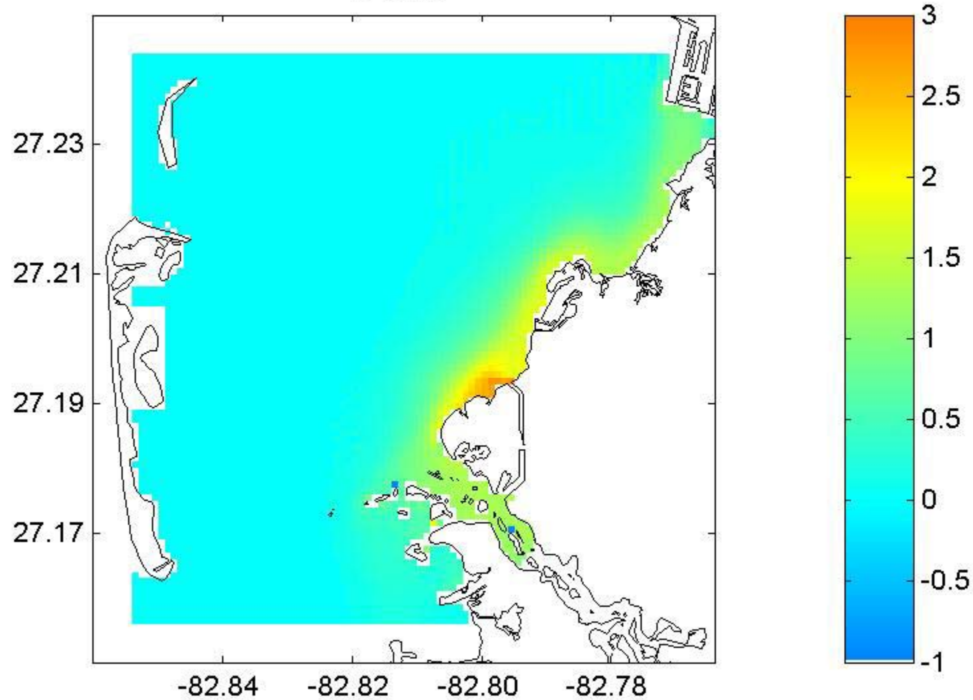
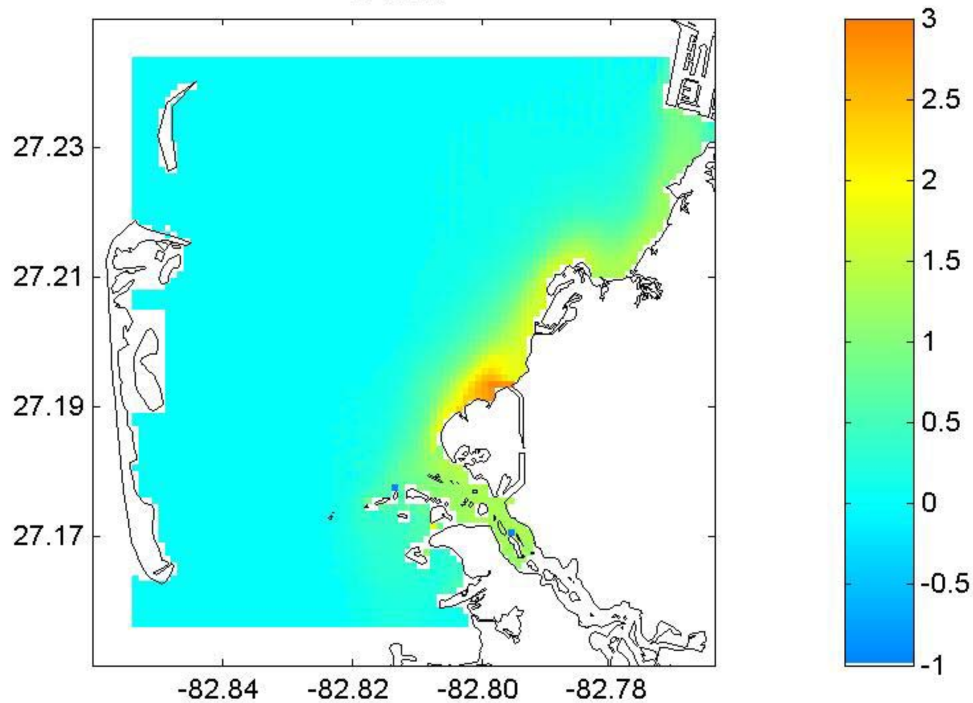
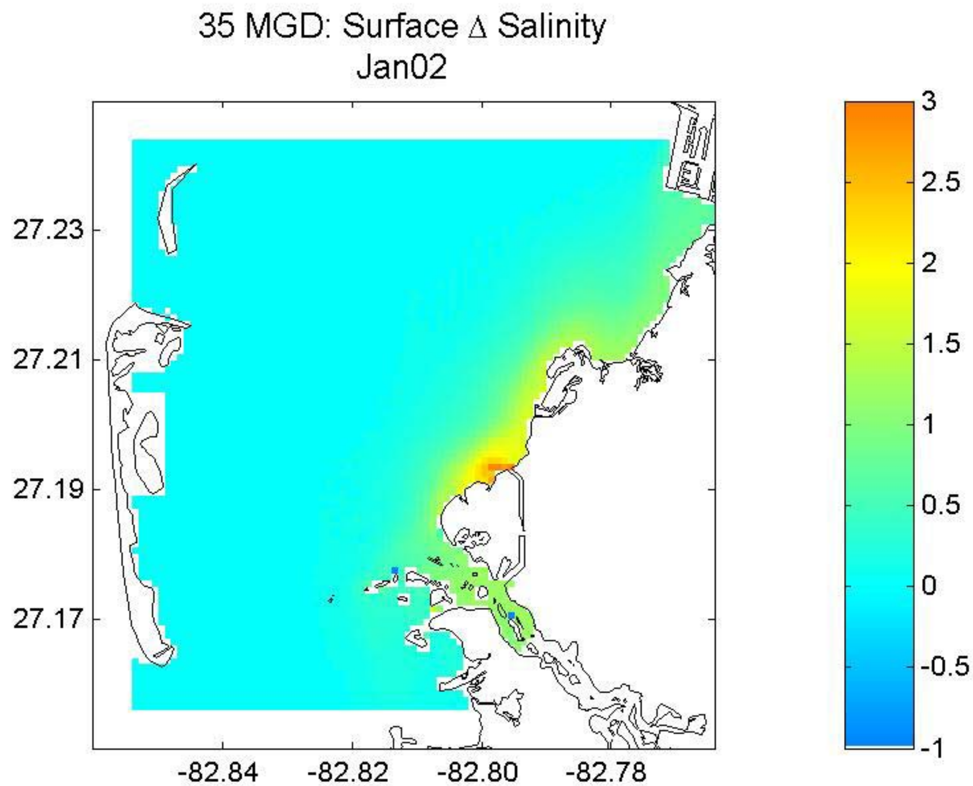

35 MGD: Bottom Δ Salinity
Nov01
27.23
27.21
27.19
27.17
-82.84
-82.82
-82.80
-82.78
3
2.5
2
1.5
1
0.5
0
-0.5
-1

35 MGD: Surface Δ Salinity
Dec01



35 MGD: Bottom Δ Salinity
Dec01




35 MGD: Surface Δ Salinity
Jan02
27.23
27.21
27.19
27.17
-82.84
-82.82
-82.80
-82.78
3
2.5
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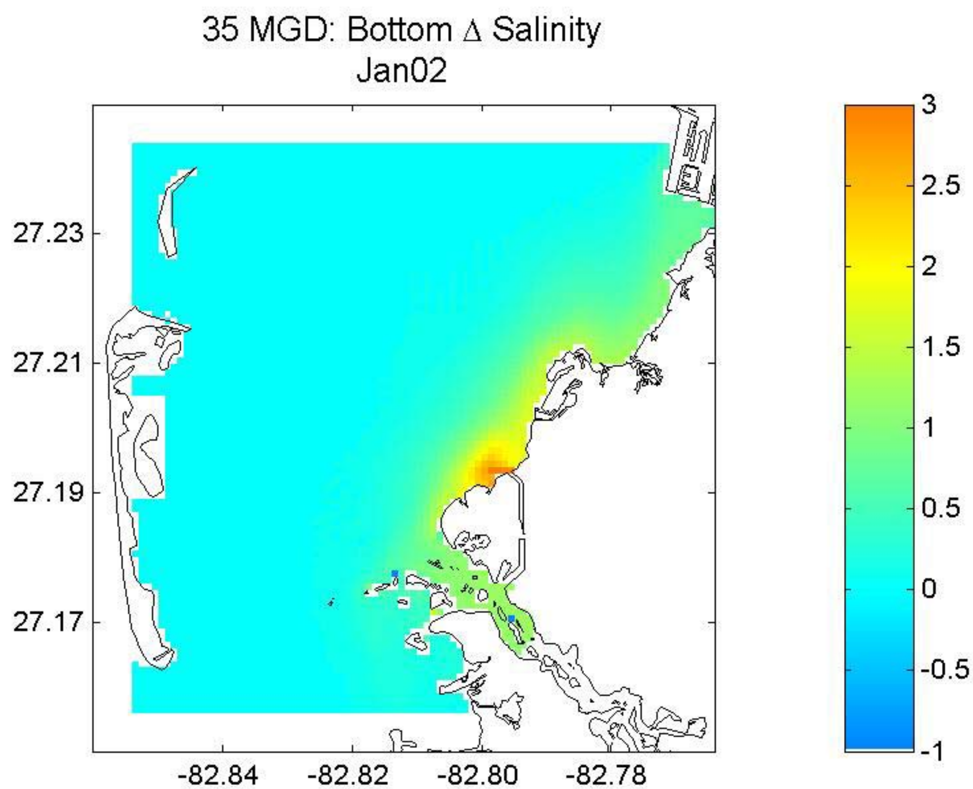
1.5
1
0.5
0
-0.5
-1


35 MGD: Bottom Δ Salinity
Jan02
27.23
27.21
27.19
27.17
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-82.82
-82.80
-82.78
3
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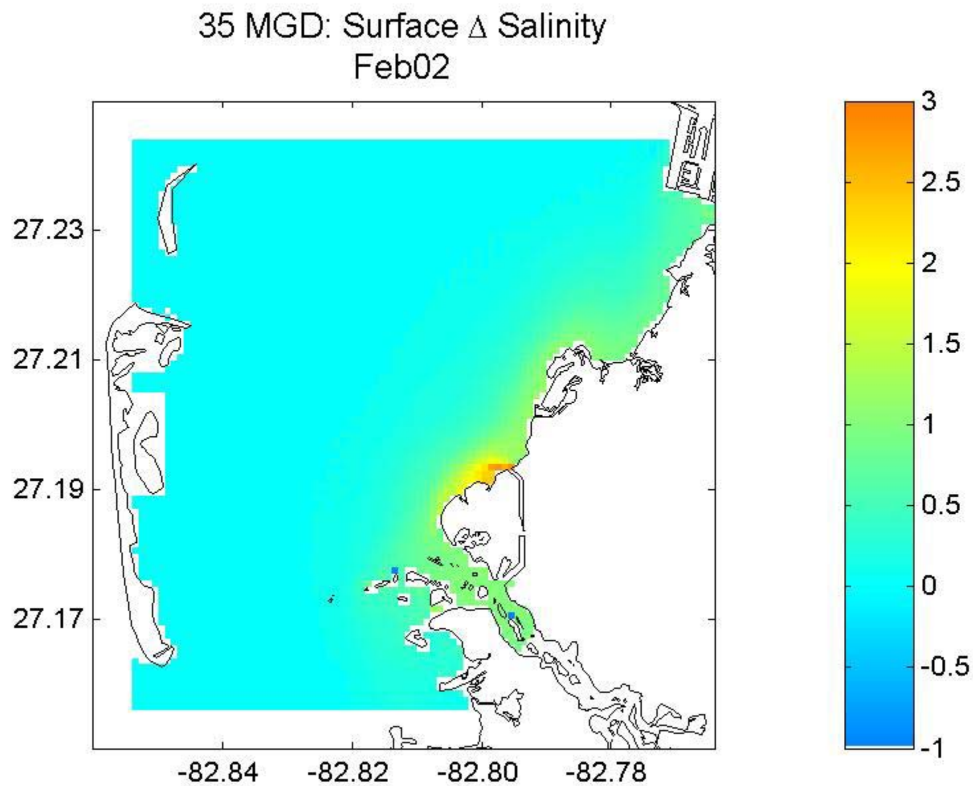
35 MGD: Surface Δ Salinity
Feb02
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27.21
27.19
27.17
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-82.82
-82.80
-82.78
3
2.5
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1.5
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0.5
0
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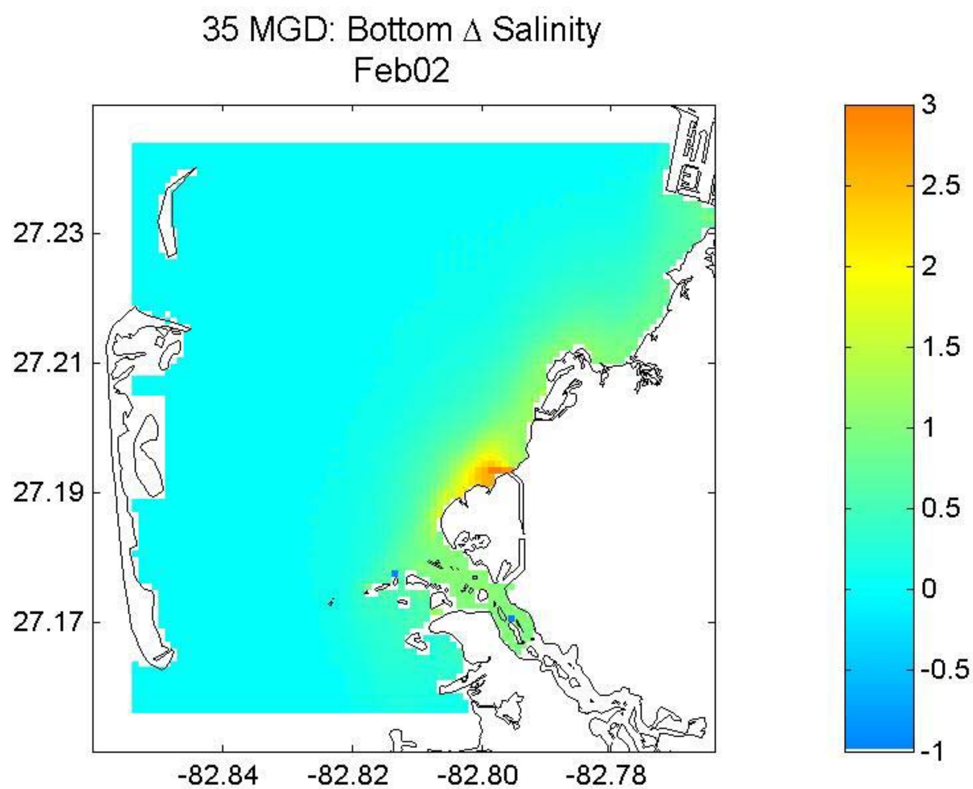
-1


35 MGD: Bottom Δ Salinity
Feb02
27.23
27.21
27.19
27.17
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-82.82
-82.80
-82.78
3
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1
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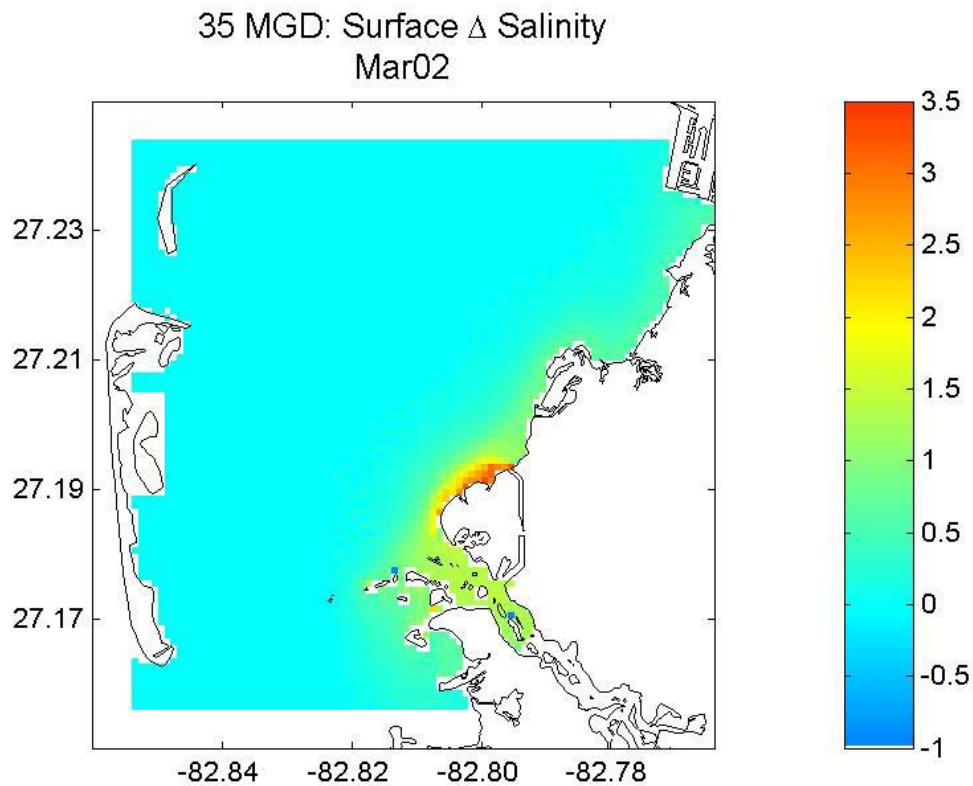
-1


35 MGD: Surface Δ Salinity
Mar02
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-82.84
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-82.80
-82.78
3.5
3
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2
1.5
1
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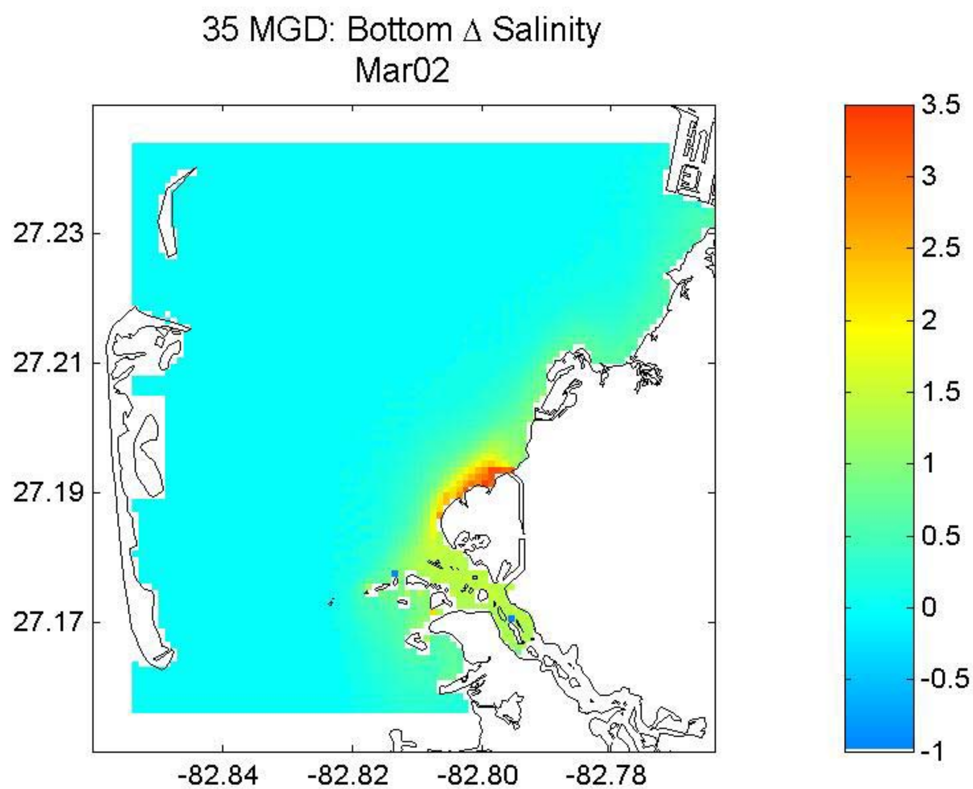
-0.5
-1


35 MGD: Bottom Δ Salinity
Mar02
27.23
27.21
27.19
27.17
-82.84
-82.82
-82.80
-82.78
3.5
3
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2
1.5
1
0.5
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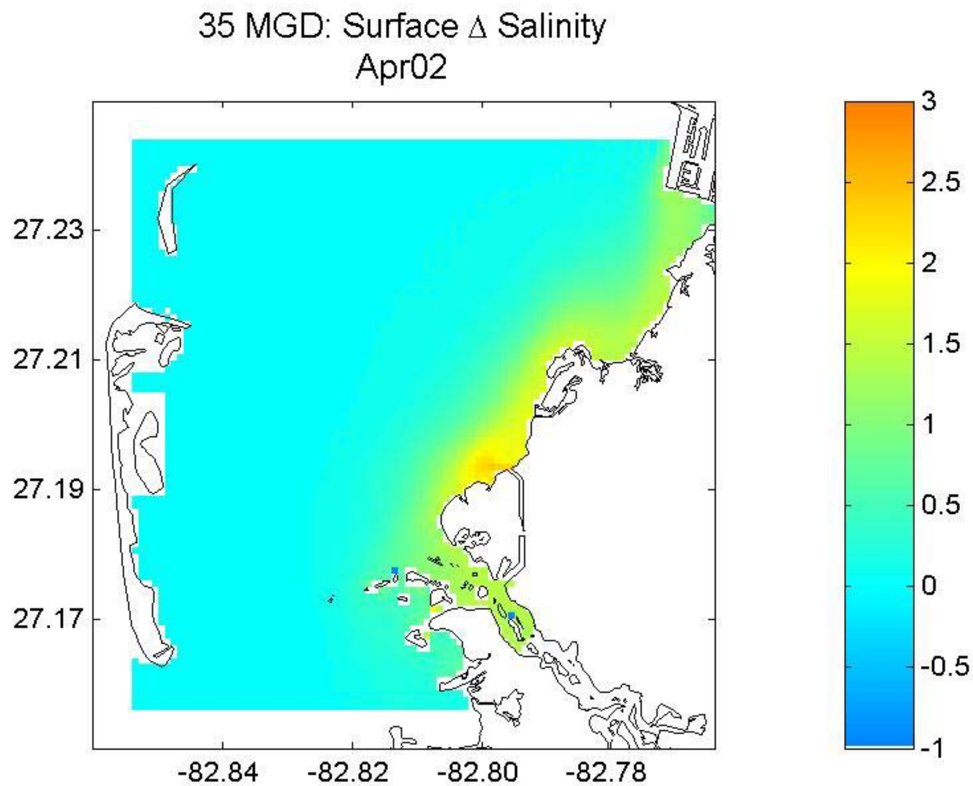
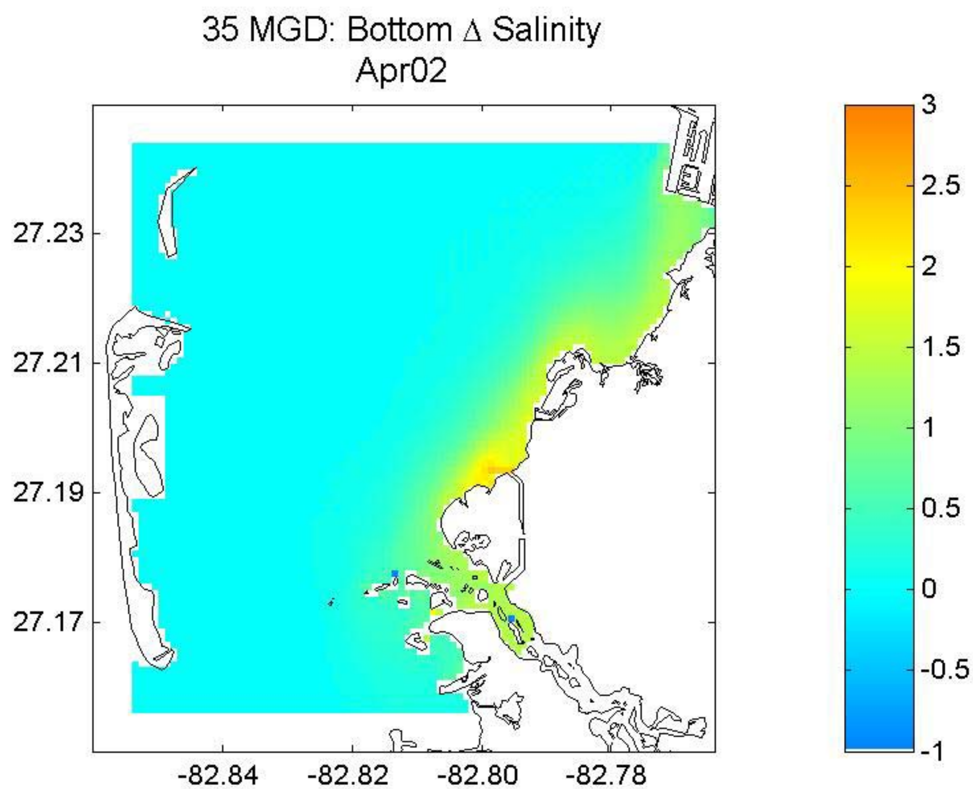
-0.5
-1


35 MGD: Surface Δ Salinity
Apr02
27.23
27.21
27.19
27.17
-82.84
-82.82
-82.80
-82.78
3
2.5
2
1.5
1
0.5
0
-0.5
-1


35 MGD: Bottom Δ Salinity
Apr02
27.23
27.21
27.19
27.17
-82.84
-82.82
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-82.78
3
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1.5
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0.5
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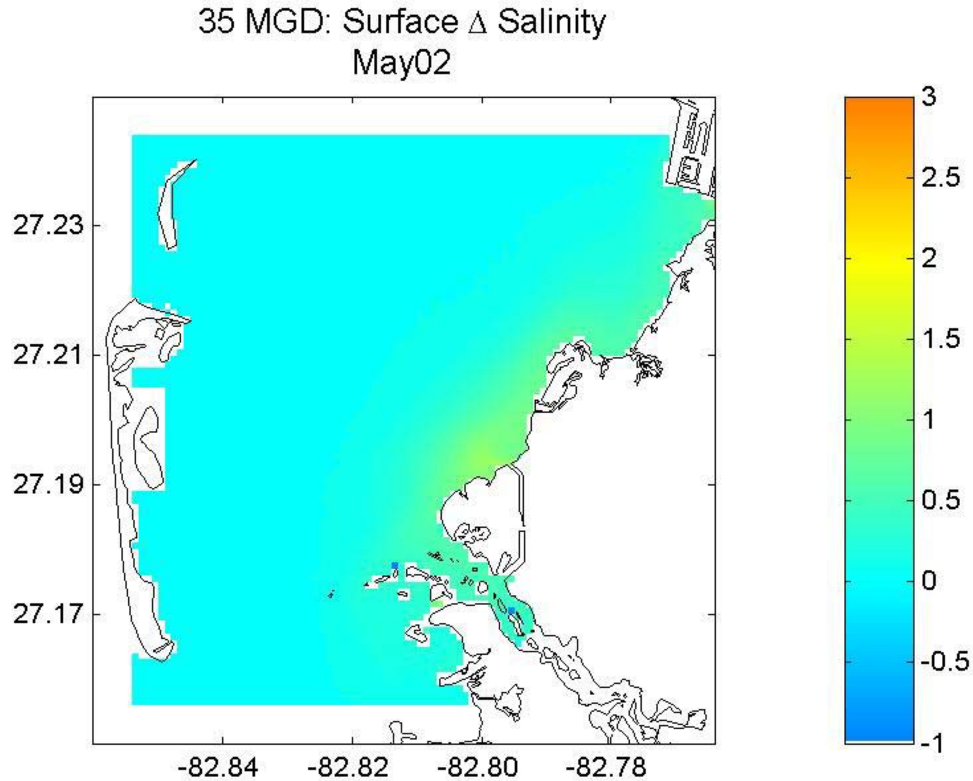
-0.5
-1


35 MGD: Surface Δ Salinity
May02
27.23
27.21
27.19
27.17
-82.84
-82.82
-82.80
-82.78
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2.5
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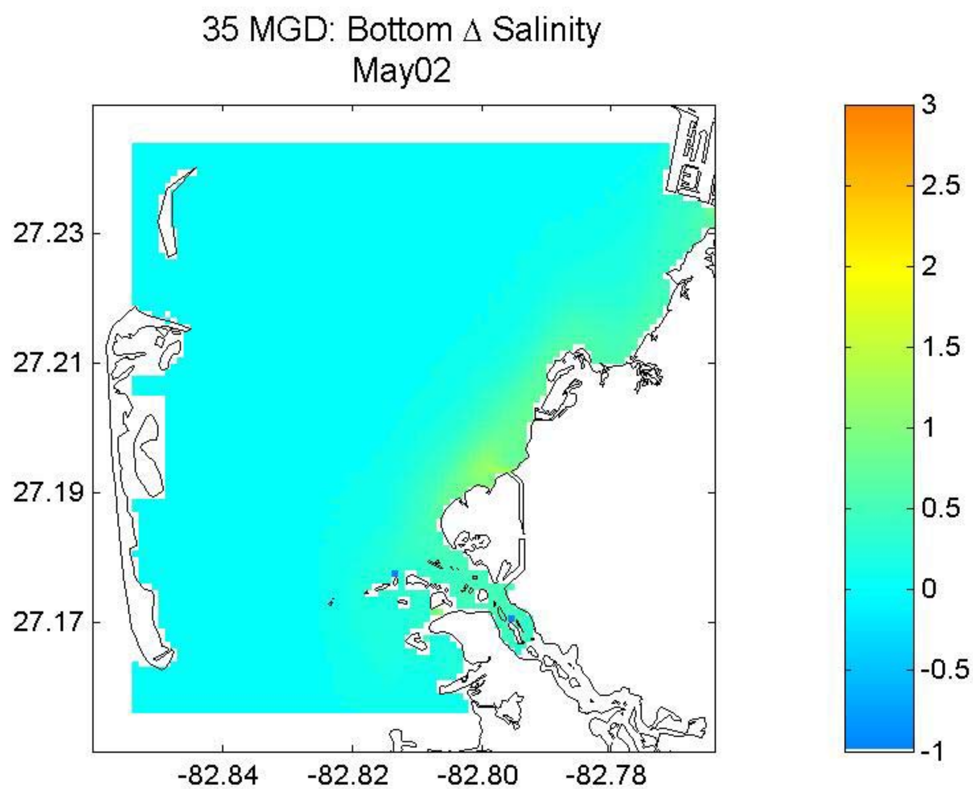
-0.5
-1


35 MGD: Bottom Δ Salinity
May02
27.23
27.21
27.19
27.17
-82.84
-82.82
-82.80
-82.78
3
2.5
2
1.5
1
0.5
0
-0.5
-1