Technical Report TAMU-CC-CBI-96-03

HYDRAULIC FEASIBILITY OF PROPOSED SOUTHWEST CUT, EAST MATAGORDA BAY, TEXAS

Final Report

by

Nicholas C. Kraus, Adele Militello

Prepared for:

Texas Department of Transportation
Office of Research and Technology Transfer
P.O. Box 5080
Austin, Texas 78763

Under Contract 0-1499

September 23, 1996

Texas A&M Research Foundation

Conrad Blucher Institute for Surveying and Science
Division of Coastal and Estuarine Processes
Texas A&M University-Corpus Christi
The Island University

DISCLAIMER

This study, Hydraulic Feasibility of Proposed Southwest Cut, East Matagorda Bay, Texas, was authorized by TxDOT Contract No. 0-1499 under joint sponsorship of the Texas Department of Transportation, TxDOT, and the Texas Parks and Wildlife Department. Upon request by the Texas Parks and Wildlife Department, TxDot agreed to fund one-half of the cost of this study, and to provide project management services. TxDOT's involvement was limited to providing administrative oversight only and as such TxDOT bares no responsibility for the technical oversight, for analysis of the research data, or for providing recommendations based upon the study's results.

As the title indicates, this study was initiated to investigate only the hydraulic feasibility of the Southwest Cut. The goal of the study was to identify any issues that might produce such undesirable hydraulic consequences as to preclude construction of the culvert bridge should the Southwest Cut project be implemented. Any resultant consequences on the ecological system were not investigated in this study.

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16. Abstract Field monitoring and numerical modeling were conducted to assess the hydraulic feasibility of the Southwest (SW) Corner Cut proposed to be opened in East Matagorda Bay, Texas, for enchancing water exchange. The SW Corner Cut would be the third inlet in East Matagorda Bay. The two existing inlets are the flood-relief channel called Mitchell's Cut, located on the eastern end of the bay, and a navigation channel bypass located on the western end. The overall objective of the study was to determine if any clear reason exists, based on the physical processes, which might preclude construction of the Cut and an associated culvert bridge.

Field data were collected from October 10, 1995, to January 26, 1996, and included synchronized measurement of the water level and current at the eastern and western ends of the bay and wind at the eastern end of the bay. The sustained monitoring recorded both summer and autumn-winter wind conditions. Hydrodynamic feasibility of the SW Corner Cut was examined by application of a two-dimensional, depth-averaged hydrodynamic numerical simulation model, calibrated with the field data. Results show that the new cut will be stable and that stability of Mitchell's Cut will not be jeopardized. In addition, the peak current at a critical maneuvering area in the navigation channel that presently poses a hazard to vessel traffic will be reduced by as much as 25% as a result of opening the new cut. The hydrodynamics of this wind-forced, shallow estuarine system and application of the model to resolve engineering questions about the physical impacts of the proposed cut are described. Appendices summarize the data and other detailed information compiled in the study.

17. Key Words
Coastal inlet, inlet stability, East Matagorda Bay, Southwest Corner Cut; Mitchell's Cut, Texas, tide wind setup, estuaries, field measurement, hydrodynamic modeling

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PREFACE

The study described in this report was commissioned by the Texas Department of Transportation (TXDOT) at the request of the County of Matagorda, Texas. The objective was to determine the hydraulic feasibility of a proposed water exchange cut in the southwest corner of East Matagorda Bay that would connect the bay to the Gulf of Mexico via the Colorado River Navigation Channel. This study was authorized as TXDOT Contract No. 0-1499 on August 2, 1995, under joint sponsorship of TXDOT and the Texas Parks and Wildlife Department (TPWD).

Oversight of the study was provided by a Technical Advisory Panel consisting of the following members: Ms. Cindy L. Loeffler, (TPWD); Dr. Robert McFarlane, McFarlane &Associates (an environmental consultant); and Ms. Dana Honganen and Mr. Jay Vose, TXDOT. Ms. Dana Honganen was the TXDOT Project Director, and Mr. Leland Roberts was the project coordinator for TPWD. Mr. Tom M. Yarbrough and Ms. Sylvia Medina of the TXDOT Office of Research and Technology Transfer provided coordination and assistance on contracting matters.

The study was conducted and the main text of this report written by Dr. Nicholas C. Kraus, Director of the Conrad Blucher Institute for Surveying and Science, Texas A&M University-Corpus Christi (TAMU-CC), and Ms. Adele Militello, visiting researcher at the Blucher Institute and Ph.D. Candidate at the Florida Institute of Technology, Melbourne, Florida. Mr. Beau Hardagree, Research Associate at the Center for Coastal Studies, TAMU-CC, wrote Appendix C, an assessment of historic salinity data available for East Matagorda Bay. Ms. Julie Celum, undergraduate assistant at the Blucher Institute, prepared Appendix E, photographic documentation of the site. A draft of this report was submitted for review on May 31, 1996.

The participation of Mr. Albert Green, Ms. Loeffler, and Mr. Roberts, all of the TPWD, in the synoptic field data collection project is gratefully acknowledged. Ms. Loeffler also provided documents for the literature review and salinity assessment. Messrs. William Templeton and D. W. Benthall of the East Matagorda Bay Foundation provided logistical support for the hydrographic survey, as well as information and guidance during reconnaissance tours of the site. Mr. George Deshotels, Commissioner of Precinct 2, Matagorda County, assisted with logistical support in servicing the temporary monitoring station erected at the southwest corner of the bay. Mr. Sid Tanner of the U.S. Army Engineer District, Galveston, provided support materials and insights on physical processes along the Texas coast. Mr. Joe Ward of Baker & Lawson, Inc., Angleton, Texas, clarified details of the survey performed for the permit application for the Southwest Corner Cut.

Blucher Institute staff provided technical assistance in the multitude of tasks associated with this study. Messrs. Zach Jeffries and Mark Earle established and maintained the water-level gauge deployed at the southwest corner of East Matagorda Bay; Messrs. John Adams and James Rizzo, and Ms. Carrie Garske-Shank assisted in installation and maintenance of instruments at all measurement platforms; Messrs. Adams and Daryl Slocum participated in the synoptic survey, for which Mr. Slocum, as Chief of the Blucher Environmental Instrumentation and Calibration Laboratory, prepared data loggers and integrated the measurement systems. Mr. Jeffries conducted the survey level (elevation) tie between the Texas Coastal Ocean Observation Network Rawlings gauge in the Colorado River Navigation Channel and the temporary gauge in the southwest corner. Messrs. Daniel Prouty and Donald Waechter conducted the hydrographic survey and associated data reduction, aided by Mr. Greg Hauger, undergraduate student. Ms. Celum aided in data organization and plotting, as well as in logistical preparation of this report.

EXECUTIVE SUMMARY

Field monitoring and hydrodynamic modeling were conducted to assess the hydraulic feasibility of the Southwest (SW) Corner Cut proposed to be opened in East Matagorda Bay, Texas, for increasing water exchange. The overall objective of the study was to determine if any clear reason exists based on the physical processes that might preclude construction of the Cut.

Sustained monitoring was conducted over a period of three months (October 10, 1995, to January 26, 1996) and included synchronized measurement of the water level and current at the eastern and western ends of the bay, wind measurement at the eastern end of the bay, and salinity and other common water-quality parameters at four locations in the bay. The sustained monitoring recorded both summer and autumn-winter wind conditions. An intensive synoptic survey was conducted by three boats on November 7 - 8, 1995, to measure the current and water quality in and around the bay. A hydrographic survey encompassing 140 miles of transects was also conducted to update and compliment existing bathymetry data. The field monitoring provided a comprehensive and accurate data set for calibrating a numerical simulation model of the hydrodynamics of East Matagorda Bay and associated existing and planned cuts. The data set also serves to characterize and document the bay in its present state.

A depth-integrated numerical simulation model consisting of 8,000 active cells was applied to compute the water level change and horizontal current velocity in East Matagorda Bay, the Gulf Intracoastal Waterway, Mitchell's Cut, the southern end of Caney Creek, the Colorado River Navigation Channel, and the proposed SW Corner Cut. The model included wind forcing and Gulf tidal forcing, and calibration was accomplished for a month-long period using measured water level at the eastern and western ends of the bay and at a gauge in the Navigation Channel, as well as the current measured at both ends of the bay.

The following is a summary of conclusions and recommendations obtained in this assessment:

1. The SW Corner Cut, if opened, will remain open unless artificially closed. The flow in the Cut will be ebb dominated because of a bias introduced by the wind, and the flow speed will regularly reach 60 to 90 cm/s (2 to 3 ft/s) if the design dimensions of the Cut are maintained. It is recommended that scour be anticipated and taken into account in both box culvert design of the bridge on FM 2031 and in any bulkheading and revetments placed in the channel. Provision for protecting the integrity of structures under scour and for reducing flow in the Cut should be part of the design.
2. Scour in the wetland area adjacent to the channel of the SW Corner Cut is not expected to occur. It is recommended that a no-wake zone be established in regions of the channel of the SW Corner Cut that are directly adjacent to wetlands.
3. Opening of the SW Corner Cut to the CR Navigation Channel will create only a small cross current in the Channel if the design dimensions of the Cut cross section are maintained.

Scour of the west bank of the Navigation Channel may occur if the discharge from the SW Corner Cut increases beyond that expected with its design dimensions maintained.

4. If the SW Corner Cut is opened, the peak flow speed and discharge will decrease at the intersection of the GIWW and the CR Navigation Channel Land Cut. A 25% decrease in peak flow speed is expected, and the decrease will be greater if the SW Corner Cut scours beyond its design dimensions. The decrease in flow speed will improve navigability in the GIWW.
5. If the SW Corner Cut is opened, there will be a slight increase in both ebb and flood peak flow speed at the mouth of the CR Navigation Channel
6. The stability of Mitchell's Cut will not change with opening of the SW Corner Cut.
7. Mitchell's Cut is necessary for promotion of maximum water exchange in East Matagorda Bay. Mitchell's Cut allows dynamic movement of water to take place between the Gulf and the Bay that accompanies weather fronts and large-scale forcing in the Gulf.
8. If the SW Corner Cut is constructed and Mitchell's Cut closes (closure being independent of the existence of the SW Corner Cut), then the presence of the SW Corner Cut and absence of replacement water that would otherwise enter through Mitchell's Cut would lead to appreciable lowering of mean water level in East Matagorda Bay.
9. Wind is the dominant force for day-to-day water movement and exchange in East Matagorda Bay. The dominance over the tide occurs not only because of the strong and persistent wind in the area, but also because of the east-west orientation of the bay, which results in westerly movement of water driven by winds out of both the northeast and southeast. There is a mean tilt of approximately 3 cm (1 inch) in the water surface across the long axis of the bay, with the western side higher, due to persistent wind forcing. The tilt was measured and calculated to reach as much as 60 cm (2 ft) under typical winter frontal movement and is expected to be greater under stronger winds. Opening of the SW Corner Cut will only slightly reduce this tilt.
10. Circulation in and flushing of East Matagorda Bay will be increased with opening of the SW Corner Cut.

1. INTRODUCTION

This chapter introduces the study problem statement and objectives. An orientation to the site is then given, followed by an overview of the technical approach taken. The chapter concludes with a short description of the contents and structure of this report.

Problem Statement

The County of Matagorda, Texas, has proposed installation of a water-exchange cut that would connect East Matagorda Bay at its southwestern end to the Colorado River Navigation Channel. The navigation channel used to be part of the Colorado River, but in 1992 the river was routed west to empty into Matagorda Bay through a diversion channel. The intersection of the cut and the Colorado River Navigation Channel would be located approximately 2 miles (3.2 km) upstream of the mouth of the channel at the Gulf of Mexico. Figure 1 is a site location map showing East Matagorda Bay and major features discussed here. Figure 2 gives a close-up view of the western end of the study site, including the CR Navigation Channel and the location of the proposed SW Corner Cut. A copy of the permit for the proposed SW Corner Cut obtained by the County from the U.S. Army Corps of Engineers (USACE), Galveston District, is contained in Appendix A.

If the SW Corner Cut project were implemented, the Texas Parks and Wildlife Department (TPWD) and Matagorda County would dig the channel from East Matagorda Bay to the Colorado River Navigation Channel, and the Texas Department of Transportation (TXDOT) would erect a box culvert bridge on Farm Road 2031, which runs parallel to the navigation channel. Prior to moving forward in final design and construction of the project, the County of Matagorda requested that the TPWD conduct a study to determine the physical consequences of installing the cut. The general aim of the study documented in this report was to identify and quantify any issue which might be of such serious consequence to the physical environment or project as to preclude construction of the culvert bridge and associated dredging for the SW Corner Cut. Such concerns extend to the eastern end of the bay, where a flood relief pass called Mitchell's Cut (Figure 3) exists. Data collected in this study will also serve to characterize the existing condition of the bay.

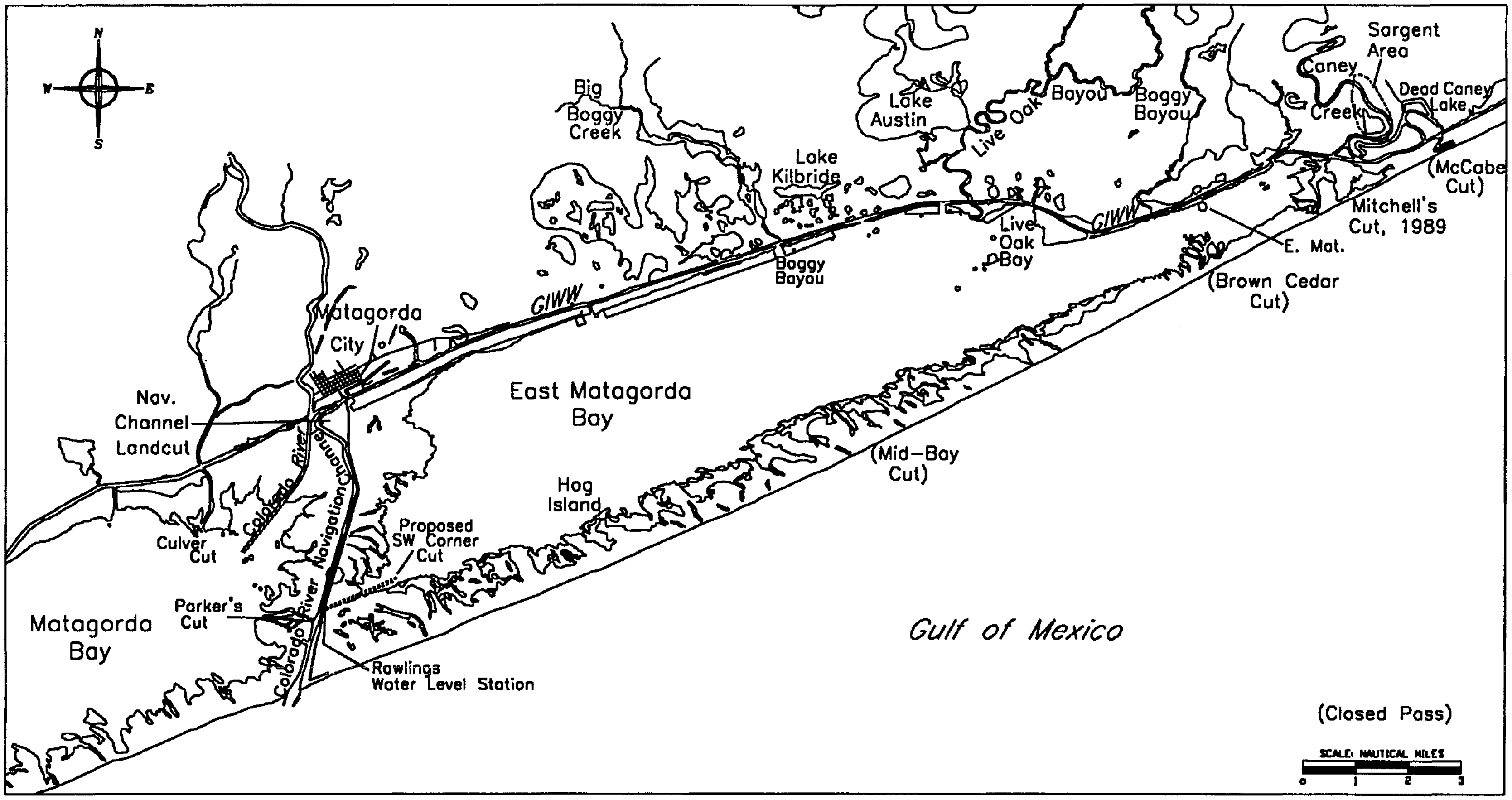

Figure 1. Location Map for East Matagorda Bay.

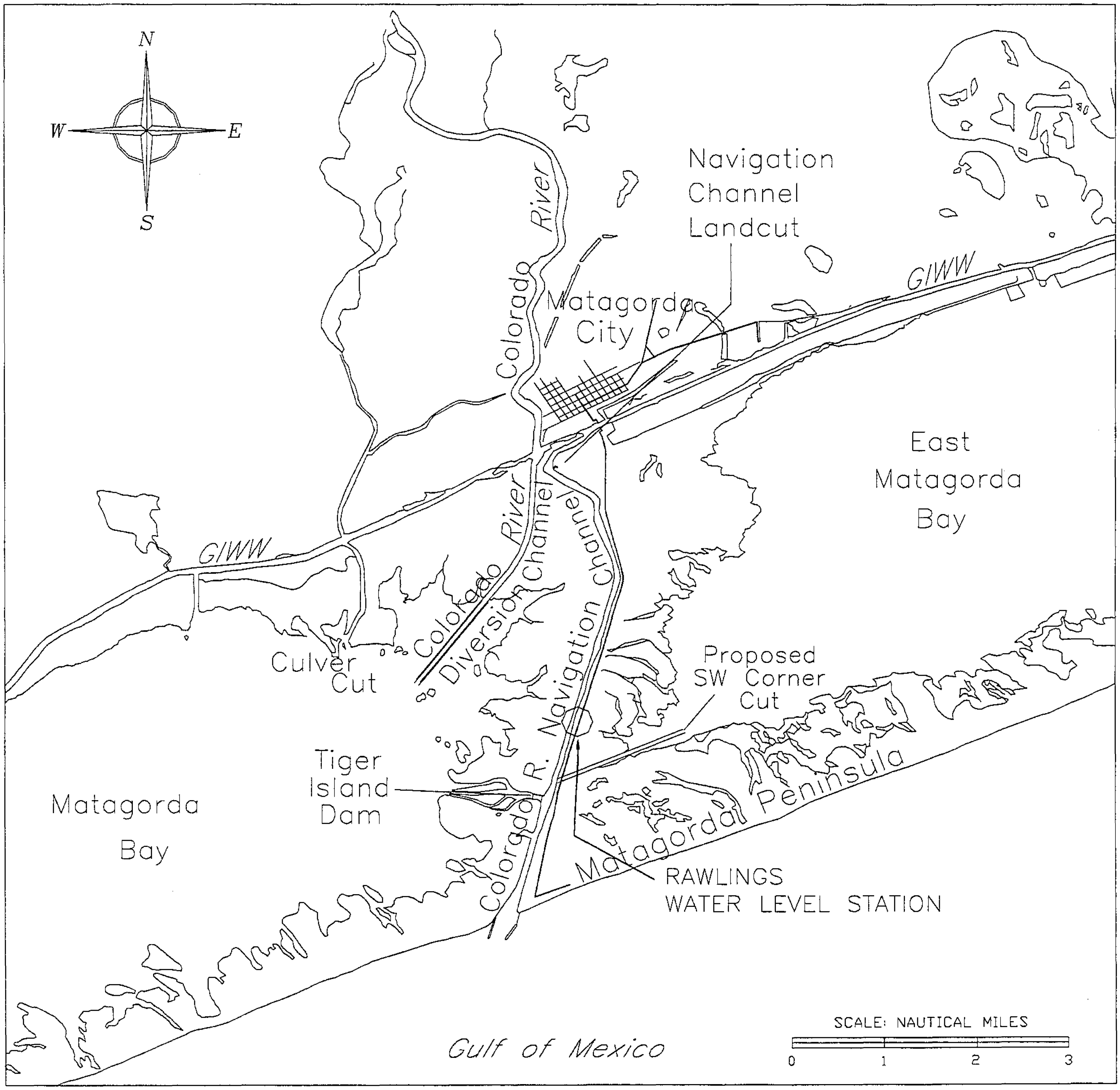

Figure 2. Western end of East Matagorda Bay, including the location of the proposed SW Corner Cut.

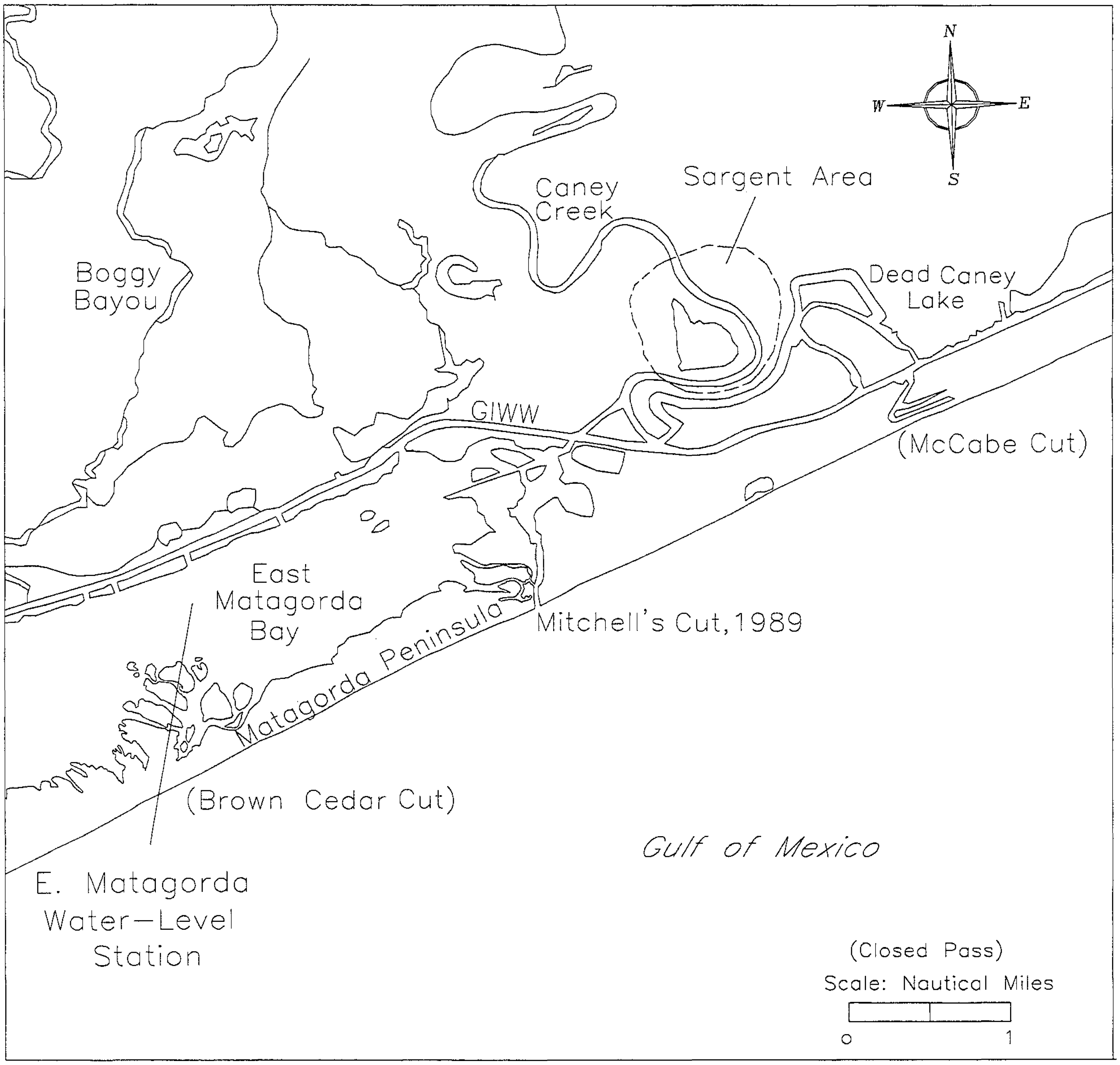

Figure 3. Eastern end of East Matagorda Bay, including the location of Mitchell's Cut.

Background and Overview of the Site

Considered a relatively small bay for Texas, East Matagorda Bay is a pristine, approximately rectangular-shaped estuary about 1 mile (1.6 km) wide on average and about 23 miles (37 km) long from Caney Creek to the mouth of the Colorado River Navigation Channel. The long axis of the bay is oriented approximately east - west, but tilted 27° counterclockwise.

East Matagorda Bay became isolated from the western and larger part of Matagorda Bay, and, in particular, from the now mile-wide (1.6 km) Pass Cavallo located at the southwestern end of Matagorda Bay, by a prograding delta that crossed the bay from the mainland and joined to Matagorda Peninsula. The delta formed rapidly starting in 1929, when a log raft and massive sediments that had apparently been entrapped for centuries on the Colorado River were freed by local interests concerned with flooding of low-lying inland areas (Bouma and Bryant 1969, Morton et al. 1976, Ward and Armstrong 1980, USACE 1992a). The delta reached Matagorda Peninsula in 1935. Figure 4 is a digitized rendering of a survey map prepared in January, 1839 (original map located in the archives of the TGLO). It is seen that Matagorda Bay was a continuous water body from Caney Creek to Pass Cavallo (not labeled on the map, but is the pass between Matagorda Peninsula and Matagorda Island). Also, the map shows numerous branches at the termination of the Colorado River, presumably caused by water seeking a way through the log jam.

Caney Creek and the communities of Sargent (the Sargent Area) are located on the eastern boundary of East Mat Bay, and the wetland adjacent to the Navigation Channel and Farm Road 2031 are on its western boundary. There is no industry and only very light residential development along the perimeter of the bay. The Gulf Intracoastal Waterway (GIWW) is routed along the northern margin of East Matagorda Bay, sheltered from wind waves on the bay by numerous islands composed of material dredged from the GIWW. There are approximately 15 openings between the islands, and the openings tend to increase in size through time by the action of waves and currents. In the 1940s, the GIWW had been routed through the middle of the bay, but was later moved to the northern perimeter to reduce maintenance dredging. Remnants of the old GIWW channel can still be observed, although most of the channel has filled in.

Typical bay water depth ranges between 2 and 4 ft, whereas the GIWW is maintained to a depth of 12 ft, with advance dredging and overdredging potentially adding another 2 ft of depth, and the waterway has a design bottom width of 125 ft and top width of 300 ft. Water flow in the GIWW is thus efficient as compared to the shallow bay. The USACE, Galveston District, measures water depths to their mean low tide (MLT) datum, which for this area lies 1.43 ft (0.43 m) below the National Geodetic Vertical Datum (NGVD) of 1929.

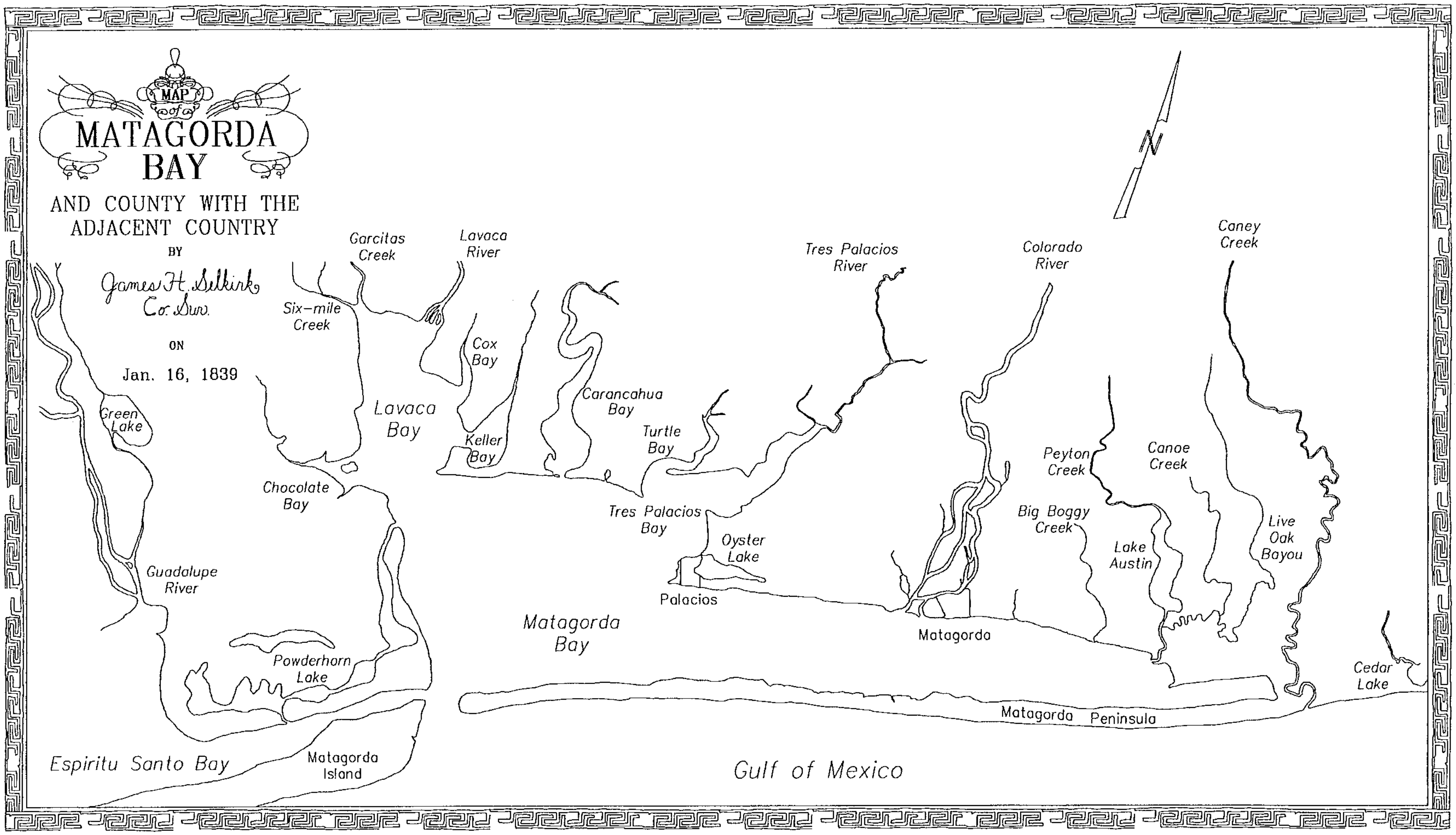

Figure 4. Survey map of Matagorda Bay, dated January 16, 1839.

In their natural state, Texas lagoons typically possess major freshwater inflows at their northern ends and a pass on their southern ends (Price 1951). In a comprehensive study for the time, Carothers and Innis (1960) discuss the perceived need for artificial opening of several passes in the Texas barrier islands for improvement of coastal fisheries. East Matagorda Bay presently does not have an opening in its southwest corner.

In the case of East Matagorda Bay, the main freshwater inflow is provided by Caney Creek and, to a lesser extent, by Big Boggy Creek and other creeks on the northwest perimeter. Free exchange of water brings nutrients for enhancing productivity and sediments for wetland development, and the freshwater inflow establishes a salinity gradient favorable to estuarine organisms. For completeness, it is noted that Pass Cavallo is presently closing owing to capture of the tidal flow at the Matagorda Ship Channel Entrance that lies approximately 3 miles (5 km) to the east. The ship channel entrance was cut in 1963.

The SW Corner Cut would be located about 5 miles (8 km) south of the City of Matagorda and connect to the Colorado River Navigation Channel at USACE, Galveston District, Colorado River Station 24+235 through culverts to be installed under Farm Road 2031. The cut is expected to be 100 ft (30 m) wide at the bottom and approximately 5 ft (1.5 m) deep with respect to mean water level, although interpretation of elevation datum is somewhat obscure (cf. Discussion in Appendix A). The dredged channel leading to the culvert bridge would be routed approximately 10,800 ft (3.3 km) so as to least impact tidal marsh in East Matagorda Bay (Appendix A). The material dredged from the channel is expected to be deposited as a thin layer in subsiding marsh areas to restore intertidal elevations.

The contemplated opening of SW Corner Cut calls into consideration a number of issues such as the resulting adjusted water current patterns and strength, adjusted water level, stability of the cut, water-borne transport and exchange processes, and associated alterations in fishery ecology, shrimp, and oyster populations. There is only limited monitoring and modeling information available of the physical processes of East Matagorda Bay as compared to that for Matagorda Bay (e.g., for Matagorda Bay, consult Ahr et al. 1974, Ward and Armstrong 1980, and Mueller and Mathews 1987).

An introduction to several pertinent works on East Matagorda Bay consulted in the present study is given in this paragraph. Comparisons with these and other studies are contained in the technical chapters of this report. An assessment of physical processes at Brown Cedar Cut (presently closed) was made by Mason and Sorensen (1971), who deployed two water-level gauges for two months and conducted a stability analysis of the cut. Seelig and Sorensen (1973) studied shoreline change and inlet processes at Sargent Beach, a severely eroding Gulf-fronting beach located just east of East Matagorda Bay, and their report has some information on specific and general physical processes at the study site. Brown and Root, Inc. (1979a, 1979b) conducted hydrodynamic and salinity numerical modeling studies for East Matagorda Bay, supplemented by soils investigations and local hydrographic and topographic surveys. The aim of the Brown and Root studies was to determine the hydraulic feasibility of opening of a cut to the Gulf of Mexico for environmental enhancement and development of recreational opportunities. Corner Cut was one of four alternatives studied. The USACE, Galveston District (1987) conducted an initial reconnaissance study at the request of the Matagorda County Commissioner's Court to determine the feasibility of providing flood-control improvements to the East Matagorda Bay area. Five alternatives were studied, which included the SW Corner Cut. Both the Brown and Root, Inc., and the USACE studies concluded that the SW Corner Cut alternative was questionable because of anticipated sluggish flows in the long, shallow channel. Hauck (1992) conducted a numerical modeling study for design of the lock system and diversion channel on the Colorado River. Morton et al. (1976) describe shoreline changes along the Matagorda Peninsula from Brown Cedar Cut to Pass Cavallo, including the histories and primary references on delta formation across Matagorda Bay from the Colorado River. Longshore sediment transport and dredging practice at the mouth of the Colorado River Navigation Channel have been studied by Heilman (1995) (see also, USACE 1993).

Although not directly related to East Matagorda Bay, Carothers and Innis (1960) present a comprehensive methodology for the design of inlets or passes for "Texas coastal fisheries." The paper covers simple hydraulic models, water exchange, sediment transport, inlet stability, stabilization works, and salinity changes. Experiences with several Texas fish passes are summarized. Although some of the material is dated, the paper is a valuable contribution that meets the expectation of "...the hope that by this publication others will be able to avoid some pitfalls (in fish pass design) as of a result of the experiences reported."

In light of limited available information on the physical processes in East Matagorda Bay, achievement of comprehensive understanding of the bay processes prior to opening the SW Corner Cut would require implementation of a costly, multi-year effort. An alternative is to simply open the cut and observe the results. If it is determined that the damages outweigh the benefits brought by SW Corner Cut, it could then be closed, minimizing overall cost and time to conduct the project.

Opening of the SW Corner Cut does bring the potential for undesirable consequences to the physical processes and, therefore, to the ecological system. It is prudent to study the critical issues identified as producing these impacts, both to proceed with the project if it is safe and to provide information that will aid in its design to prevent or mitigate problems. This report describes such a study, called a feasibility analysis, aimed at identifying and focusing on critical issues that would *a priori* make the cut unacceptable. Also, a quantitative estimate of the flow conditions to be expected at the Southwest Corner Cut, at Mitchell's Cut, and in East Matagorda Bay will aid in the design of the bridge culverts, channel stabilization, and overall flow conditions and water exchange.

Eastern End of the Bay

Several inlets or cuts have opened naturally or have been artificially opened at the eastern end of the bay. These openings owe to a variety of causes including hurricane breaching, discharge from Caney Creek, the necessity to provide flood relief at the eastern end of the bay, and the desire by commercial and recreational interests to have access from the bay to the Gulf and to beaches on Matagorda Peninsula.

Mitchell's Cut was dug in May, 1989, to provide drainage for flood waters in the Sargent and Caney Creek communities, and, presently, it provides the sole direct communication of Gulf of Mexico waters with East Matagorda Bay. Mitchell's Cut derives its name from a historic cut that had existed at the same location (also called "Mitchell Cut") that was observed as early as 1875 (Seelig and Sorensen 1973). The location of this cut has been referred to as Caney Fork Cut (USACE 1987). It is somewhat remarkable that Mitchell's Cut has not closed since being opened in 1989, becoming wider during times of flooding from Caney Creek and shoaling to near closure during times of drought. The stability of Mitchell's Cut is discussed in Chapter 4. The orientation of the channel at the mouth of Mitchell's Cut appears to oscillate between being directed more or less straight offshore to being at an angle to the southeast.

Just prior to opening of Mitchell's Cut, another drainage-relief cut to the north, called McCabe's Cut, was closed by the Matagorda Drainage District. McCabe's Cut had to be closed because it was widening and producing strong currents that threatened barge traffic owing to the proximity of the GIWW to the Gulf of Mexico at the cut, and it was increasing sedimentation in the GIWW (Hauck 1992).

Although presently closed, in this century, Brown Cedar Cut has been a major pass through Matagorda Peninsula for East Matagorda Bay. According to Mason and Sorensen (1971) and Seelig and Sorensen (1973), Brown Cedar Cut was first opened artificially in 1905, but quickly closed due to inadequate design. Brown Cedar Cut opened again circa 1929, and, from 1929 to 1971, it remained open more than 90% of the time. Brown Cedar Cut has opened intermittently under force of hurricane storm surges from the Gulf to the bay or to release floodwater accumulation (USACE 1987) from the bay to the Gulf. The cut has a tendency to open both because of: (Gulf side) breaching by hurricanes of the low-lying section of barrier island in front of it, and (bay side) flow conveyed by natural channels leading to it that were formed when the cut was open. A large flood tidal shoal complex and storm washover deposit sheets protrude into East Matagorda Bay at the location of Brown Cedar Cut. This large subaqueous feature, associated shallow margins, and the broad shallows on the eastern end of the bay, (believed to be deposits from dredging of the original GIWW), tend to hydrodynamically isolate Mitchell's Cut from the main portion of East Matagorda Bay because of large bottom-frictional resistance to the flow.

Western End of the Bay

Toward the west, the GIWW proceeds past the Navigation Channel Landcut that connects the GIWW and the CR Navigation Channel, and then it passes through a pair of locks or flood-control gates operated by the USACE. When closed, the locks isolate the Colorado River from East Matagorda Bay, directing all the fresh water flowing down the Colorado River into (West) Matagorda Bay through the Diversion Channel. The CR Navigation Channel from its entrance to the GIWW is maintained to 12-ft (4.5 m) depth and 100-ft (30.4 m) width by the USACE (1993) (at the entrance to the Gulf the channel is maintained to 15-ft (4.6 m) depth and 200-ft (61 m) width). The CR Navigation Channel no longer directly connects to the Colorado River, and the Navigation Landcut at its northern end provides an indirect access for Gulf water to reach East Matagorda Bay via the GIWW. The first major opening to the bay between dredged material islands heading east from the Navigation Landcut is called "2-Mile Cut" or the "Gulf Cut."

Complex and strong currents are frequently experienced in the vicinity of the intersection of the GIWW and the Navigation Landcut. The pattern of the current is made more complex by the presence of a pontoon bridge crossing the GIWW on FM 2031. The pontoon bridge, operated by TXDOT, is normally closed to form the road. It consists of a partially submerged barge and is a substantial block to the current in the GIWW. There is a small opening on the south side of the bridge when it is closed that is sufficiently wide to allow small recreation boats to pass.

The current in the GIWW in the vicinity of the locks can be extremely swift, particularly during strong winds blowing from either the northern quadrant or from the southeast, and the fast moving water sometimes poses a hazard to push-barge navigation. Because of the strong and somewhat unpredictable current, multi-barge loads traversing the GIWW tie off before reaching the locks, and barges are then pushed through the locks one by one. *A priori*, the proposed SW Corner Cut is expected to carry some of the flow that would otherwise pass through the GIWW, thereby improving navigation in the vicinity of the locks.

Objectives of the Study

The overall objective of this study was to determine the hydraulic feasibility of the proposed SW Corner Cut. Major issues addressed were:

1. Stability of the proposed SW Corner Cut and of Mitchell's Cut, which included analysis of the potential for closure or shoaling of the cuts, and, conversely, extreme widening and scouring of the cuts;

2. Possibility of creating a strong flow in the channel of SW Corner Cut, causing loss of a portion of the neighboring intertidal wetland;

3. Disturbance of the flow and sedimentation in the CR Navigation Channel, which has implications on dredging requirements and navigation safety, creation of shoals at the cut, and enhancement of shoaling at the mouth of the river;

4. Extraordinary changes in the water level and water circulation pattern in East Matagorda Bay; and,

5. Flow conditions at the intersection of the GIWW and the CR Navigation Channel Landcut.

The objectives were met through the work described in the next section.

Study Procedure

On August 30, 1995, at the inception of the study, a letter was sent to key Federal, State, and local government agencies and private organizations informing them of the study and its purpose, soliciting information, and inviting the recipients to participate in the synoptic survey discussed below. The letters were sent to: (Federal) USACE Galveston District, USACE Waterways Experiment Station, and the U.S. Fish and Wildlife Service; (State) TPWD, TXDOT, Texas Water Development Board (TWDB), and the Bureau of Economic Geology and the Center for Research and Water Resources at University of Texas; (local government) Matagorda County Precinct 2; and (private) the East Matagorda Bay Foundation, and McFarlane and Associates. Several of these sources furnished information, and TPWD personnel participated in the synoptic survey. In addition, the Texas General Land Office (TGLO) assisted in providing access to several aerial photographs of the study area.

The study consisted of field data collection, numerical simulation of the hydrodynamics, and an inlet stability analysis.

Monitoring

The field measurement program consisted of *sustained monitoring* for an approximate 3-month interval (October 10, 1995, to January 26, 1996), and (semi-) *synoptic* or simultaneous wide-area monitoring for 2 days (November 7-8, 1995). Over the period August 13-17, 1995, a hydrographic survey was conducted to obtain water depths at key areas. The sustained monitoring was performed in the winter in order to record the passage of weather fronts that periodically arrive out of the north and northwest starting in about October and ending in April. For the remainder of the year, winds from the southeast are prominent.

The data collection was designed for validating a numerical model of the hydrodynamics and for characterizing the physical state of the East Matagorda Bay estuarine system. The field data collection covered water-level and its change, water current, and salinity (plus other common water-quality parameters). The hydrodynamic and bathymetry data collected in this study augment long-term wind and other water-level measurements made on the bay by the Blucher Institute as part of the Texas Coastal Ocean Observation Network (TCOON) sponsored by the Texas General Land Office and the TWDB. TCOON water-elevation measurements of great value to this study are also made at Rawling's Bait Camp in the Navigation Channel, located just north of the proposed entrance of the SW Corner Cut. The monitoring campaigns also provide baseline data to which measurements made in future studies can be compared in determining changes in the system if the SW Corner Cut is opened.

Hydrodynamics

The strongest water flow in East Matagorda Bay (and in other shallow bays of Texas) is produced during times of strong wind, dominating the current produced by the tide. In East Matagorda Bay, understanding of the flow is complicated by the presence of the GIWW, the Navigation Channel Landcut, and Mitchell's Cut, as well as by the planned SW Corner Cut. For this relatively fast-track hydraulic feasibility analysis, it was originally proposed in the scope of work to apply a one-dimensional numerical simulation model (Amein and Kraus 1991, 1992), a model that would simulate flow along the major axis of the bay. However, circulation patterns observed during the synoptic monitoring (described in Chapter(2) and in analysis of the data from sustained monitoring of the current indicated that a more sophisticated two-dimensional model would be required to account for the many complicating factors and to resolve the level of detail needed. The model employed, called M2D solves the full depth-averaged non-linear two-dimensional momentum equations and the mass conservation equation. The model M2D includes a provision for describing multiple channels or water bodies of arbitrary dimensions, variable bathymetry and bottom friction, non-linear bottom friction stress and advection terms, forcing by tide and wind, and specification of general boundary conditions such as no flow, an input discharge, an input water level (in the present project, forcing from the Gulf), and an open boundary that allows water to flow unrestricted across it (such as in the GIWW).

Predictions of current flow differ greatly according to the strength of the wind in shallow-water bodies such as in the bays and lagoons of Texas (Militello and Kraus 1994). Further, it is sometimes possible to numerically simulate water elevation to reasonable accuracy by using only water-level forcing and neglecting wind forcing. However, neglect of wind forcing can greatly degrade the accuracy of the prediction of the current (Militello and Kraus 1994, Brown et al. 1995). Because the direction and speed of the current are critical parameters in the stability analysis, the sustained monitoring program was designed to provide measurements of the current in addition to the water level and wind.

The hydrodynamic model was calibrated with water-level, wind, and current data for the existing condition, then run in predictive mode for the planned condition with the SW Corner Cut. Because the magnitude of the current depends on the water depth, which enters non-linearly through the bottom friction, reliability of model predictions is dependent on accurate bathymetry, acquired in this study. The model provided quantitative information on the water level and current for the existing condition and for the situation with the proposed SW Corner Cut. The calculated current velocities served as input for a stability analysis and general physical processes assessment.

Stability Analysis

Creation of a cut in a bay will alter the water circulation, as was the case in Matagorda Bay after the Matagorda Ship Channel was opened, and in Apalachicola, Florida, (Raney 1988) when a pass was opened. A major concern is the long-term stability of SW Corner Cut. The term "stability" refers to the condition of whether an inlet or pass will tend to close, remain open, or become wider. Stability is a dynamic condition, as the hydrodynamic forcing changes daily, weekly, seasonally, and with hurricanes. Similarly, an estimate must also be made of the stability of Mitchell's Cut, considered an important feature for flood relief. The combination of two cuts in the single bay complicates the problem, although some analytical work has been done (van de Kreeke 1990a, 1990b). In a typical design process, one must consider both the tidal prism (Escoffier 1940, 1977; Jarrett 1979) and longshore transport in the case of Mitchell's Cut and the mouth of the Colorado River Navigation Channel (e.g., O'Brien and Dean 1972, Bruun et al. 1978).

The stability analysis described in Chapter 4 combines knowledge of the stability of inlets such as contained in the cited references and the power of a numerical simulation model of the hydrodynamics. The results are then transferred to empirical relations for predicting stability. A pioneering reconnaissance stability analysis for the SW Corner Cut (Martin 1993) was inconclusive because of the lack of velocity data available through the modeling performed in the present study. In contrast to classical studies of inlet stability that depend primarily on knowledge of tidal flow (tidal prism), for this project and most embayments in Texas, the wind-induced current is a critical factor.

Organization of this Report

Chapter 1 contains the statement of the study problem, objectives, and an overview of the study site and technical approach taken. Chapter 2 describes the data-collection program, physical processes as measured at the site, and trends and major features of the bathymetry, wind, water level, current, and salinity. Chapter 3 describes the numerical simulation model and calculation results, including calibration of the model and sensitivity tests. Chapter 4 contains the stability analysis for the SW Corner Cut and Mitchell's Cut, and Chapter 5 contains conclusions and recommendations.

Background information is provided in Appendices. Appendix A contains the permit for the SW Corner Cut. Appendix B contains a chronology of field data collection and instrument maintenance activities. Appendix C is a summary of an analysis of historic salinity data available for East Matagorda Bay. Appendix D contains graphs of the water-quality data and the hydrodynamic data plotted at monthly intervals. Appendix E contains selected photographs of the site and monitoring equipment.

2. DATA COLLECTION AND PHYSICAL PROCESSES IN EAST MATAGORDA BAY

This chapter summarizes the hydrodynamic and associated measurements made in East Matagorda Bay for this study. The measurements are supplemented by data from neighboring TCOON stations and by reference to the results of previous studies. Properties and trends observed in the data are discussed.

Types of Monitoring

Three types of data collection methods were employed in the field study; a hydrographic survey, near-synoptic monitoring for short periods (typically 5 to 20 min) at many locations, and sustained monitoring (approximately 3 months) at four locations. This section gives an overview of the data collection as an introduction to the detailed results.

Hydrographic Survey

After making several reconnaissance trips to the site, a hydrographic survey was conducted during August 13-17, 1995, to provide measurements of water depth for the numerical modeling study discussed in Chapter 3. The hydrographic data were used to verify, update, and complement the depths given in National Oceanic and Atmospheric Administration (NOAA) National Ocean Service Nautical Chart 11319 dated November 4, 1995. Although this chart has a recent date, the modification(s) to previous version(s) are probably minor. For example, the chart still shows McCabe Cut and does not show Mitchell's Cut, which were closed and opened, respectively, in May, 1989.

The hydrographic survey was performed by Blucher Institute personnel, who operated a dual-frequency echosounder and differential global positioning system (GPS) from a boat. The echo sounding was supplemented by pole surveys made from the boat in water depths in the range of 2 to 3 ft (0.6 to 0.9 m). During the hydrographic survey, the water elevation in the bay was at an annual high, affording access to more areas of the bay than might typically be traversed other times of the year. The survey encompassed approximately 140 miles (220 km) of transects that included all regions of East Matagorda Bay, the CR Navigation Channel, the GIWW, and Mitchell's Cut. The water depths obtained were reduced to local mean lower low water (MLLW) or chart datum for input to the hydrodynamic numerical model.

Synoptic Monitoring

Monitoring was conducted from three boats on November 7, 1995, and by two boats on November 8, while the sustained monitoring stations were collecting data. Two boats were operated by Blucher Institute personnel and recorded the current and water state properties electronically. The current was measured with a new type of current meter called an Acoustic-Doppler Velocimeter (ADV) (Kraus et al. 1994), which measures the three components of flow (two horizontal components and the vertical component) at high frequency (25 Hz) at a point. Main interest in this study is in the horizontal components. The salinity and other water-state variables were measured with a Hydrolab Corporation H_2O Multiprobe Unit (HU). Measurements were recorded digitally on PC-based data loggers. The ADV was lowered over the side of the boat on a pipe and aligned such that a known horizontal component of the current would be directed positively toward the north. The HU was lowered over the side of the boat to an estimated mid depth unless a vertical profile was taken. At mid-afternoon on November 7, the HU on one of the boats was lost overboard in a strong current at Mitchell's Cut. (This unit was found washed up on shore in March, 1996, and returned to the Blucher Institute.)

On the third boat operated on November 7-8, personnel from the TPWD recorded values of the current and water state in a log book. The current was measured with a Marsh-McBirney electromagnetic current meter (EMCM), which gives the two components of horizontal flow. The EMCM was lowered from a winch on the boat after the boat was aligned in a certain locally appropriate direction, such as along the axis of the GIWW.

The boats moved from location to location in the bay, recording time and position with non-differential GPS. The survey is considered "near" synoptic in that measurements were made nearly simultaneously over a wide area.

Sustained Monitoring

A sustained monitoring campaign was conducted from approximately October 10, 1995, through January 26, 1996. The measurement period is approximate, because some limited measurements were made prior to October 10 and after January 26. This nominal 3-month period (108 days) contains almost complete time-series records of water elevation and current at the two longitudinal ends of the bay, and of wind at the eastern end. One instrument platform (called EMAT) was located at the eastern end on a long-term TCOON wind and water-level platform. The other platform (called SWEMAT) was specially constructed for this study at the southwestern end of the bay. Although the project was inaugurated in July, 1995, the sustained monitoring was postponed until the late autumn so that both summer southeasterly winds and winter northeasterly winds would be experienced.

In addition to the hydrodynamic monitoring, the sustained monitoring included measurements of salinity and other standard water-state parameters at four locations. These locations were: the bay side of the Old Gulf Cut (platform called POLE 1), about mid-bay across from POLE 1 (platform called POLE 2), and EMAT and SWEMAT. The locations of TCOON stations and monitoring stations established in this study are shown in Figure 1, and the parameters measured are listed in Table 1. Long-term TCOON water-level data supporting this study were available at Rawling's Bait Camp in the Navigation Channel and at the Galveston Pleasure Pier.

The TCOON stations report water level at 6-min intervals as an average of 181 readings taken every second (3-min average). Water-level measurements are made with an acoustic system as used by the National Ocean Service (NOS), NOAA. The wind at station EMAT is measured with an RM Young Model 5103 anemometer of the type used by the National Weather Service. Although the anemometer typically reports wind at hourly intervals, during the middle approximate 55 days of the monitoring period, 6-min records were downloaded from the gauge to allow closer correlation with the water-level and current measurements.

At the EMAT and SWEMAT platforms, an ADV was mounted on a pipe to measure at mid depth. The probes were oriented such that a known horizontal component (positive x) was pointed toward magnetic north, so that the other positive horizontal component was directed toward the west. On some occasions in the winter, the water level in East Matagorda Bay reached extreme lows due to the seasonally low Gulf waters, such that the sensor became exposed to wave action, with intermittent or complete exposure to air. During weekly or biweekly visits to the site, the ADV probes were twice lowered to compensate for the low water in the bay. An HU was mounted at approximate mid depth at both platforms. The current meters and HUs were serviced during the site visits, at which time the data were downloaded.

Figures 5-8, respectively, show the EMAT measurement platform, the SWEMAT platform, POLE 1, and the TCOON water-level gauge at Rawlings Bait Camp in the CR Navigation Channel. The white tubes house the acoustic water-level measurement system. Both the EMAT and Rawlings platforms contain radio and satellite communications antennas. The current meters on the EMAT and SWEMAT platforms were installed on pipes that were affixed to the platforms by clamps, whereas the HUs were typically hung with heavy chains (to reduce movement) from beams at the center of the platforms. Table B1 contained in Appendix B gives a chronology of major field data collection activities for this project. The fixed stations were serviced at nominal 7- to 10-day intervals, during which time instruments were checked and cleaned, and data downloaded for those instruments not reporting information by radio.

Table 1. Fixed measurement stations and types of instruments.			
Station Name	**Type**	**Measurement**	**Comments**
East Matagorda "EMAT"	TCOON	Water-level, and wind (long term); Current and salinity (3 months)	Located at eastern end of bay
Rawlings Bait Camp	TCOON	Water-level	Long-term water-level station in the Navigation Channel
Southwest Corner "SWEMAT"	Project-specific	Water-level, current, salinity (3 months)	Four-legged platform constructed at southwest corner of bay to mount water level gauge current meter, salinity sensors, and data loggers
POLE 1	Project specific	Salinity	Self-contained unit mounted on a pole near the Gulf Cut in the GIWW dredged islands
POLE 2	Project specific	Salinity	Self-contained unit mounted on a pole in approximately mid-bay

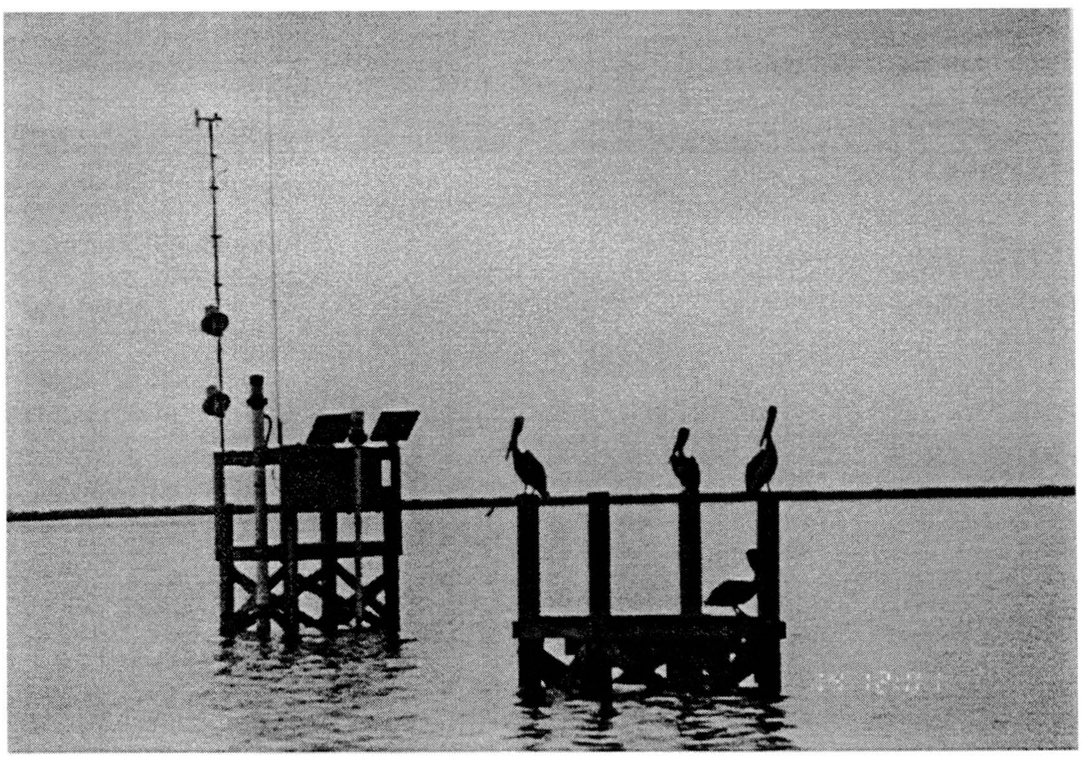

Figure 5. "EMAT" water-level and wind measurement platform.

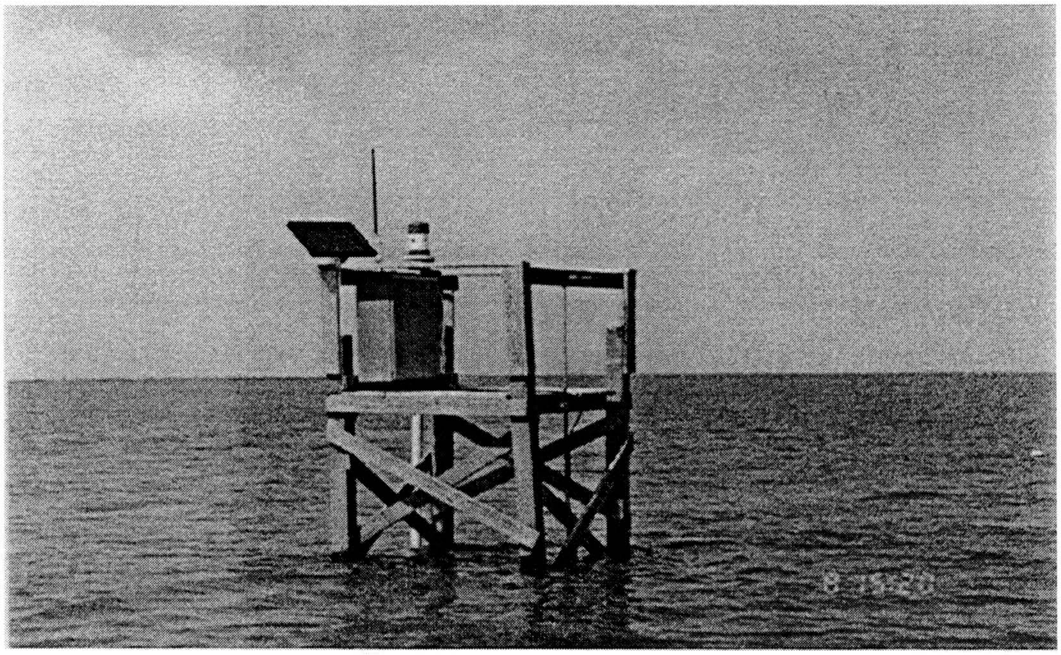

Figure 6. "SWEMAT" platform constructed for the present study.

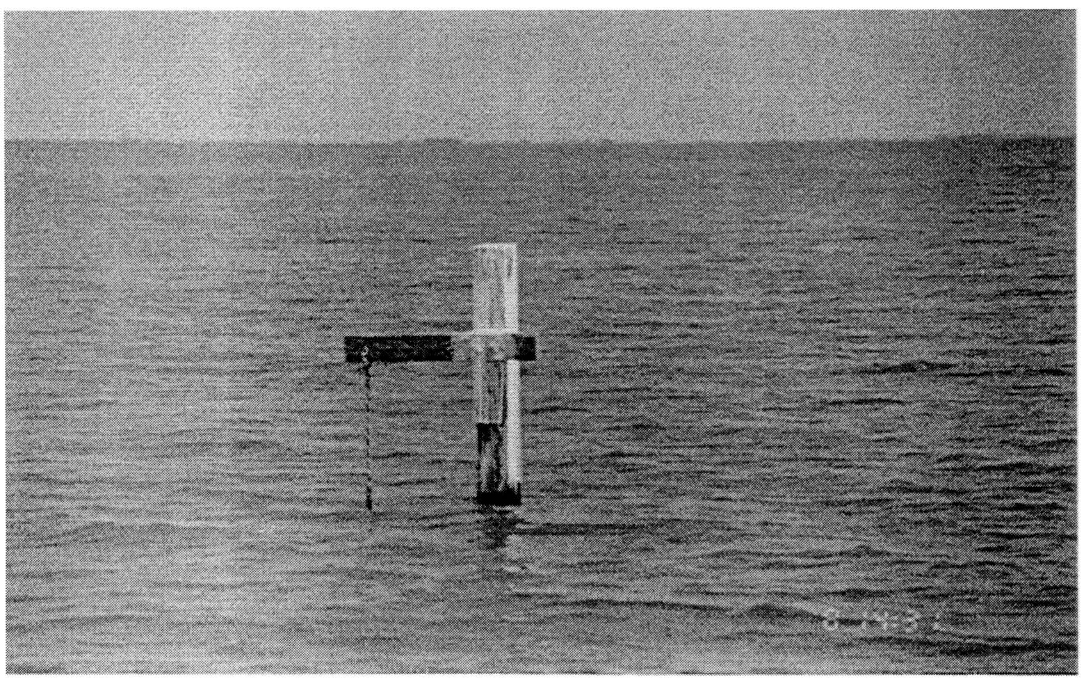

Figure 7. POLE 1 (salinity measurement) near the Gulf Cut.

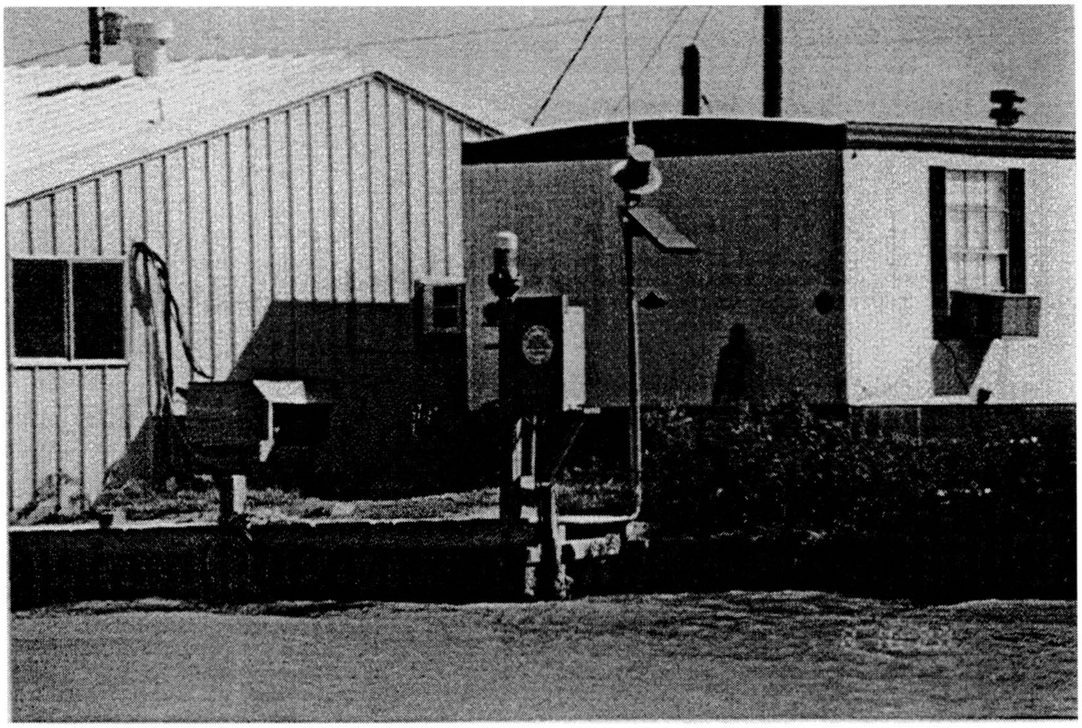

Figure 8. Rawlings TCOON water level gauge in the CR Navigation Channel.

This section contains selected results from the extensive data set pertaining to the hydrodynamic properties observed. A compilation of additional hydrodynamic data, as well as the salinity, water temperature, and pH data collected in this project, is contained in Appendix D.

Wind

A "wind rose" is a radial depiction of the wind speed and frequency of occurrence of wind direction. Wind roses developed from the EMAT gauge measurements are depicted in Figure 9 for (a) the year 1995, and (b) the 108-day observation period (Oct. 10, 1995, to Jan. 26, 1996). The annual wind rose shows that wind is incident predominantly from the southeast and east-southeast (around 120 to 150 deg) and that strong winds also blow from the east-northeast and northeast (around 45 to 75 deg), including some strong winds from the north. For shallow-water bays, the authors have found that wind with speed greater than 9 m/s (20 mph) substantially alters the tidally forced circulation. Because of the approximate east-west orientation of East Matagorda Bay, wind with an easterly component will drive water from the eastern side to the western side. Note that the wind rarely blows from the west at the study site.

As discussed in Chapter 1, the field data collection was purposefully conducted in the late fall to winter to capture the strong northeast wind fronts, and the frequency distribution by direction in Figure 9b shows a dominance of wind out of the north-northwest to east-northeast. The data collection also captured some strong wind events from the southeast.

The wind speed and direction for the observation period and for the time period simulated with the hydrodynamic model (see Chapter 4), called the "modeling period," are shown in Figure 10 and Figure 11, respectively. In these and similar figures in Appendix D, a line denotes wind speed and dots denote wind direction. The direction north is either 0 deg or 360 deg, and wind from the east has direction 90 deg. For reference, wind from the southeast has direction of 150 deg. From Figure 10, the weather fronts that periodically move across the bay are apparent as abrupt shifts from 0 to 360 deg, interspaced with periods of east-southeast to southeast wind. Wind speed shows sharp peaks associated with the passing northern fronts, and it is observed that wind is blowing almost all the time at the site. Spectral analysis performed on the 108-day observation record showed maximum wind energy to have a 5.2-day period, corresponding to the movement of fronts, and its peak was slightly above the 1-day period corresponding to the daily land-sea breeze.

During the 30-day modeling period (Figure 11), several fronts moved through the area, with wind speeds exceeding 10 m/sec (22 mph) at least ten times. Some fronts pass through to bring sharp impulses of wind, such as on JDs 287 and 294. A sustained interval of strong wind speed occurred during JDs 301 to 304, with associated direction fairly steady from about 45 deg or northeast.

Water Level

Water level recorded at the EMAT gauge for the time encompassing the observation period is plotted in Figure 12, starting on JD250 (Sep. 7, 1995) and ending on JD404 (Feb. 8, 1996). The overall trend of the water level is to decrease until approximately JD400, after which the water level trend first becomes constant then rises. The small daily fluctuations in the water level correspond to the astronomical tidal forcing from the Gulf. As is discussed at the end of this chapter, the tidal range (difference between daily high waters and low waters) for EMAT is only 10 cm (0.32 ft). The trend of decrease during the time period shown is part of the annual cycle of water level change in the Gulf, and the larger spikes correlate with times of sustained strong wind.

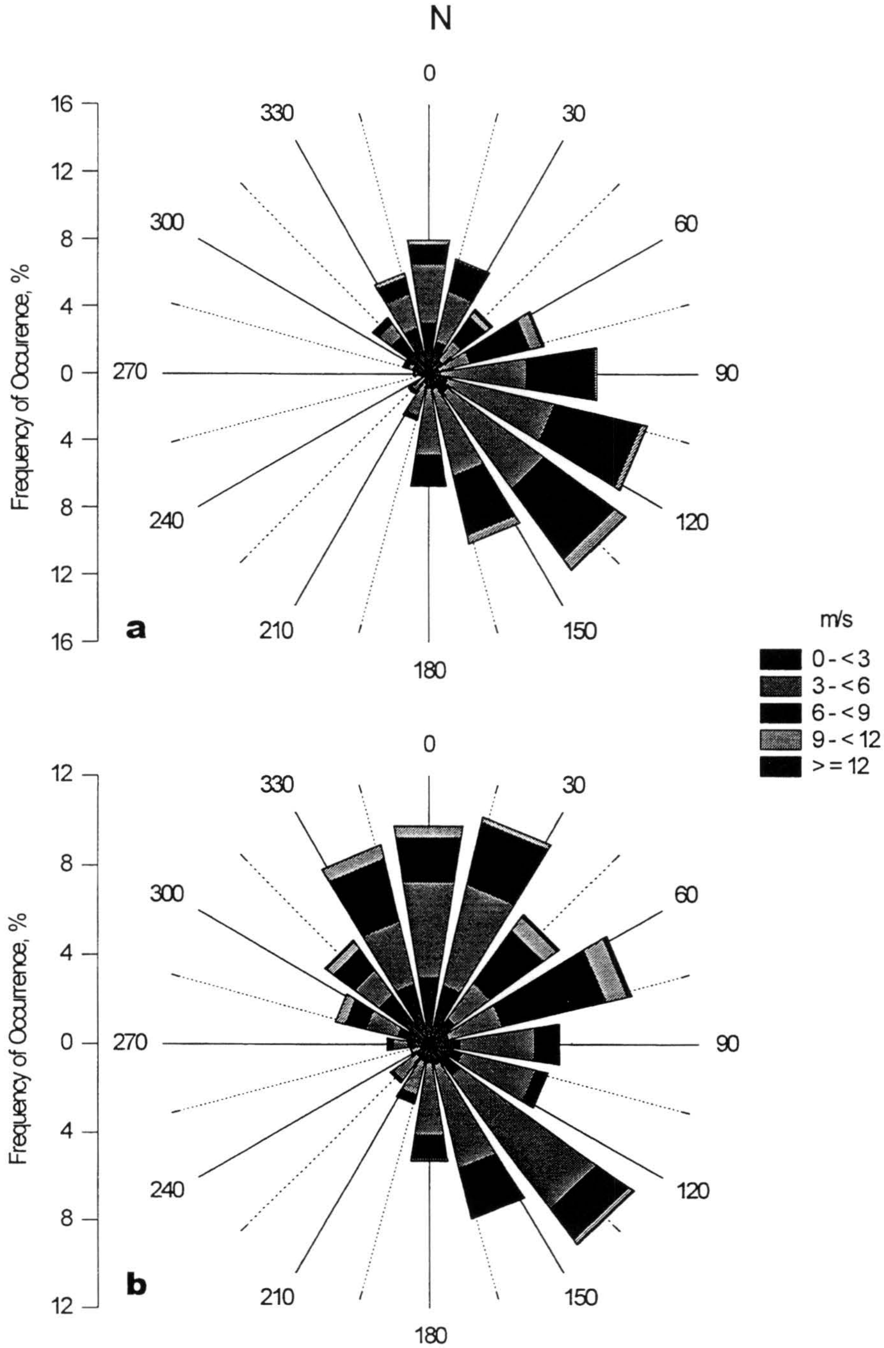

Figure 9. Wind rose for (a) 1995, and (b) monitoring period (10/10/95 - 01/26/96).

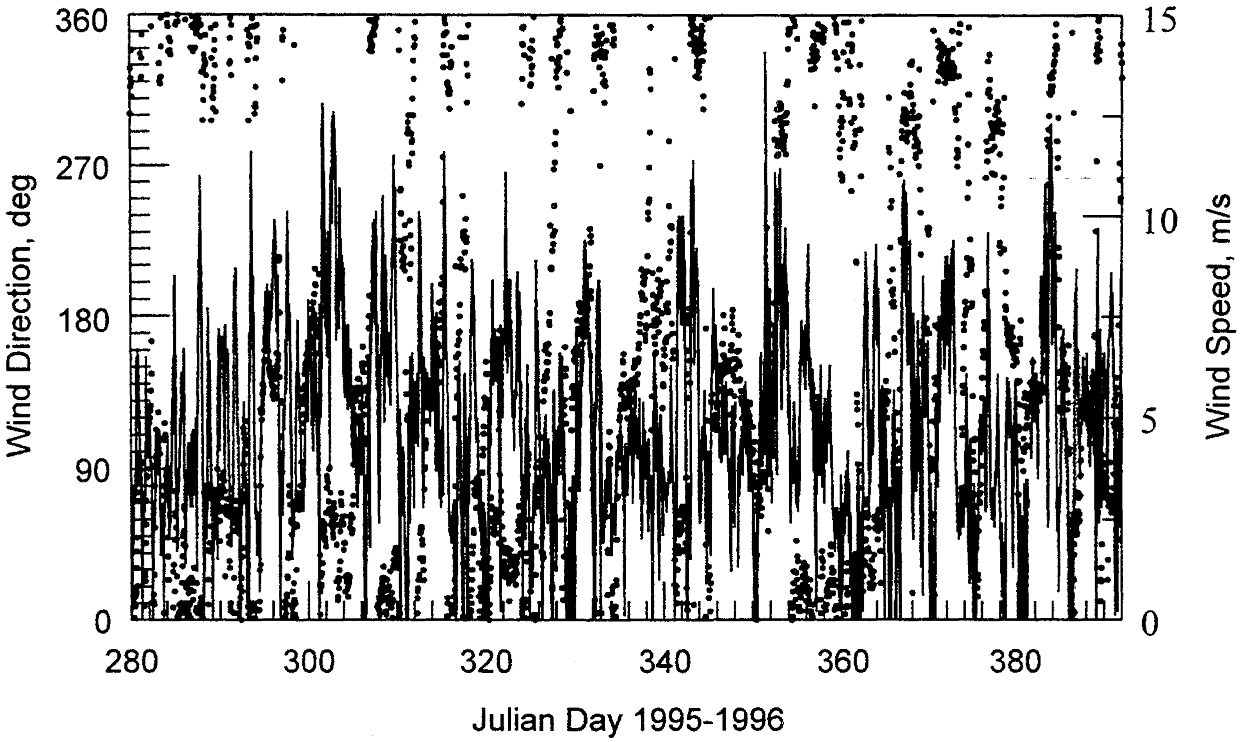

Figure 10. Wind speed and direction for study observation period.

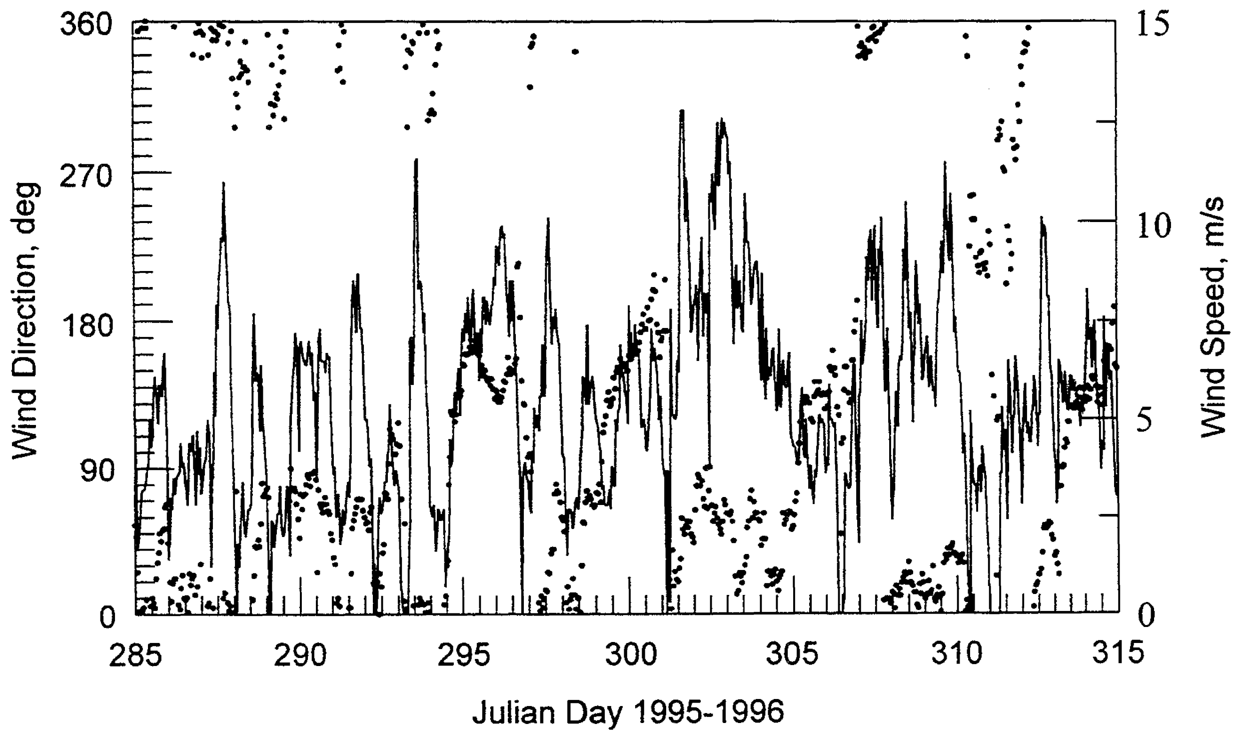

Figure 11. Wind speed and direction during modeling period.

Figure 13 plots the water level at EMAT and SWEMAT during the observation period, with the mean value at each location removed. The general trend of decrease in bay level as part of the seasonal cycle is seen at both gauges. However, a striking type of deviation in the two water levels is observed as numerous pairs of spikes for which the water level at EMAT lowered rapidly and the water level at SWEMAT increased rapidly. Such rising and lowering of the water level by the wind is called wind setup and wind setdown, respectively. For example, on JD302, the difference in water level between the eastern and western ends of East Matagorda Bay was almost 0.6 m (2 ft). As seen from Figure 11, this substantial tilt in water level was produced by an impulsive northeast wind front that had a wind speed of about 12 m/s (26 mph). The frontal wind impulse had been preceded by several days of moderate wind from the southeast, after which the wind direction turned sharply and blew from the northeast. A 2-ft tilt (1 ft up at the western end and 1 ft down at the eastern end) in the water level over some 18 miles is remarkable considering that the bay has a typical depth of about 4 ft in its deeper regions.

De-meaned water levels for the modeling period are shown in Figure 14. In addition to the relatively sharp setup and setdown event on JD302 described in the preceding paragraph, an approximately 4-day long (JD307 - JD310) persistent 0.3-m (1-ft) tilt in the water surface is observed for winds that blew steadily from the north-northeast with speeds typically in the range of 6 to 10 m/s (13 to 22 mph). The data on water-level elevation obtained at EMAT and SWEMAT during the monitoring period of this study provide an excellent and exceptionally dynamic record of water movement for calibration of the numerical model.

It can be concluded from this discussion that the pattern and strength of the circulation in the bay during times of moderate to strong wind is dominated by the wind-induced flow. In order for the water level to tilt 2 ft or more along the major axis of the bay, a substantial volume of water must flow from east to west. Measured currents are discussed next.

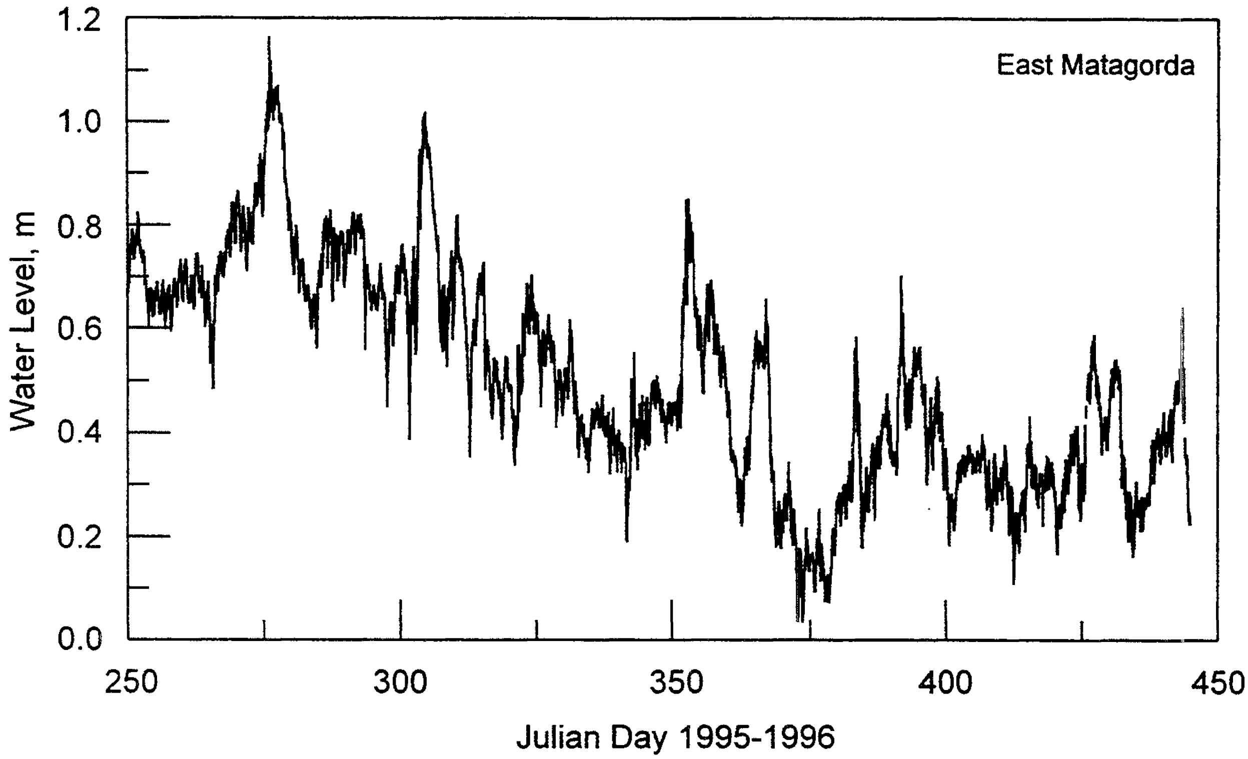

Figure 12. Water level at EMAT station during total observation period.

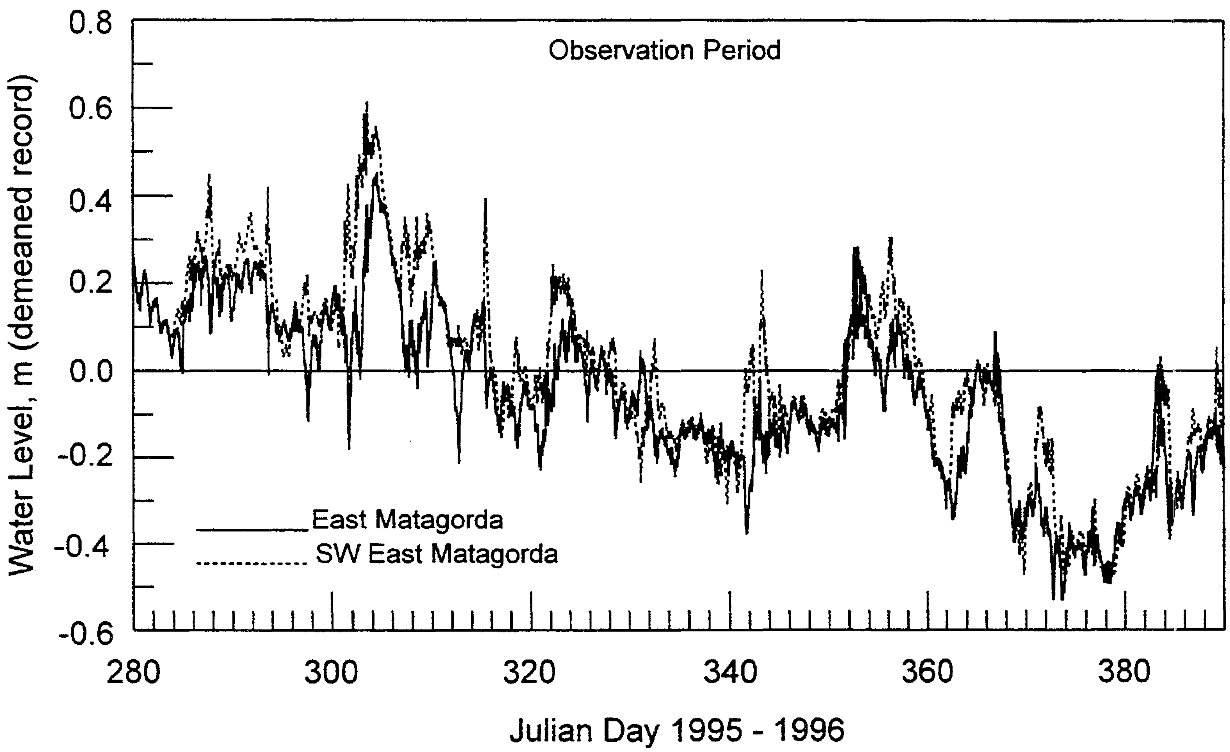

Figure 13. De-meaned water levels at EMAT and SWEMAT during total observation period.

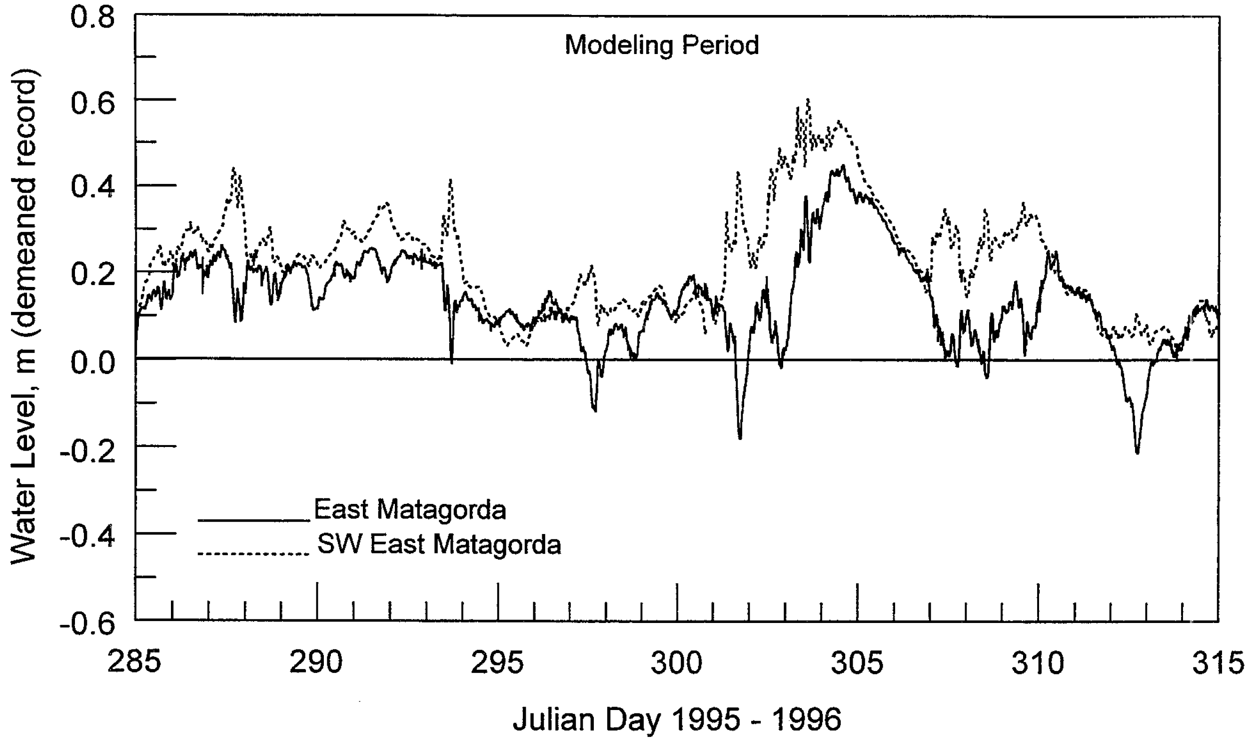

Figure 14. De-meaned water levels during modeling period.

Current

Because of the approximate east-to-west orientation of East Matagorda Bay and the large occurrence of wind with an easterly component, there is substantial movement of water along the major (E-W) axis of the bay. Therefore, in the bay and the portion of the GIWW running parallel to its major axis, we expect the along-bay or E-W component of the current to be stronger than the across-bay or N-S component. In contrast, in Mitchell's Cut, Caney Creek, and the CR Navigation Channel, which are relatively narrow channels oriented approximately N-S, the N-S component of the current is expected to be strongest. The general validity of this intuitive picture of the current pattern becomes apparent in the measurements shown below.

The E-W and N-S components of the current measured at EMAT and SWEMAT during the 108-day observation period are shown in Figure 15 and Figure 16, respectively. A gap exists in the EMAT record around JD360 because of equipment malfunction, and some weakening in the current at EMAT and SWEMAT around JD370 may be an artifact of low water level and exposure of the ADV sensor to the air. During the observation period, the E-W component of the current at both EMAT and SWEMAT has a typical maximum in the range of ±15 cm/s (±1 ft/s). The N-S component of the current (Figure 16) at SWEMAT is weak because of the surrounding wetlands located to the north and south.

The southerly directed flow at EMAT is strong and reached almost 30 cm/s (2 ft/s), as opposed to the northward flow, which is typically much weaker. The bias in the N-S current to the south owes to the location of the EMAT platform relative to land masses. The platform is located on the southwestern side of an opening between islands running parallel to the GIWW. The southward current corresponds to flooding of the bay by water flowing from the GIWW and through the opening. In contrast, ebbing water from the wide bay can flow into the opening from all sides, making the ebb (northward) component much weaker.

In this study of the hydraulic feasibility of the SW Corner Cut, we are primarily interested in mean flows on the order of hours or longer, as opposed to short-period motions of the water associated with waves, local wind gusts, and other intermittent forcing. To clarify the structure of the mean current, the record was filtered to remove components with periods of less than 6 hr. This time interval preserves the tide signal and changes produced by the longer period wind forcing. Figure 17 and Figure 18 respectively display the low-pass filtered records of the E-W component of the current for the observation period and the modeling period. It is seen that the magnitude and duration of the current are dominated by the wind. It is also noted that the along-axis current at SWEMAT tends to be directed toward the west.

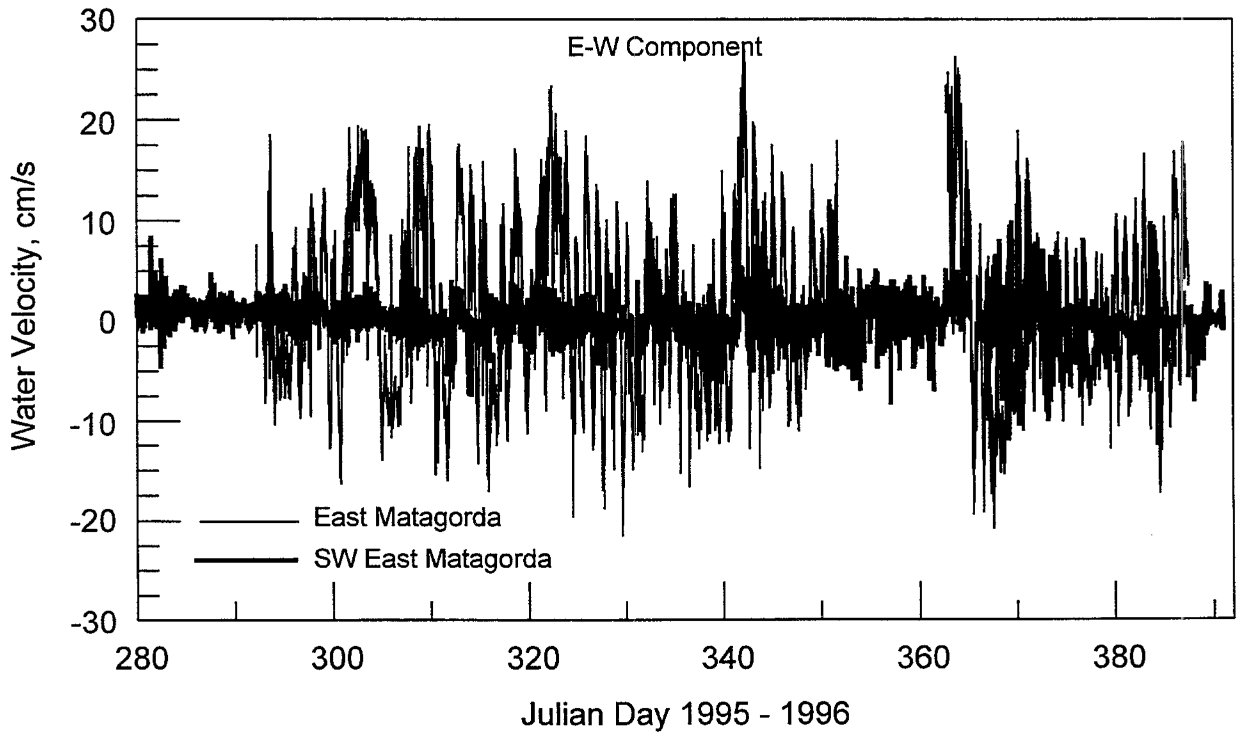

Figure 15. E-W current at EMAT and SWEMAT during the observation period.

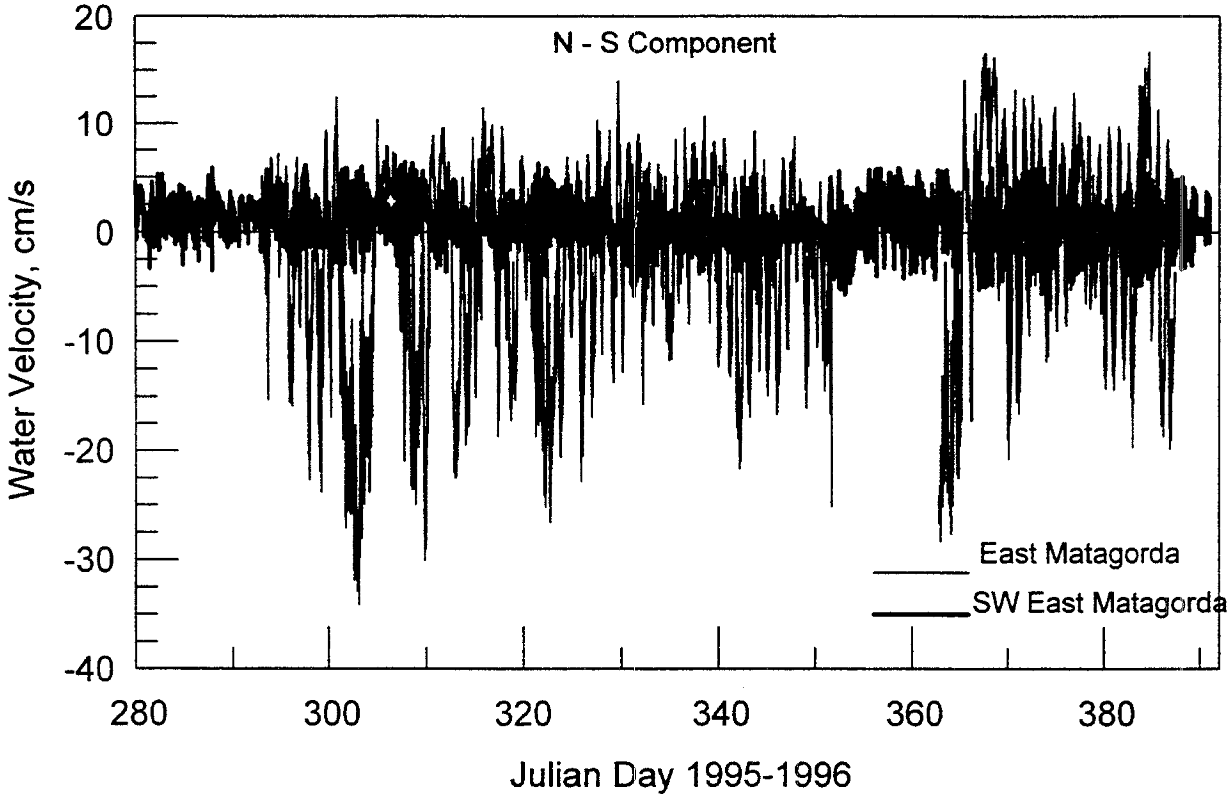

Figure 16. N-S current at EMAT and SWEMAT during total observation interval.

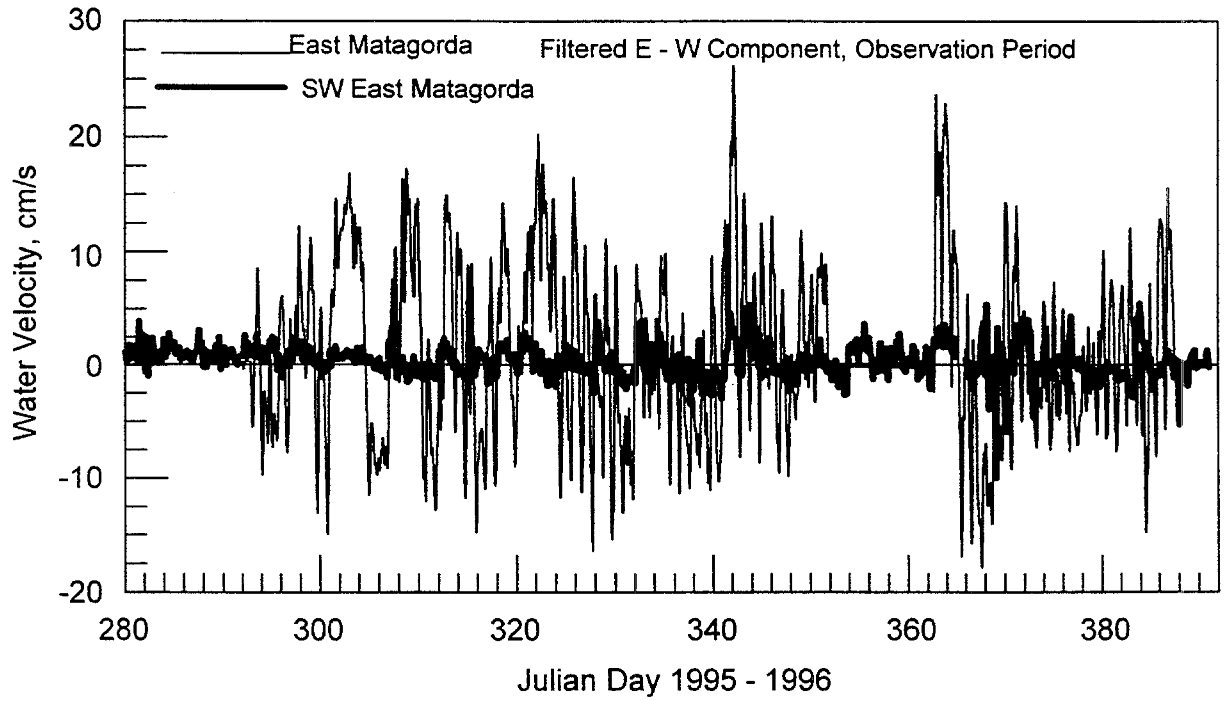

Figure 17. Filtered E-W current at EMAT and SWEMAT for the observation period.

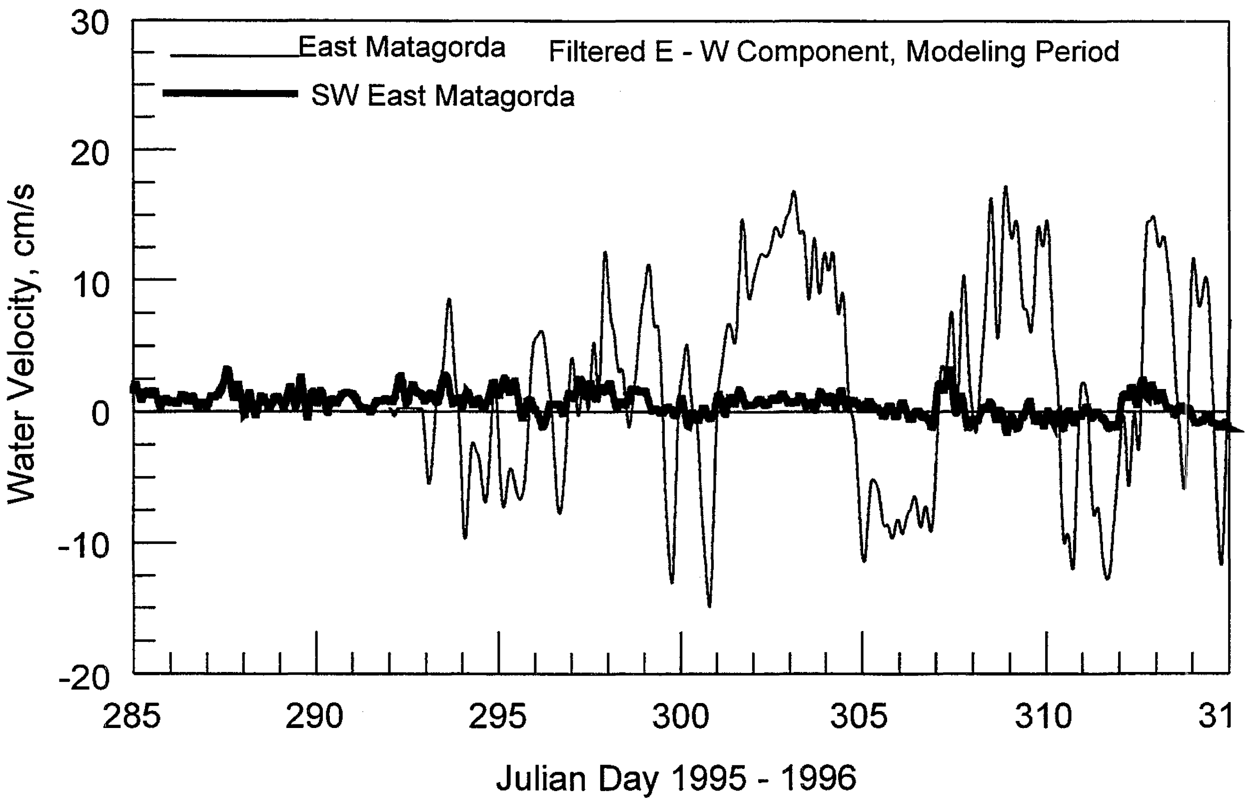

Figure 18. Filtered E-W current at EMAT and SWEMAT during the modeling period.

Synoptic Survey of the Current

This section presents representative results from the synoptic (boat surveys) measurements of the current performed on Nov. 7-8, 1995. Nov. 7 and 8 correspond to JDs 311 and 312. Tables B8, B9, and B10 in Appendix B contain summaries of the synoptic measurements, including location in latitude and longitude, general description of the area of the measurement, length of time of the measurement, average current, and standard deviation. In the figures, the file name is given in the title, and particulars about the measurement can be found by consulting Appendix B for the particular file. The current is directed positive to the north and to the west.

Mitchells's Cut

Mitchell's Cut is the main connection of East Matagorda Bay to the Gulf. Measurements of water level and current in the bay as shown above indicate that the tidal signal in the bay is relatively weak compared to the changes produced by the wind. Without Mitchell's Cut, the daily tide signal would be almost absent. However, in Mitchell's Cut, the tidal flow is powerful, as shown in Figure 19 for the N-S component. At the time of the measurement, the water was ebbing, meaning that the flow was directed out of the bay and Caney Creek. The mean current was strong at -49.6 cm/s (1.6 ft/s), with the minus sign indicating flow to the south or out of the cut and into the Gulf. As expected, the cross-channel (E-W) flow shown in Figure 20 was weak, with an average of 2.9 cm/s or about an inch per second, which could be partially an artifact of the orientation of the current meter and partially an indication of a small gyre or curve in the current produced by the shape of the bottom and side topography of the channel.

On the next day (JD312) during the time of observation, the current at Mitchell's Cut was flooding strongly (Figures 21 and 22), with a northward directed mean flow of 110.6 cm/s (3.4 ft/s), with a standard deviation of about half a foot per second over the more than 1-hr measurement interval. Measurements made just previously north of the mouth in Caney Creek and south of the GIWW showed that the tide was then just turning from ebb to flood (Figures 23 and 24). The current pattern can be highly irregular at the intersection of Caney Creek and the GIWW, with a turbulent water surface seen during times of strong current. The standard deviation in the current, indicating its variation, was comparable to or exceeded the mean value during the observation period.

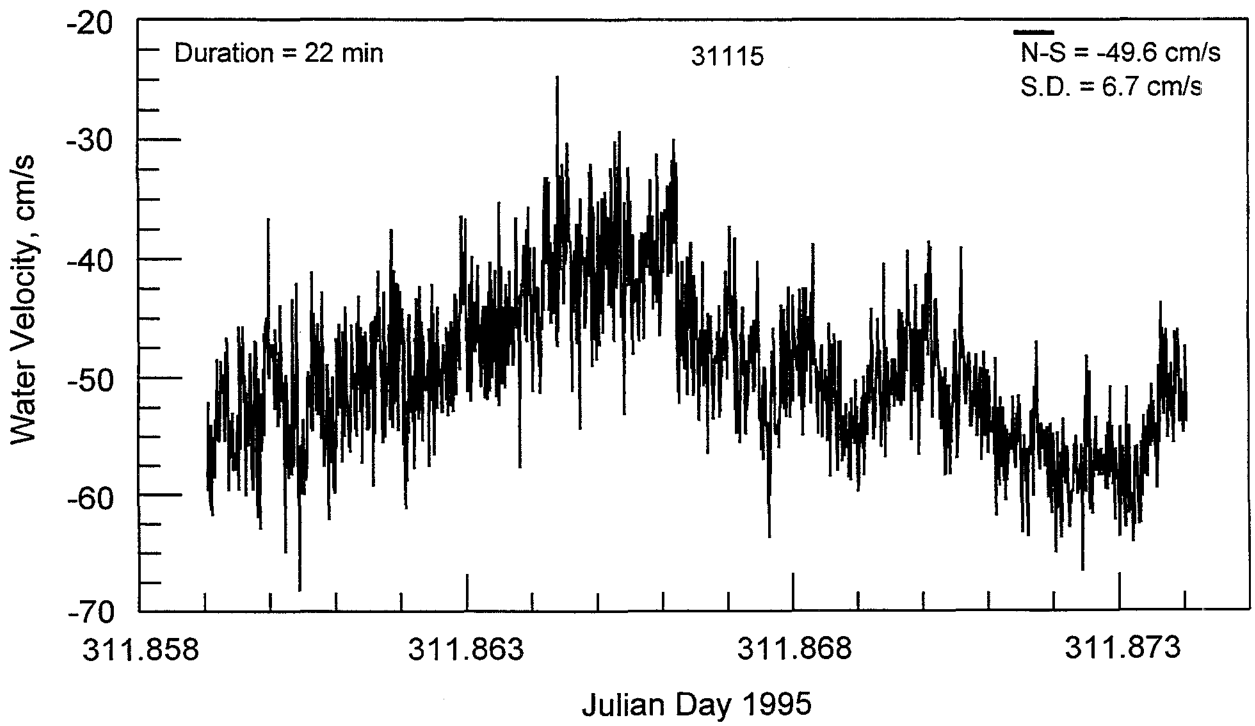

Figure 19. N-S (ebb) current, mouth of Mitchell's Cut.

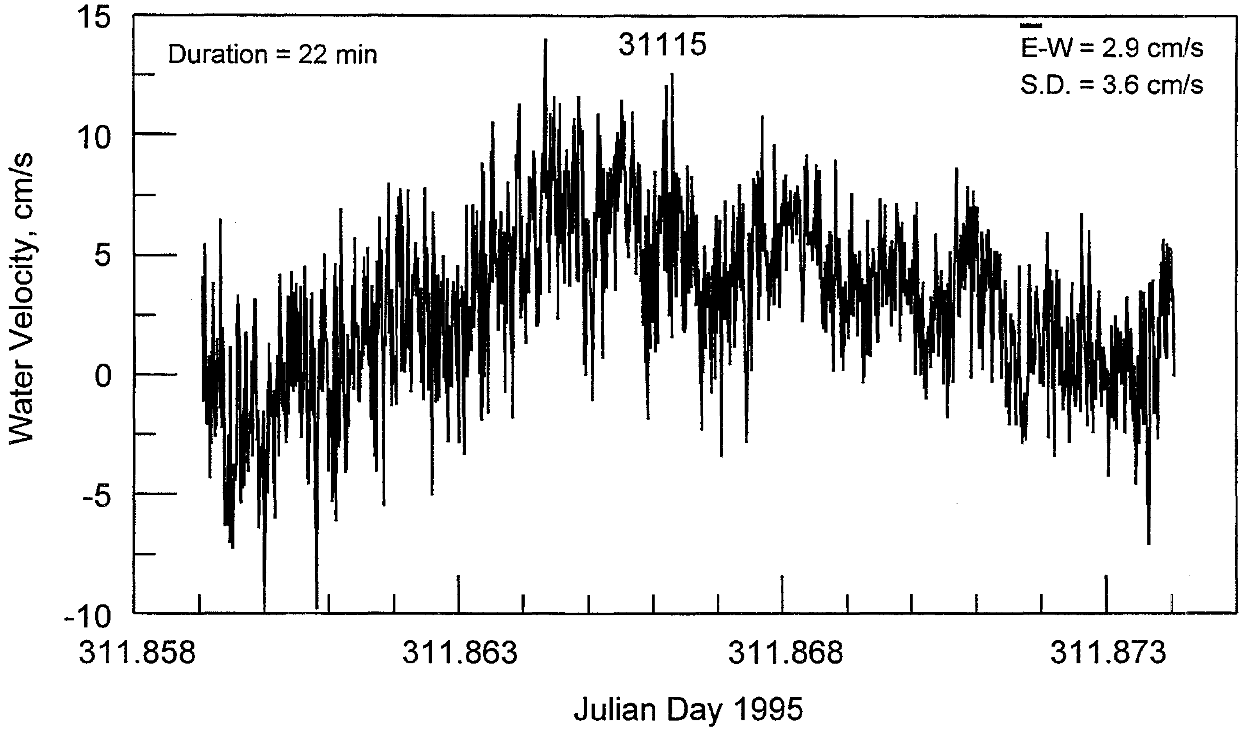

Figure 20. E-W current (during ebb), mouth of Mitchell's Cut.

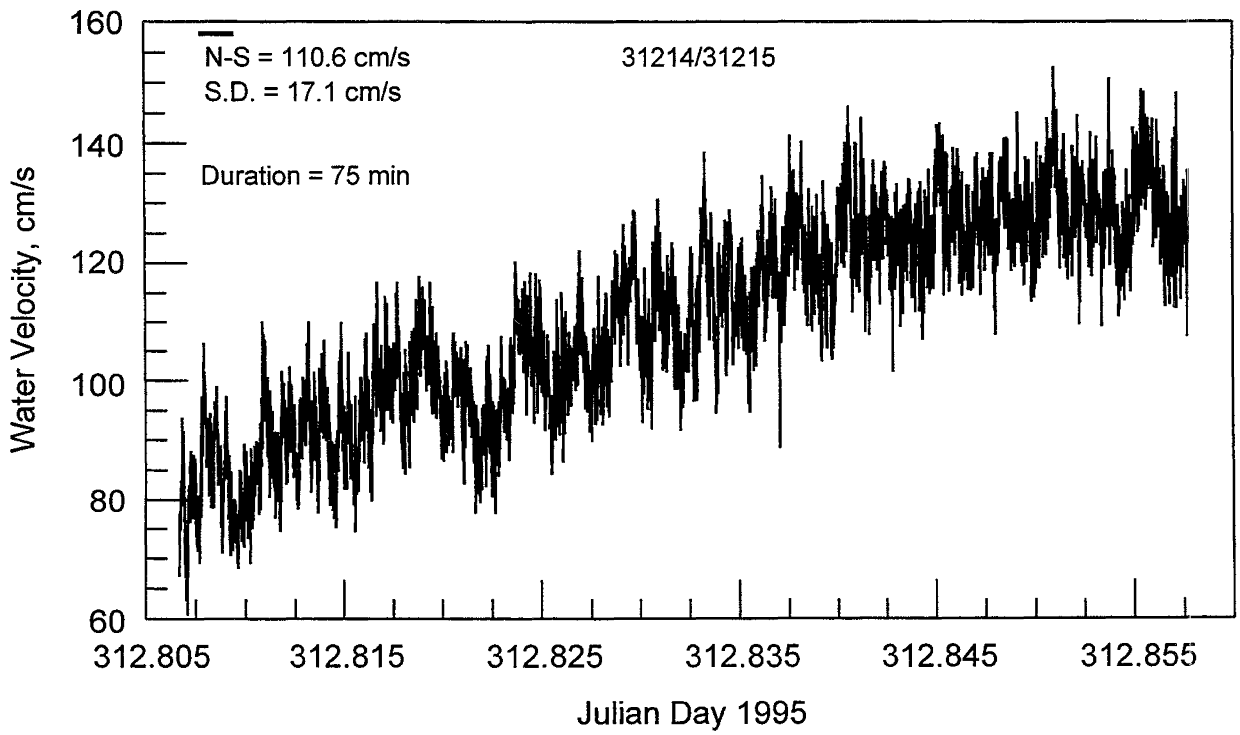

Figure 21. N-S current (flood), mouth of Mitchell's Cut.

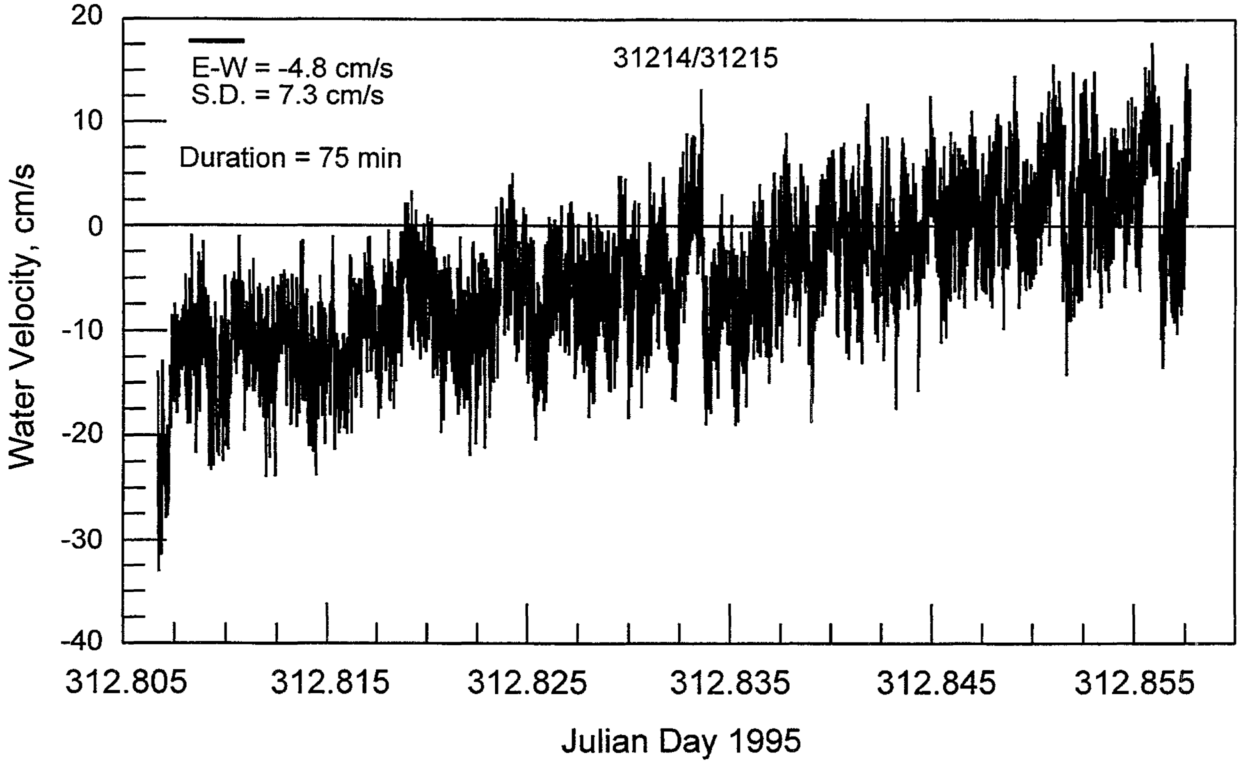

Figure 22. E-W current (during flood), mouth of Mitchell's Cut.

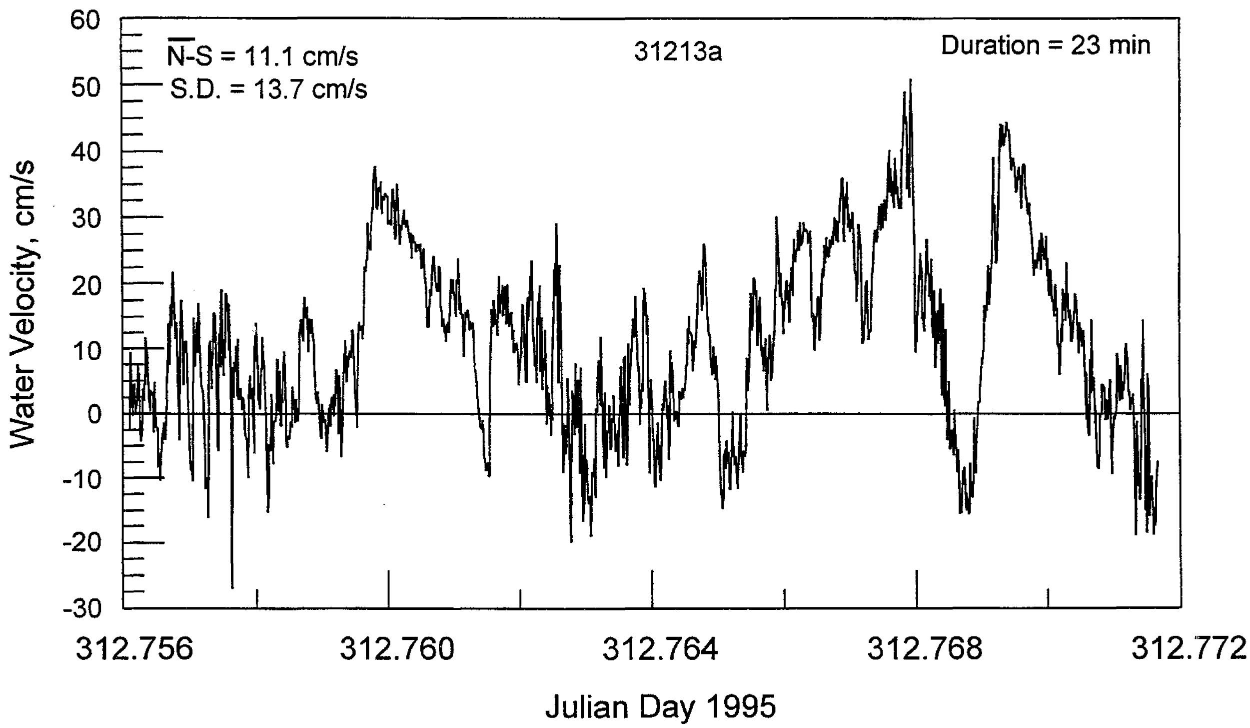

Figure 23. Inside Caney Creek, south of GIWW; tide changing ebb to flood.

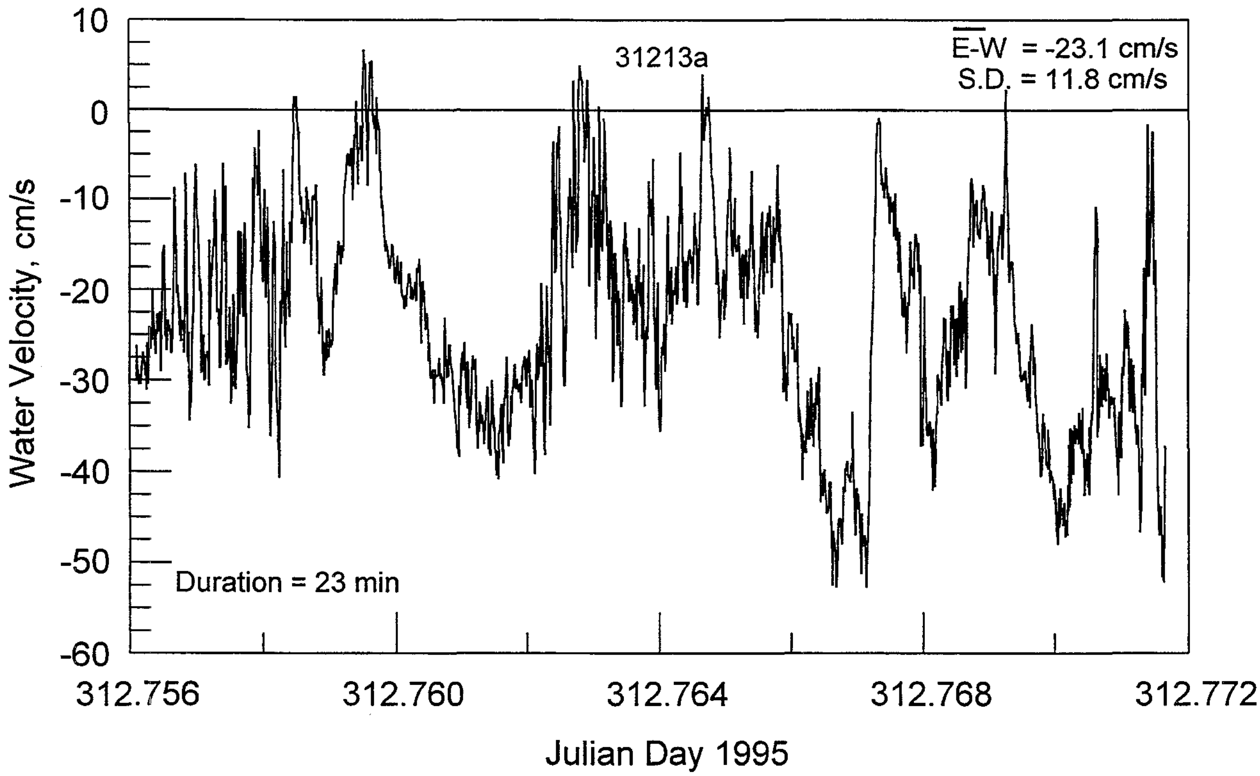

Figure 24. E-W current in Caney Creek, south of GIWW; tide ebb to flood.

Colorado River Navigation Channel

The proposed SW Corner Cut would intersect the CR Navigation Channel about 2 miles upstream from the mouth of the channel in the Gulf of Mexico. Because of the close connection to the Gulf and unknowns regarding current strength through combined tidal forcing and flow from East Matagorda Bay via the GIWW and CR Navigation Channel Land Cut, measurements of the current were made in the Navigation Channel to document the flow there and for use in verifying the hydrodynamic numerical model.

The synoptic survey captured a strong ebb flow at the mouth of the CR Navigation Channel, as shown in Figure 25 and Figure 26. The strong southward (negative N-S component) flow had a mean of -80.0 cm/s (2.8 ft/s). The high-frequency fluctuations are caused by surface waves, passage of boats, and small-scale eddies. The E-W component of the flow is minor, as expected, and is dominated by the high-frequency fluctuations.

The monitoring boat next moved north in the Navigation Channel, to a site approximately opposite to the location of the proposed SW Corner Cut. The current was still ebbing, and the N-S component had a mean value of -42.7 cm/s (1.3 ft/s). The ebbing current probably did not weaken in the short time after the measurements had been made at the mouth (Figure 25). Flow speed depends on the local water depth and width of the channel, as well as where in the channel the current was measured. An attempt was always made to make measurements in the middle of the channel, but this sometimes could not be accomplished because of the great water depth and strong flow, which made anchoring difficult. Cross-channel flow (Figure 28) was weak, and the larger oscillations appearing in the record may be due to cross-channel seiching or simply to the to-and-fro motion of the boat at anchor. The mean cross-channel flow is almost zero, as expected.

The next measurements shown here, Figure 29 and Figure 30, were taken later in the CR Navigation Channel at Channel Marker 15, in the Land Cut near to the GIWW. The current was still ebbing, with the N-S component having a mean of -32.0 cm/s (1 ft/s) and the E-W component having a mean of -7.9 cm/s (about ¼ ft/s). The wake from passage of at least two boats is seen near the start and end of the N-S component.

As a final example of the flow regime in the study area, Figure 31 and Figure 32 show the N-S and E-W components of flow measured inside the East Lock on the south side of the GIWW, where there is an area for small boats to wait while the lock is closed with a barge inside. During the 20.9-min observation interval, the lock doors closed and opened twice (probably to check repairs that were being made to the doors). When the doors close and open, a large circulation gyre is created inside the lock, as can be seen in the shift in flow speed between the N-S and E-W components. A speed exceeding 40 cm/s (1.3 ft./s) was sustained for a few minutes, and speeds exceeding 60 cm/s (2 ft/s) occurred. The passage of fast-moving recreational boats is contained in the record as high-frequency spikes. The first passage occurred just before time JD311.895, after the lock door was opened, and is seen in both the N-S and E-W components. When the locks had been closed the current was greatly reduced. The second boat passage occurred near the end of the record and is only distinguishable in the N-S component.

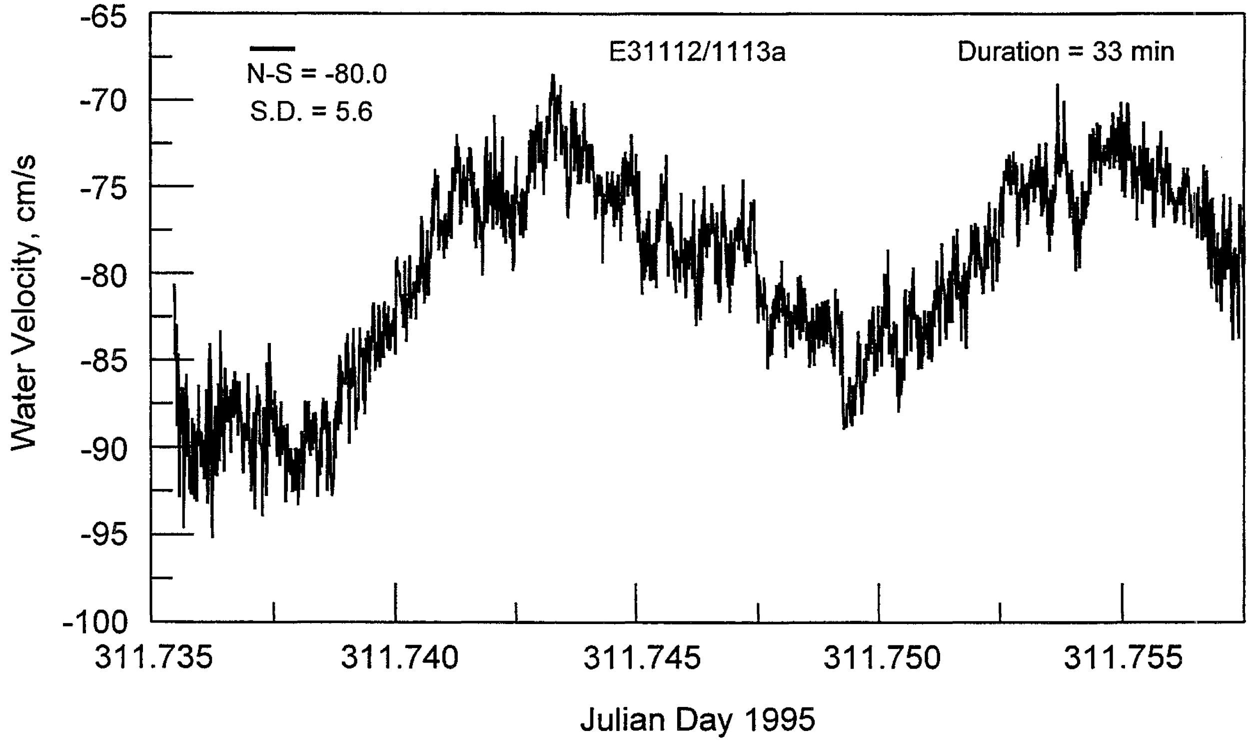

Figure 25. N-S current (ebb); CRNC (Marker 4).

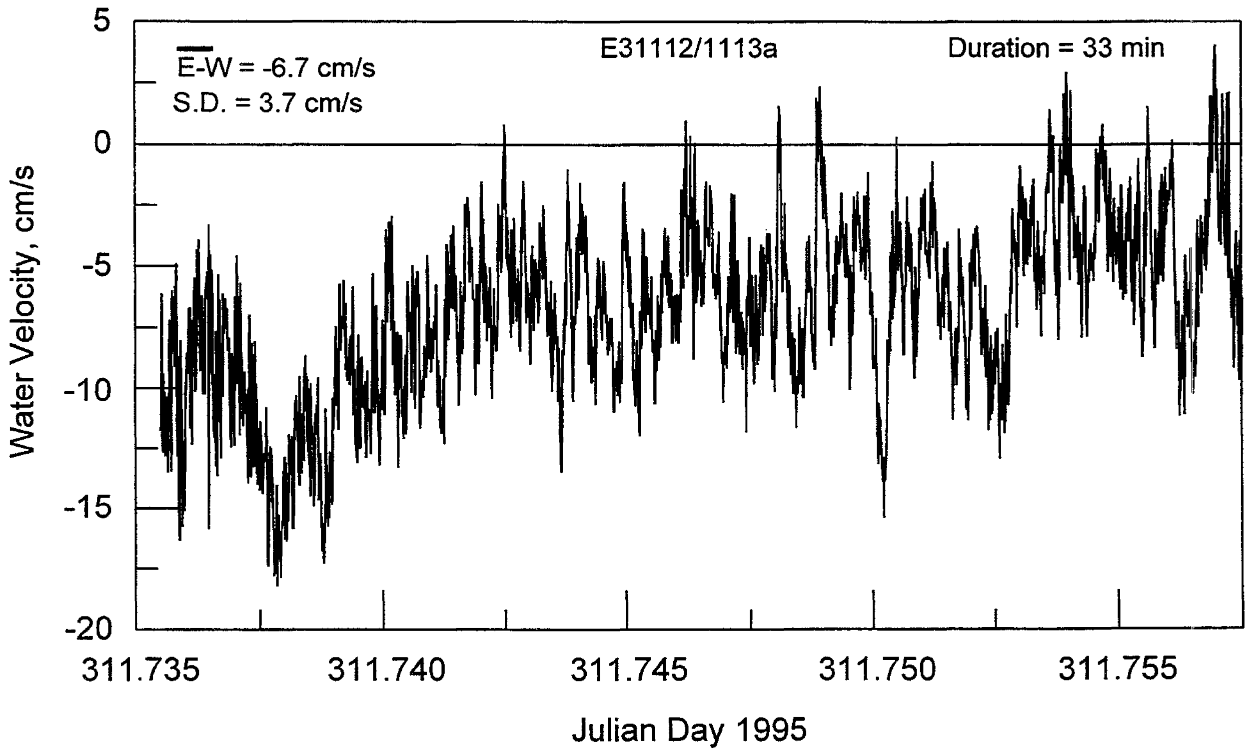

Figure 26. E-W current (during ebb); CRNC (Marker 4).

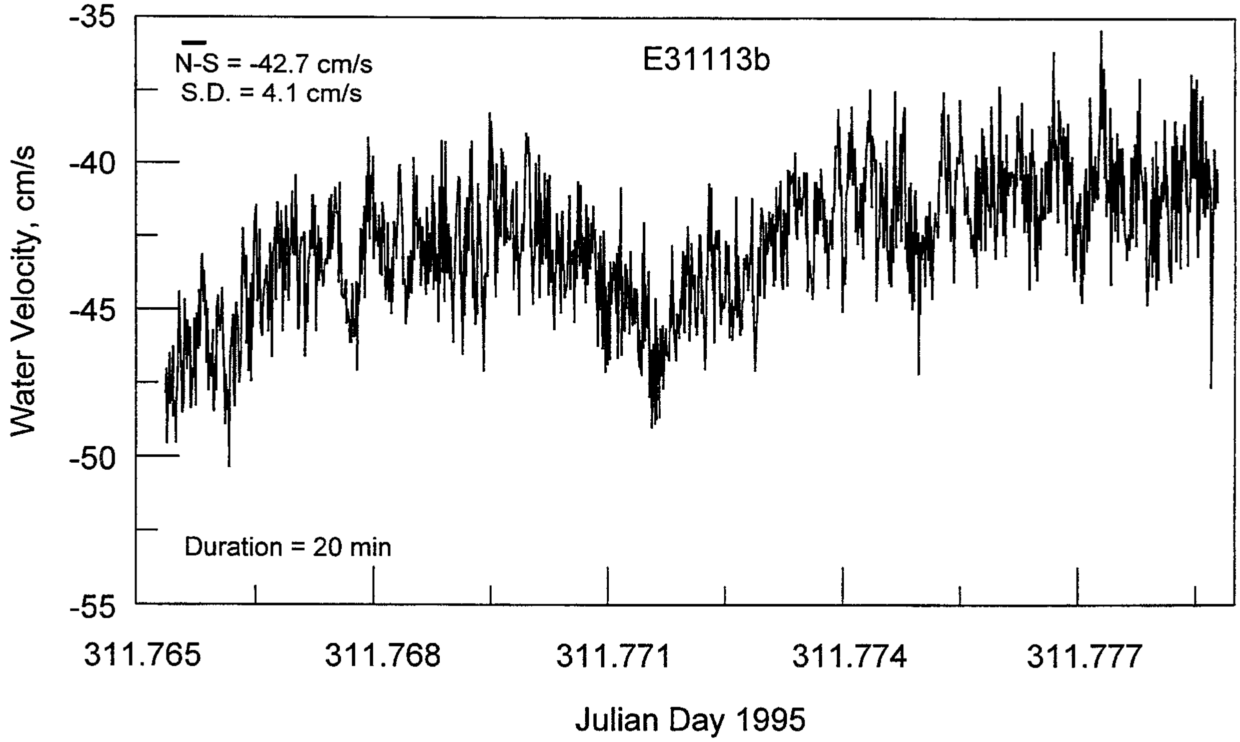

Figure 27. N-S current (ebb); in CRNC, near proposed SW Corner Cut entrance.

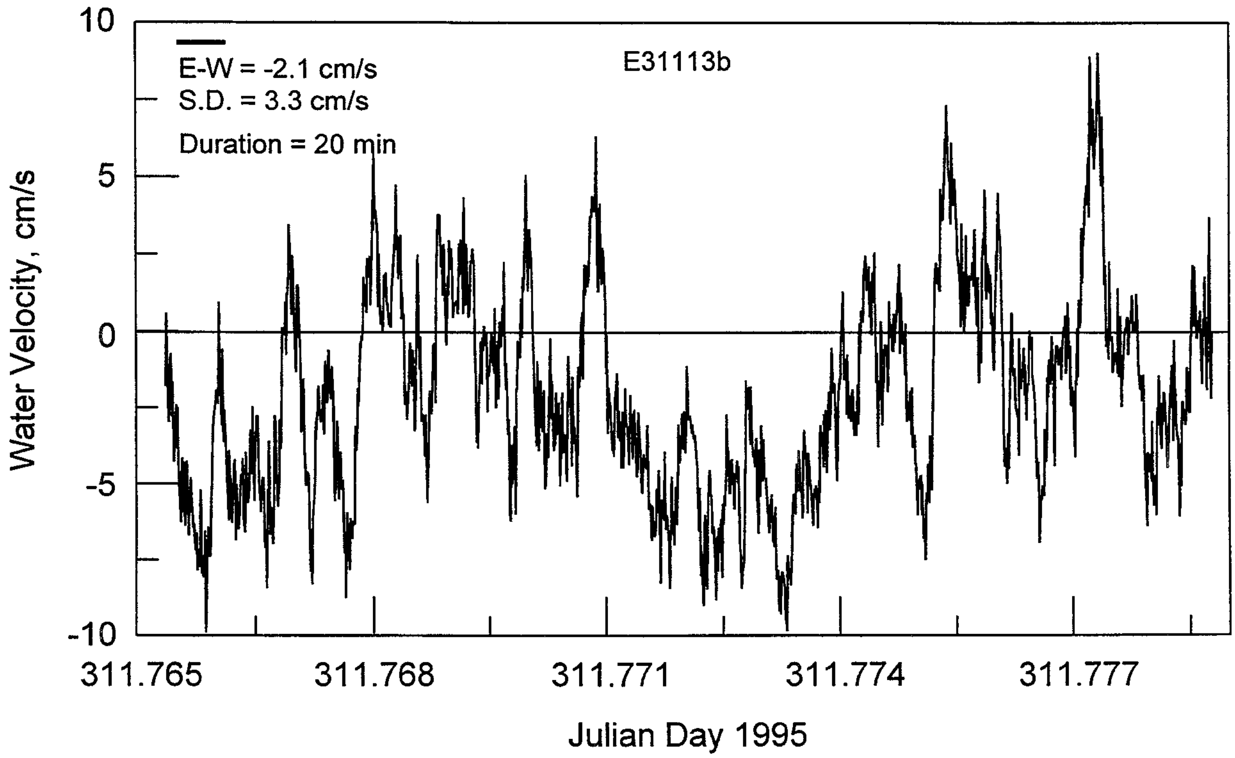

Figure 28. E-W current (during ebb); in CRNC, near proposed SW Corner Cut entrance.

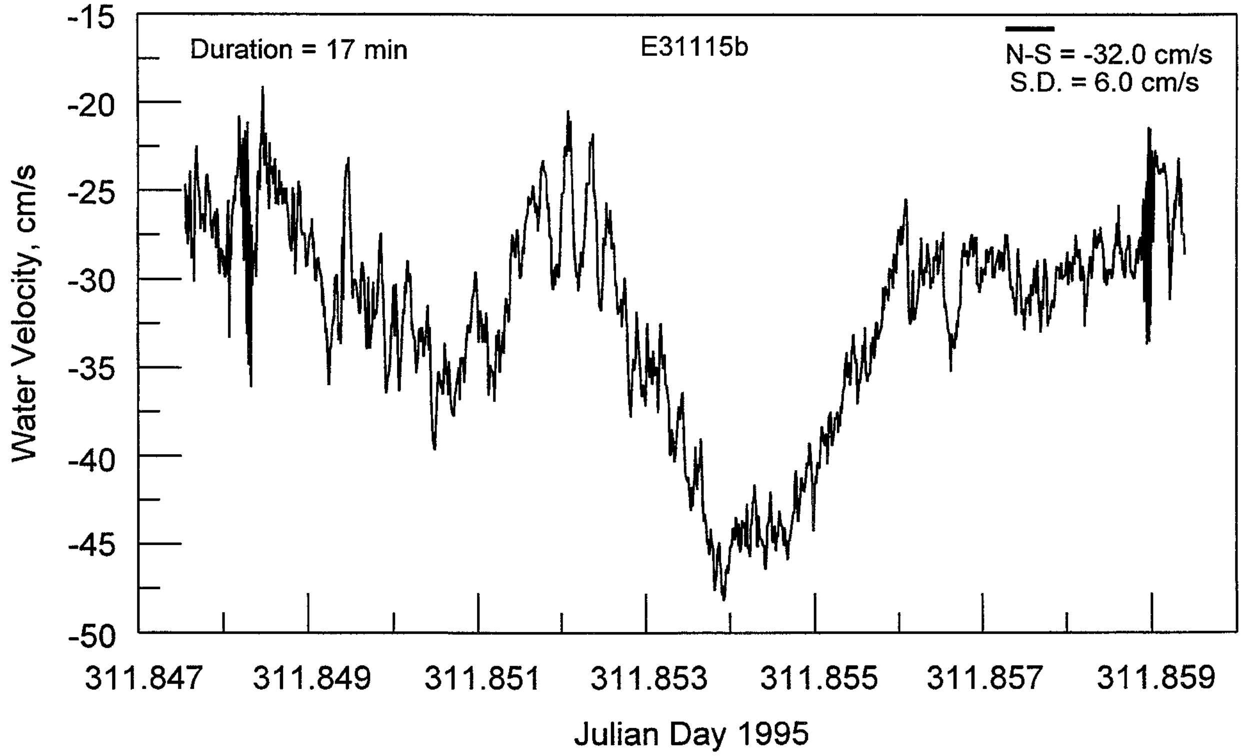

Figure 29. N-S current (ebb); CRNC Land Cut, Channel Marker 15.

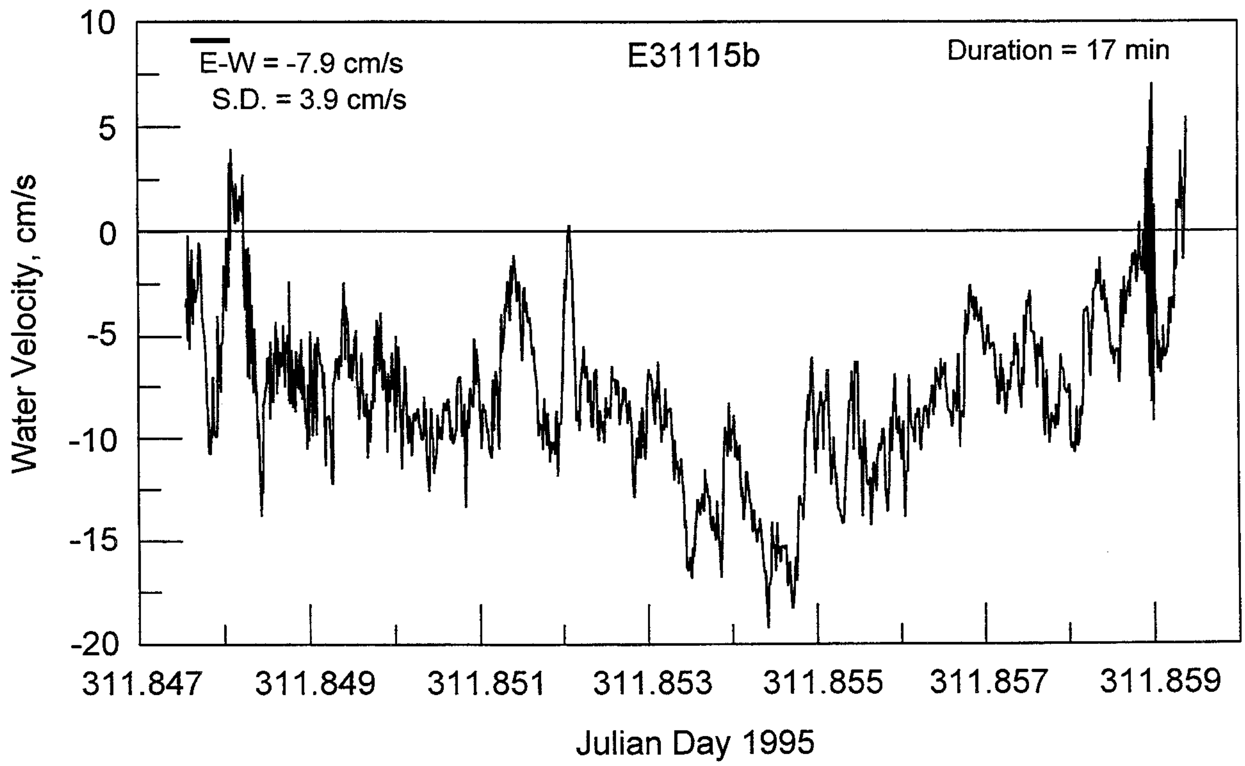

Figure 30. E-W current (during ebb); CRNC Land Cut; Channel Marker 15.

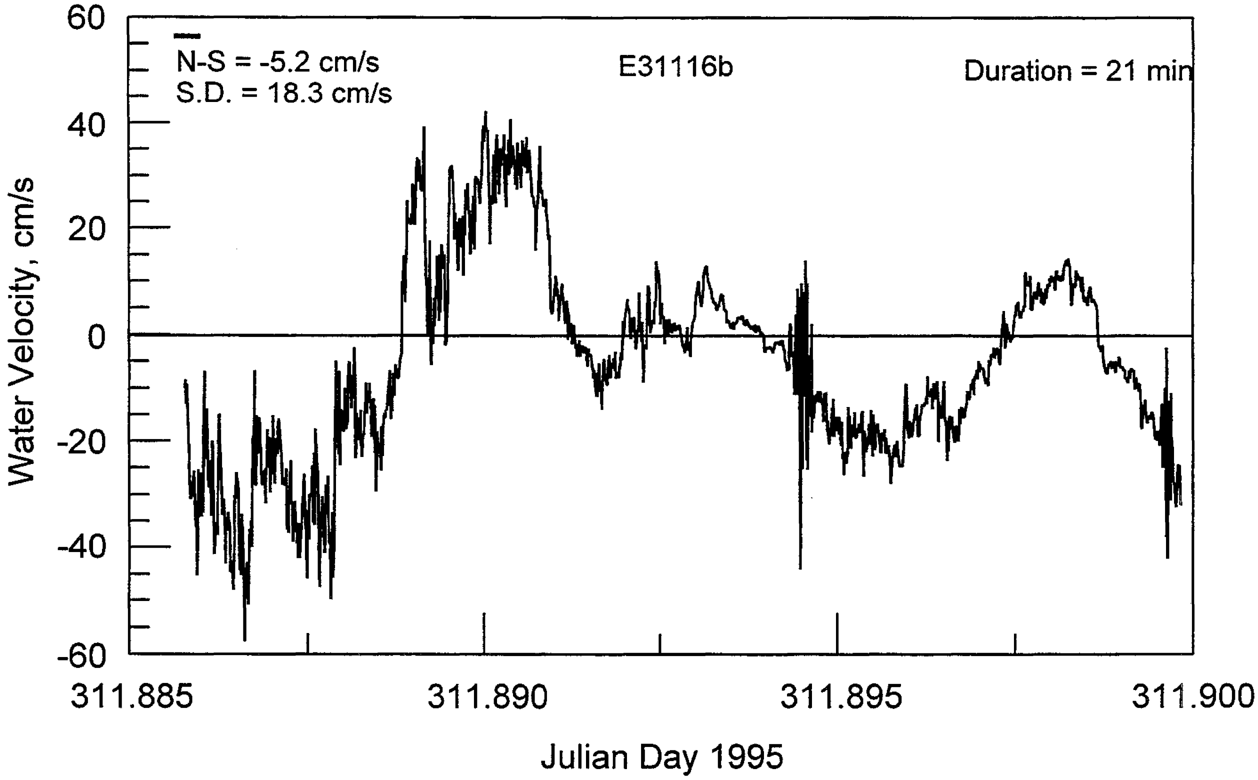

Figure 31. N - S current in the East Lock (south side of GIWW).

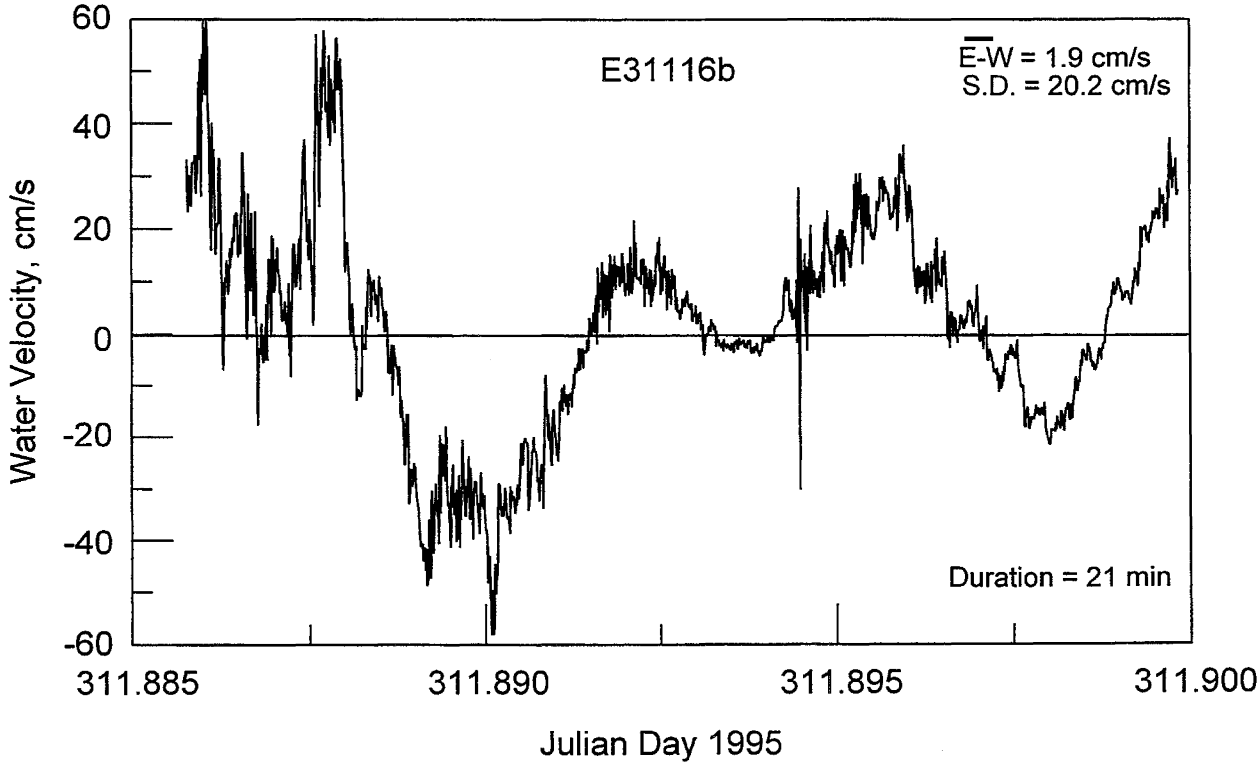

Figure 32. E - W current in the East Lock (south side of GIWW).

Water Level Datums on Both Sides of the SW Corner

Because the SW Corner Cut, if built, would connect East Matagorda Bay to the CR Navigation Channel, the relation between mean water level and other tidal datums in the two water bodies is relevant to this hydraulic feasibility study. To determine these relations, a leveling survey was conducted to tie the local elevations at the SWEMAT temporary gauge and the Rawlings gauge. The leveling was conducted for a distance of approximately 1.2 miles each way and had loop closure within 1 mm.

The trend and change in water level at the SW Corner (SWEMAT platform) and at Rawlings share common features, as seen in Figure 33, which plots the demeaned 6-min water level at both stations for the sustained observation period of this study. Fluctuations associated with frontal movement (order of 5 days) and the long term trend are similar in the records. The frontal-scale fluctuations deviate during the approximate interval JD354 to JD358, with the water level at SWEMAT elevated and the water level at Rawlings lowered. Inspection of the wind direction and speed in Figure 10 indicates this time interval was one of dominant north to north-northeast winds, but of relatively moderate speed. It is believed that this wind blew water offshore in the Gulf, lowering the water level at Rawlings, while tending to pile water up in the southwest corner of East Matagorda Bay.

The major difference in character of the water-level records visible in Figure 33 is the larger high-frequency (tidal) variation or range at Rawlings, as compared to SWEMAT. Although the trends track, the fluctuations are much greater at Rawlings. As would be expected intuitively, water level in the shallow bay has a much smaller range than at Rawlings, which is located in a relatively deep channel just 2 miles from the Gulf of Mexico

The result of the level tie survey is shown in Figure 34, which also contains quantitative information on the water-level variation as well as on the tidal datums. The scale in the middle shows a common elevation base (zero) for the two water-level gauges, which was made possible by the level tie. The zero is taken to be mean lower low water (MLLW) at Rawlings. Tidal datums and associated quantities were calculated by NOS procedures and are displayed in Figure 34. In this figure, to compare datums, the value of 1.254 m (4.14 ft) should be subtracted from datums pertaining to SWEMAT. For example, MSL at SWEMAT is listed as 1.812 m relative to its local station datum. Then, to compare to Rawlings, we have 1.812 - 1.254 = 0.558 m for MSL at SWEMAT. At Rawlings, MSL is located at 0.478 m above its station datum (MLLW). Therefore, it turns out that MSL at SWEMAT is 0.558 - 0.478 = 0.080 m = 3.14 inch = 0.26 ft higher than MSL at Rawlings. This result is reasonable because wind-induced setup at the western end of East Matagorda Bay would tend to keep the water level there superelevated, as discussed above in the section on wind and as discussed further in Chapter 3.

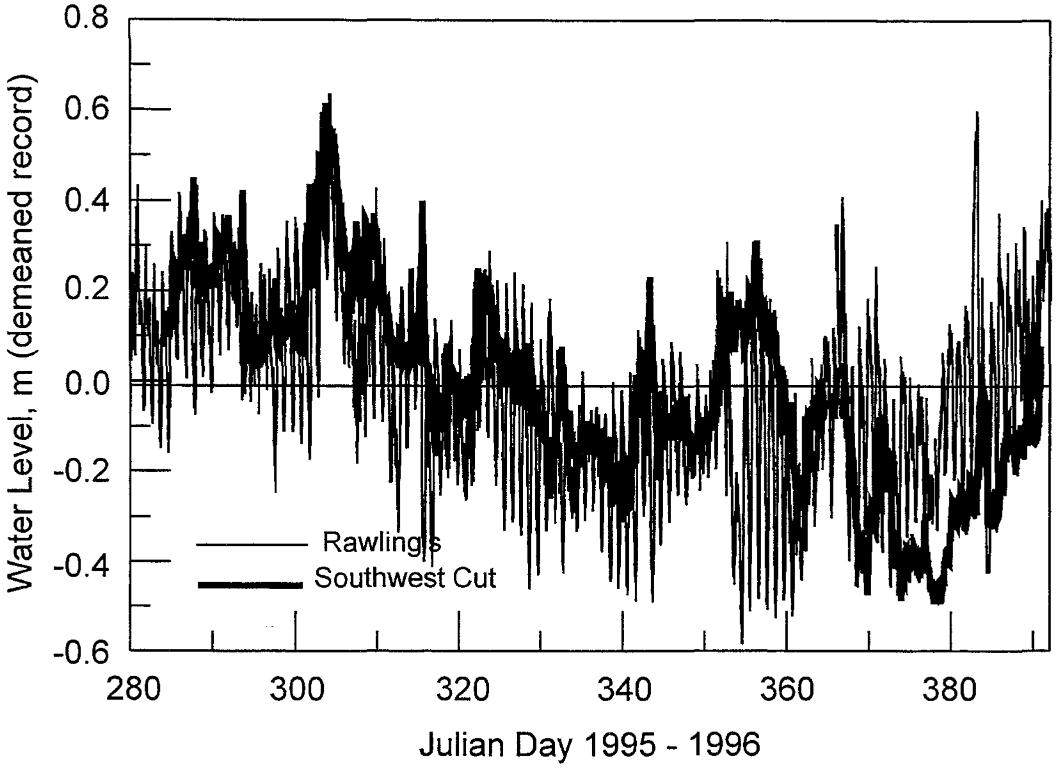

Figure 33. Water Level at Rawlings gauge for observation period.

The symbol "Mn" is an NOS abbreviation for the mean range of tide and is defined as the difference in height between mean high water (MHW) and mean low water (MLW). At Rawlings, the mean range of tide is 0.358 m (1.17 ft), whereas at the SW corner it is only 0.100 (0.33 ft). The significant difference in range carries over to the extreme datums of MLLW and mean higher high water (MHHW), which are the average height of the lower low waters and higher high waters, respectively, over a 19-year period or equivalent. Although we have seen that MSL in the SW corner of East Matagorda Bay is about 0.08 m higher than at Rawlings, MHHW is higher in the Navigation Channel than in the corner, and MLLW in the channel is much lower than in the SW corner of the bay.

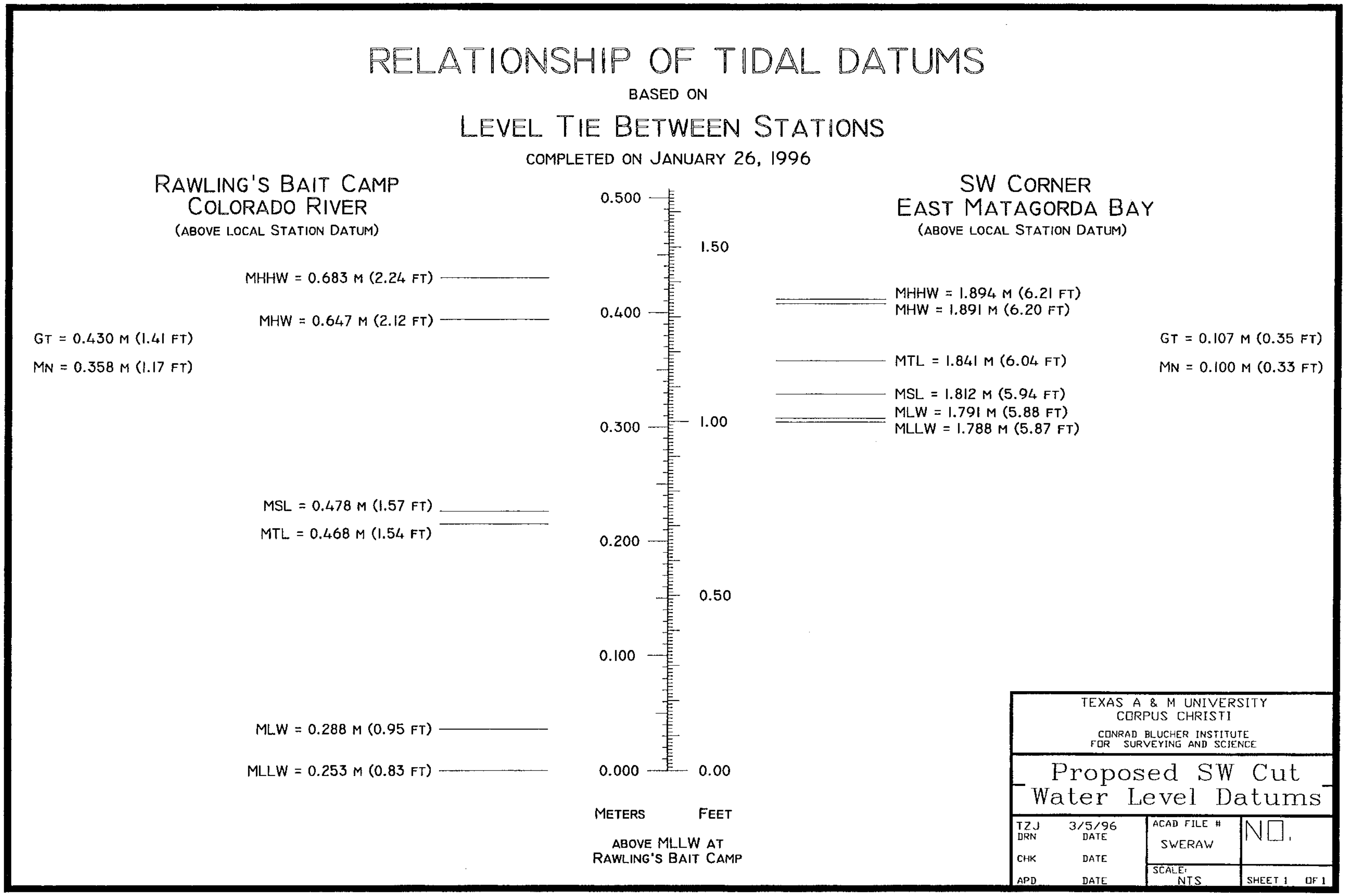

Figure 34. Relationship of tidal datums at Rawling's and SW East Matagorda.

3. Numerical Simulation of Hydrodynamics

Two central objectives of this study were (1) to assess potential changes in the magnitude and pattern of the circulation in and around East Matagorda Bay with the opening of the SW Corner Cut, and (2) to examine the stability of the cut. Meeting of these objectives required application of a relatively sophisticated numerical model of the hydrodynamics of the East Matagorda Bay and adjoining cuts, the GIWW, and Caney Creek.

A modeling effort (Brown & Root 1979) had previously been undertaken for East Matagorda Bay to simulate the circulation and salinity for four alternatives for proposed cut locations, including the SW Corner Cut. The model included the tide, freshwater inflow, and steady wind forcing, and it was performed on a 57-cell equally-spaced grid. Results showed that the simulated net circulation in East Matagorda Bay is composed of two well-defined gyres under conditions of mild (5 m/s) southeast winds. The maximum current velocity in the area of the SW Corner Cut was calculated to be 0.60 ft/s (18 cm/s).

Hydrodynamic modeling of the study area was accomplished here by application of a two-dimensional, depth-integrated, finite-difference model called M2D. The steps taken were: grid generation, assemblage of input and calibration data, calibration of the model, production runs, and interpretation of results. The model and these steps are described in this chapter, together with a general discussion of the circulation and water elevation change in the bay and associated cuts.

Description of the Model

The two-dimensional numerical model applied in this study calculates water surface fluctuations and two horizontal components of the depth-averaged current at cells defined by a rectangular computational grid. The water surface fluctuations over the grid are referenced to a common datum, which was specified to be MLLW as determined at the East Matagorda gauge. The model calculates depth-integrated currents, which are the mean currents through the water column, for each cell in the grid. Vertical currents are not considered.

Model features implemented in this study include: water-level forcing at specified locations, open-flow boundary conditions (applied at Caney Creek and the GIWW boundaries where no flow information was available), wind forcing with the wind stress coefficient varying with wind speed, and spatially variable bottom friction coefficient (Manning's n).

Application of any hydrodynamic model requires a set of simplifying assumptions. The assumptions for this application are:

1. Incompressible fluid
2. Inviscid fluid
3. Spatially and temporally well-mixed fluid
4. Current speed is vertically constant
5. Wind speed and direction are spatially constant at an instant in time

The model is a finite-difference approximation of the mass continuity and momentum equations given by

$$\frac{\partial \eta}{\partial t} = h\left(-\frac{\partial u}{\partial x} - \frac{\partial v}{\partial y}\right) \tag{1}$$

$$\frac{\partial u}{\partial t} = -g\frac{\partial \eta}{\partial x} - u\frac{\partial u}{\partial x} - v\frac{\partial u}{\partial y} + 2a_h\frac{\partial^2 u}{\partial x^2} + fv - C_b\frac{u|u|}{(h+\eta)} + C_d\frac{\rho_a}{\rho_w}\frac{W^2\cos(\theta)}{(h+\eta)} \tag{2}$$

$$\frac{\partial v}{\partial t} = -g\frac{\partial \eta}{\partial y} - u\frac{\partial v}{\partial x} - v\frac{\partial v}{\partial y} + 2a_h\frac{\partial^2 v}{\partial y^2} - fu - C_b\frac{v|v|}{(h+\eta)} + C_d\frac{\rho_a}{\rho_w}\frac{W^2\sin(\theta)}{(h+\eta)} \tag{3}$$

where h is the still-water level referenced to a specified datum, η is the deviation in water level from h, u is the current speed parallel to the x axis, v is the current speed parallel to the y axis, g is the acceleration due to gravity, a_h is a horizontal coefficient of eddy viscosity, f is the Coriolis parameter, C_b is an empirical bottom friction coefficient, C_d is a wind stress (drag) coefficient, ρ_a is the density of air, ρ_w is the density of water, W is the wind speed, and θ is the wind direction. The value of the eddy viscosity was not assigned for this project because the mixing term was not included in the computations. The Coriolis parameter is given by

$$f = 2\Omega\cos(\varphi) \tag{4}$$

where Ω is the angular frequency of the earth's rotation, and φ is latitude. The friction coefficient is calculated by the equation

$$C_b = \frac{g}{C^2} \tag{5}$$

where C is the Chezy coefficient given by

$$C = \frac{R^{\frac{1}{6}}}{n} \tag{6}$$

where R is the hydraulic radius and n is the Manning coefficient. The hydraulic radius is the cross-sectional area divided by the wetted perimeter. The wind stress is variable and depends on the wind speed. The formulation for the wind stress coefficient applied in the model is given by (Hsu 1988)

$$C_d = \left(\frac{0.4}{14.56 - 2\ln U_{10}} \right)^2 \tag{7}$$

where U_{10} is the wind speed at 10 m. The value of U_{10} from measurements collected at other anemometer heights is approximated by (USACE 1984)

$$U_{10} = W\left(\frac{10}{H_w} \right)^{\frac{1}{7}} \tag{8}$$

where H_W is the anemometer height.

A finite-difference approximation was implemented expressing the governing equations in numerical form. The finite-difference scheme is central in space, explicit in time for the momentum equations (with the exception of the advective terms), and partially explicit in time for the continuity equation. The approximation for the continuity equation incorporates updated values of velocity from momentum equation calculations and applies those values to the calculation of the water surface elevation. The advective terms (second and third terms in Eqs. 2 and 3) are spatially and temporally averaged to reduce numerical instabilities.

The time step Δt for the model is limited by the stability criterion

$$\Delta t \leq \frac{\Delta s}{\sqrt{gh}} \tag{9}$$

where Δs is the size dimension of a cell, and s is representative of either the x or y coordinate. Practical application of this criterion for the M2D model requires the time step to be approximately 0.6 to 0.7 times the theoretical maximum time step given by Eq. 9. For the East Matagorda application, the time step was 3 sec.

Three types of boundary conditions were applied for this study and consisted of

1. Water surface elevation forcing boundary.
2. Open boundary with no forcing.
3. Closed, reflective boundary.

The water surface elevation forcing boundaries were applied at grid edges in the Gulf of Mexico seaward of the CR Navigation Channel mouth and Mitchell's Cut. These boundary conditions apply water-level data to specific grid boundary cells so that the water surface in these cells vary exactly as the input data.

Open boundary conditions were applied at grid cells that reside on water conduits extending beyond the grid domain. Water can flow in and out of the domain at these boundaries. The locations where this type of boundary were applied are Caney Creek (north of the GIWW) and the GIWW (east of the study area). An open boundary condition represents a flow for which there is no gradient (no change) between the cell just inside and the cell just outside the grid boundary.

Closed reflective boundaries do not allow water to flow through them and can be considered as walls. Velocities in cells with this type of boundary condition must be aligned parallel to the boundary so that the velocity perpendicular to the boundary is zero. Closed reflective boundaries were specified at the perimeter of the bay and at the CR Navigation Channel East Lock.

Grid

A computational grid is a discretized representation of the model domain and contains information specific to each cell included in the grid. M2D requires a rectilinear grid, but the grid can be variably spaced. Spacing of grid lines, which define the borders between cells, can be finer or coarser depending on the resolution required of a particular region of the grid. The grid contains the following information for each cell:

1. Cell number.
2. Cell numbers of neighboring cells.
3. Boundary conditions for each side of the cell.
4. Cell type.
5. Cell dimensions.
6. Cell depth referenced to a specific datum.
7. Manning friction coefficient.
8. Row and column numbers.
9. Latitude.
10. x- and y-coordinates of the cell center.

Grid generation software was used to develop the various grid layers and incorporate bathymetric data. The grid was aligned with the x-axis oriented along the longitudinal axis of East Matagorda Bay.

Main features represented in the grid domain were: East Matagorda Bay, the CR Navigation Channel, the Gulf of Mexico in the region of the mouth of the CR Navigation Channel, the GIWW extending from the East lock to approximately 23 mi east of the intersection of the

GIWW and Caney Creek, Mitchell's Cut, and the Gulf of Mexico in the vicinity of Mitchell's Cut. Gulf of Mexico areas were included for accurate application of Gulf forcing. Four complete grids were generated in the course of this study and are given in Table 2. Each grid consisted of approximately 8,000 active computational cells with the minimum spacing being 33 m (108 ft) and the maximum spacing being 505 m (1,657 ft). Figure 35 shows the bottom topography and grid domain with the SW Corner Cut installed. This grid differs from the existing condition only by the existence of the SW Corner Cut. Note that the resolution of the color mapping algorithm applied to the bottom topography is limited and can cause some depths to be mapped with the incorrect color, such as in sections of the GIWW. All of the GIWW cells were given depths of at least 12 ft (3.66 m), and, in many cells, the depths were greater than 12 ft.

Table 2. Numerical grids generated for East Matagorda Bay and cases run

Grid No.	Configuration
1	Existing condition
2	SW Corner Cut installed
3	Existing condition, but with Mitchell's Cut closed
4	SW Corner Cut installed, Mitchell's Cut closed
Case No.	**Description**
1	Existing condition, with wind
2	SW Corner Cut installed, with wind, constant friction coefficient in Cut*
3	SW Corner Cut installed, with wind, increased friction at ends of Cut*
4	Existing condition, without wind
5	SW Corner Cut installed, without wind
6	Existing condition, with wind, Mitchell's Cut closed
7	SW Corner Cut, with wind, Mitchell's Cut closed
8	SW Corner Cut installed, with wind, weir emplaced in middle of Cut*
9	SW Corner Cut, with wind, Cut scoured to 12-ft depth

* "Cut" indicates the confined reach of the SW Corner Cut located between the CR Navigation Channel and East Matagorda Bay, and does not include the part of the channel that would extend into East Matagorda Bay.

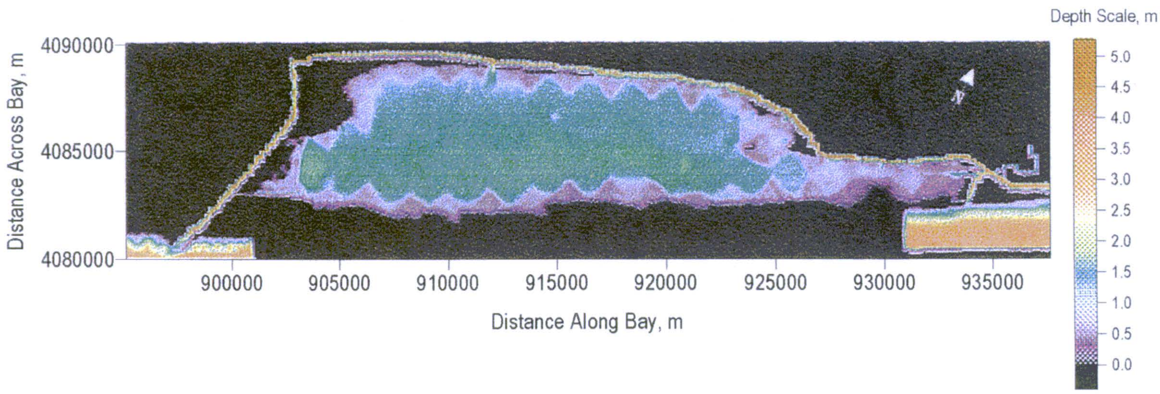

Figure 35. Bottom topography and grid domain for East Matagorda Bay.

Input and Calibration Data

Water-level data from five stations were input as forcing and for calibration of the model. Data from the Galveston Pleasure Pier gauge were applied as forcing at the two Gulf entrances (Mitchell's Cut and CR Navigation channel mouth), and data from the Rawling's Bait Camp, EMAT, and SWEMAT gauges were compared to model output for calibration. These data were collected at 6-min intervals. The water-level data were adjusted so that they were referenced to MLLW at the EMAT gauge. Data from the Freeport Harbor gauge located 35 mi south of the study site showed negligible change in tidal phasing, implying that the Galveston Pleasure Pier forcing could be applied at both Mitchell's Cut and the mouth of the CR Navigation Channel without loss of accuracy.

Wind data collected at EMAT were input into the model as surface stress forcing. The data were collected at hourly and at 6-min intervals during one portion of the observation period. The 6-min wind data were input into the model where available and allow the model to respond to fluctuations in the wind speed and direction more quickly than with hourly measurements.

Bottom topography data were obtained from the bathymetric survey performed for this study and from a NOAA chart in regions that were not covered by the survey. The bottom topography data were input into the grid generation software which applied an inverse distance weighted interpolation relationship between data points to calculate depths for all cells.

Model Calibration

Calibration is an iterative process in which the model is run and the output compared to measurements; then the model parameters are adjusted to bring the calculations closer to agreement with the measurements. The model is considered calibrated if the output compares well to the measurements for a range of conditions expected to be modeled. In this study, the only parameter adjusted for the calibration was the bottom friction coefficient, which took on values in the typical range (Chow 1959).

Calibration required larger values of the Manning coefficient, up to 0.1 $s/m^{1/3}$, in the vicinity of the mouth of the CR Navigation Channel. Although this value is large, it accounts for transition losses at the entrance as well as losses due to bottom friction. For grids containing the SW Corner Cut, entrance and exit losses were accounted for by assigning values of Manning's *n* of 0.08 and 0.06 $s/m^{1/3}$ at two cells on the ends of the confined portion of the SW Corner Cut (Cases 3, 5, 7, 8, and 9). The value of 0.08 $s/m^{1/3}$ was applied at the outermost cells, relative to the confined region of the SW Corner Cut, and the value of 0.06 $s/m^{1/3}$ was applied to the adjacent inner cells. In other areas of the grid (the great majority of cells), the Manning coefficients ranged between 0.022 to 0.028 $s/m^{1/3}$ and are within the normal range for this coefficient. Friction losses in the SW Corner Cut for Case 2 were limited to bottom stress (entrance and exit losses were not accounted for) and all cells in the confined portion of the Cut were assigned values of Manning's *n* of 0.025 $s/m^{1/3}$.

Calibration of the model revealed that a small channel that connects Mitchell's Cut to East Matagorda Bay near the opening to the Gulf (see Figure 3) plays a role in the long-period (order of days) exchange of water between the Gulf and the bay. Without this channel, the bay responded slower to the long-period Gulf forcing. This small channel may not be open to the Gulf during some time periods, but was observed to be open during the synoptic survey (Nov. 7 and 8, 1995) conducted at a time of seasonally higher water levels. Water level fluctuations are greatly attenuated at the location of the old GIWW after the water propagates up Mitchell's Cut. However, the water-level fluctuations at this small opening connecting East Matagorda Bay and Mitchell's Cut are not attenuated and are as great as those in the Gulf (although the volume of water exchanged is limited).

Figures 36 to 38 show the calibrated model output of water level as compared to the measured water level fluctuations at Rawling's, EMAT, and SWEMAT, respectively. The simulation duration was 30 days starting on Oct. 12, 1995 (JD285) and extending through Nov. 11, 1995 (JD314). The calculated water level fluctuations follow closely those of the measurements and both the short-period and long-period motions are reproduced by the model.

Comparisons of the E-W simulated current speed and measurements are shown in Figure 39 and Figure 40 for EMAT and SWEMAT, respectively. The measured currents shown in the plots were low-pass filtered with a cutoff frequency of 12 cycles/day. The simulated currents generally follow the measured currents and show that the model was well calibrated. Errors in the simulated currents are typically 2 to 3 cm/s at EMAT and 1 to 2 cm/s for SWEMAT. The current speeds at SWEMAT are small and constitute approximately zero percent of the specific energy at that location because the potential energy, relative to the bottom, is of O(1) and the kinetic energy is of $O(10^{-6})$. Comparisons of the N-S current speeds for these stations are not shown because of the proximity of computational cells to closed boundaries in the N-S direction. Additionally, the currents at EMAT, SWEMAT, and in the GIWW are predominantly in the E-W directions because of the E-W orientation of the bay and GIWW and the persistent winds that have an easterly component.

The calibration plots show that the simulated water-level fluctuations and currents closely follow the measurements, indicating that the model accurately simulates the overall hydrodynamics of the study site.

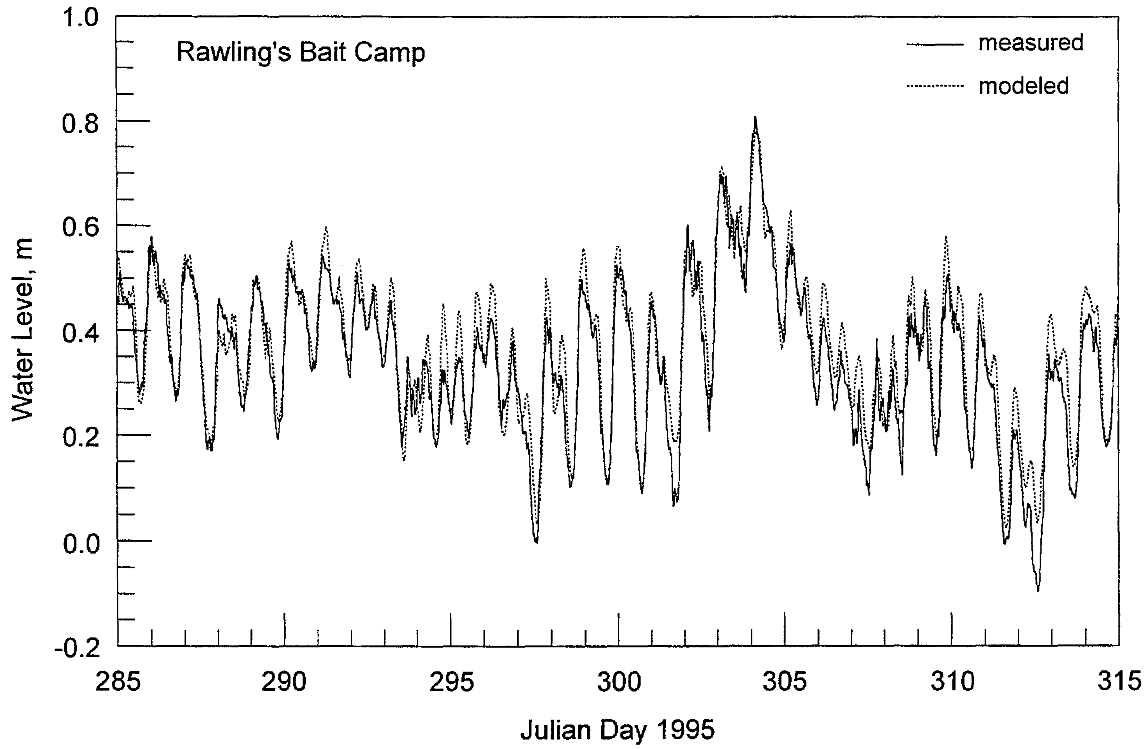

Figure 36. Comparison of measured and simulated water level at Rawling's.

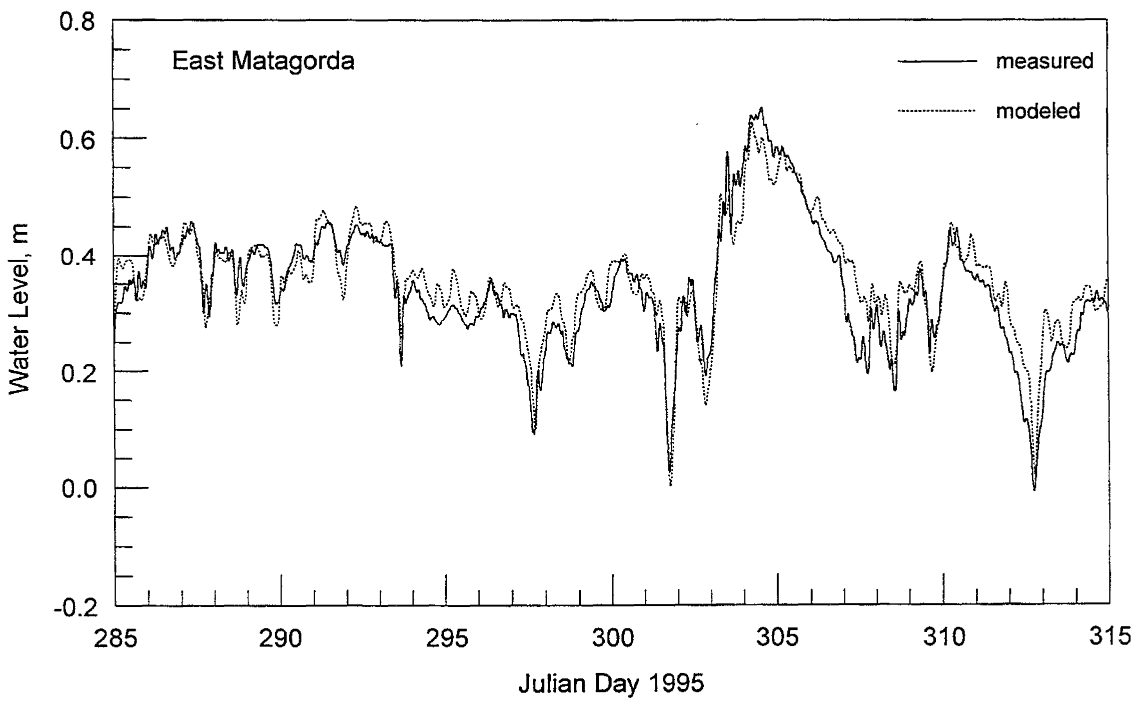

Figure 37. Comparison of measured and simulated water level at EMAT.

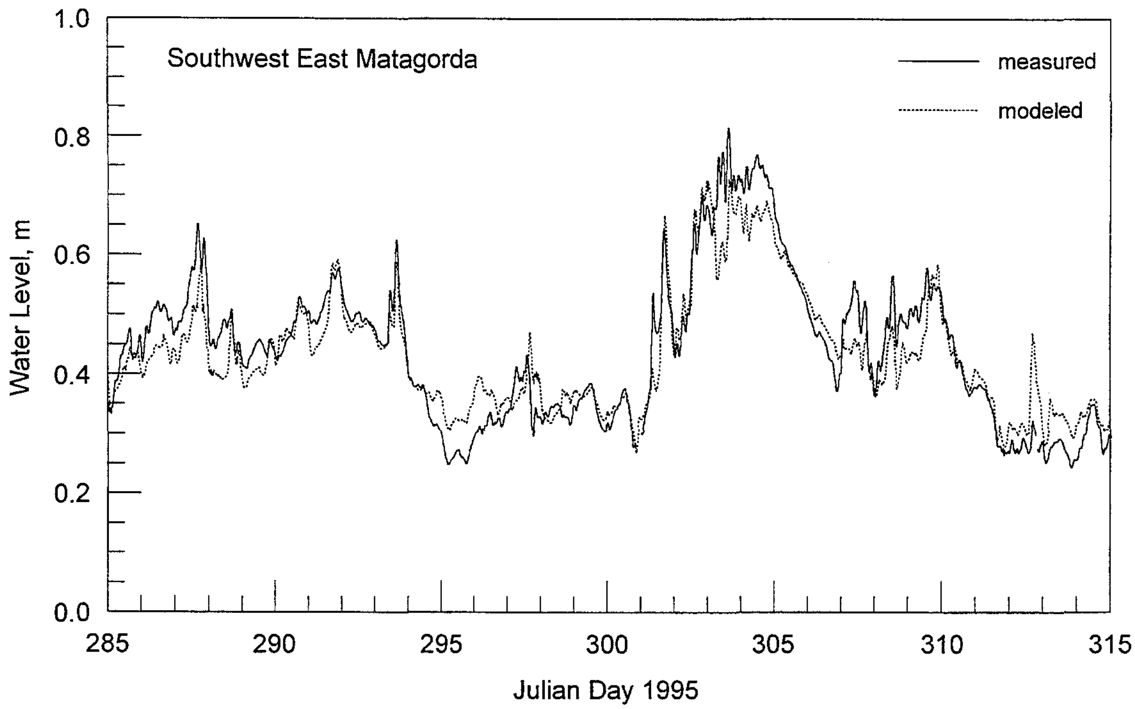

Figure 38. Comparison of measured and simulated water level at the SWEMAT.

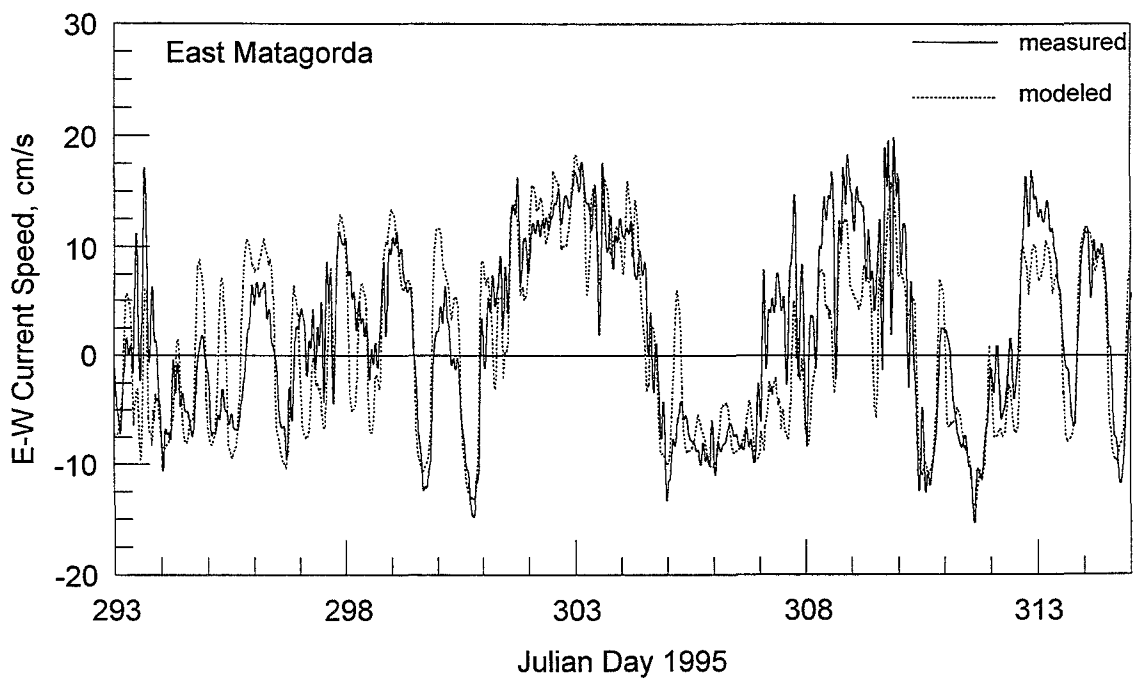

Figure 39. Comparison of measured and simulated E-W current speed at EMAT.

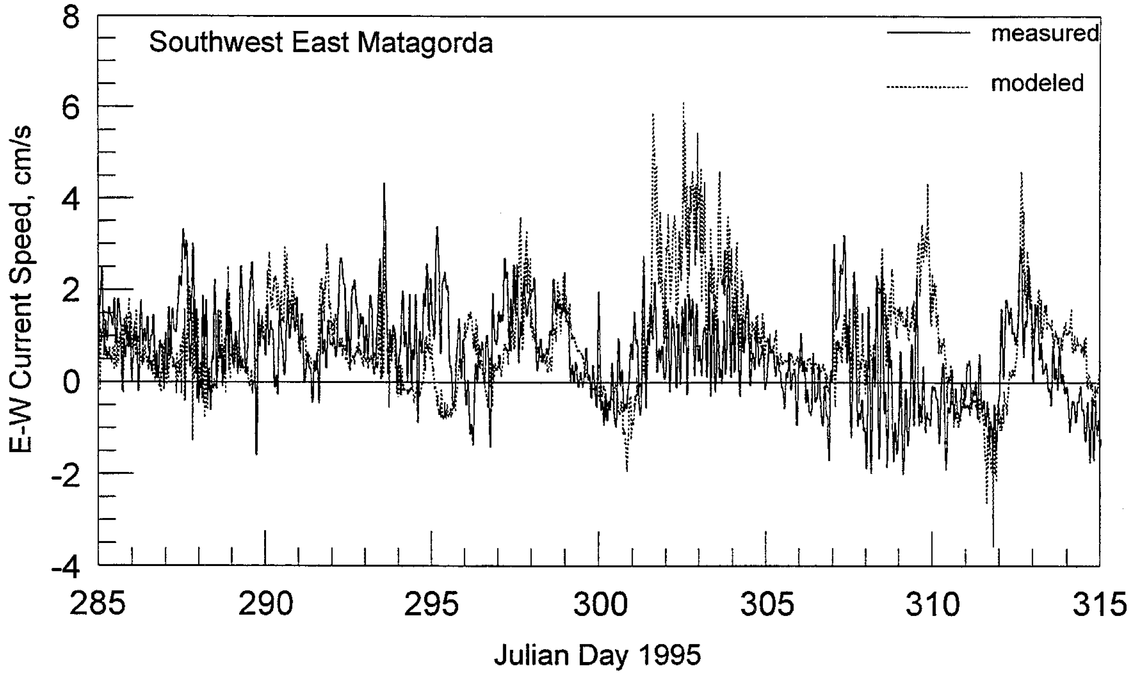

Figure 40. Comparison of measured and simulated E-W current speed at SWEMAT.

Simulation Results

Results from simulations with the grids listed in Table 2 are presented along with discussion and interpretation of the results. When case numbers are given, they refer to the cases listed in Table 2.

Water Level and Current With and Without the SW Corner Cut

Comparisons of water-level fluctuations with and without the SW Corner Cut (Cases 1 and 2, respectively) are shown in Figure 41 for several locations in channelized portions of the study site including the CR Navigation Channel, the GIWW, and Caney Creek south of the GIWW. The top panel of Figure 41 shows that the reach of the CR Navigation Channel located seaward of the SW Corner Cut will have a reduced tidal range with the cut installed. The reduction in tidal range toward the Gulf diminishes in the seaward direction as the influence of the Gulf forcing increases. At the mouth of the CR Navigation Channel, the reduction in tidal range is minimal and not shown in Figure 41 for this reason. During flood tide, the cut will allow water to flow into the bay, thereby reducing the hydraulic head from the point where the SW Corner Cut connects to the CR Navigation Channel to the mouth of the CR Navigation Channel. During ebb tide, the SW Corner Cut will allow water to flow from the bay to the CR Navigation

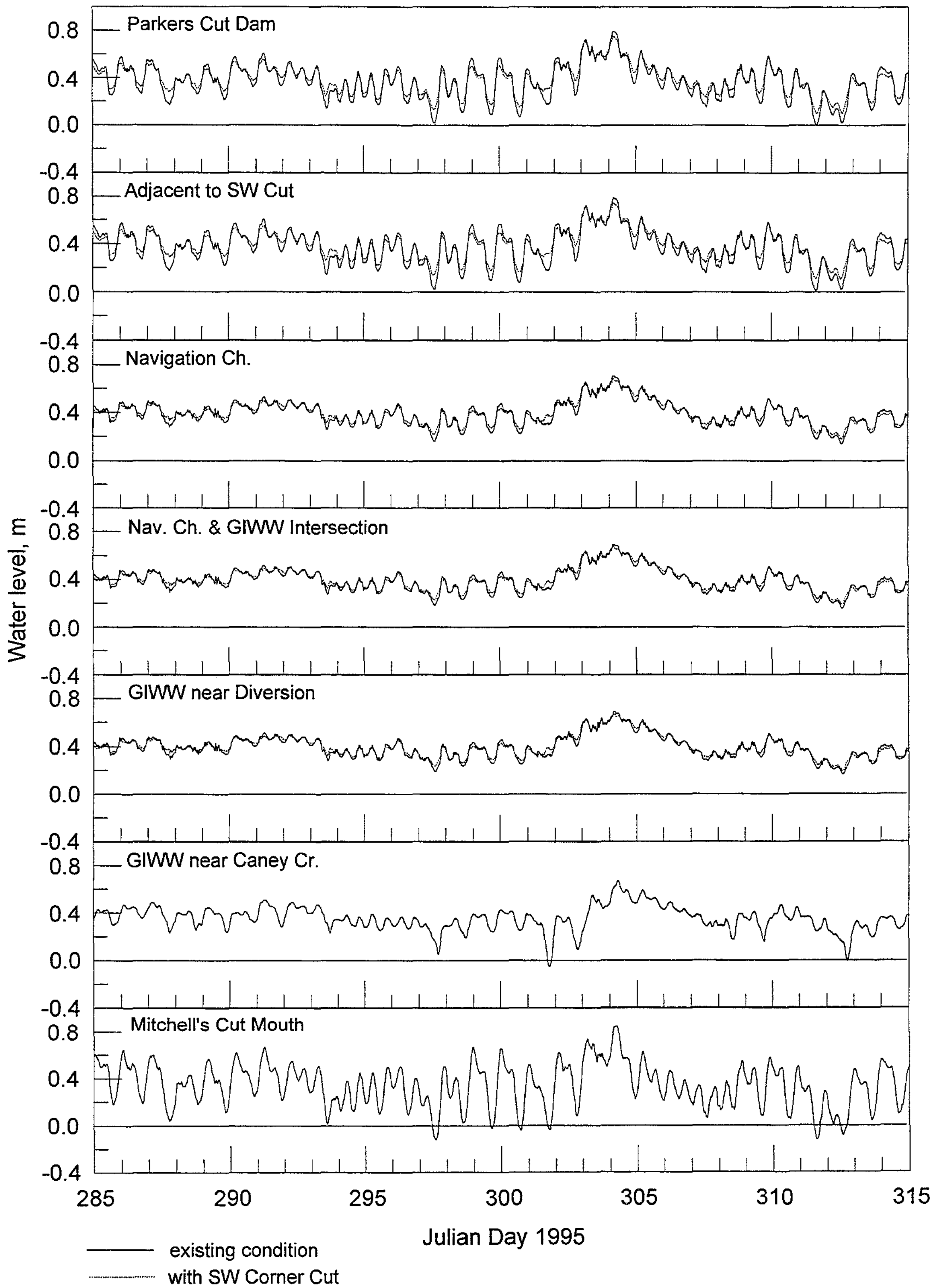

Figure 41. Water-level at specific points for the existing condition and with SW Corner Cut.

Channel and increase the hydraulic head from the point of connection to the Gulf. The flow of water out of the bay through the SW Corner Cut will be increased by winds with an easterly component and will keep the hydraulic head at the Cut higher than it would be without the wind. The effective result of the change in hydraulics for flood and ebb tide is a reduced tidal range in the reach extending from the SW Corner Cut to the mouth of the CR Navigation Channel.

Upstream of the location of the SW Corner Cut, the tidal range is diminished with installation of the Cut, as shown in Figure 41. This reduction in range occurs in the CR Navigation Channel and in the western reach of the GIWW. The tide range approaches normal (existing condition) toward the east and is only slightly altered (decreased) in the vicinity of Caney Creek. The ebb tide water levels appear to be increased more than the flood tide water levels are decreased. The SW Corner Cut takes a portion of the flow that normally flows through the CR Navigation Channel resulting in reduced water-level fluctuations north of the Cut.

Currents respond to existence of the SW Corner Cut similarly to water level as shown in Figure 42. Seaward of the Cut location, the current speed is increased with the Cut installed and it is decreased upstream of the Cut. The reduction in current speed landward of the Cut is caused by the reduction in flow up the CR Navigation Channel as the Cut will carry a portion of the flow that normally travels through this channel. The GIWW in the vicinity of Caney Creek shows no difference in current speed with or without the SW Corner Cut.

Water levels at three points inside East Matagorda Bay for the existing condition and with the SW Corner Cut installed (Cases 1 and 2) are shown in Figure 43. Case 2 has ordinary friction losses in the SW Corner Cut, i.e., transition losses are not accounted for, and there is less flow retardance in the cut than if transition losses were accounted for. Under this condition, more water can be exchanged through the Cut than with higher friction losses, providing a greater opportunity for water to flow out of East Matagorda Bay. Over the simulation period, the water level with the SW Corner Cut installed decreases from the water level with the existing condition. However, the decrease in water level with the Cut is small (approximately 1 cm at EMAT and 0.5 cm at SWEMAT) over the 30-day calculation period.

Hydraulics in SW Corner Cut

A comparison of discharge in the CR Navigation Channel at Rawling's Bait Camp with (Case 2) and without (Case 1) the SW Corner Cut, along with the discharge in the Cut (Case 2), is shown in Figure 44. The discharge in the CR Navigation Channel is calculated to be reduced by approximately 20 to 25% when the Cut is present. The SW Corner Cut diverts a portion of the flow into East Matagorda Bay, thereby reducing the discharge in the CR Navigation Channel

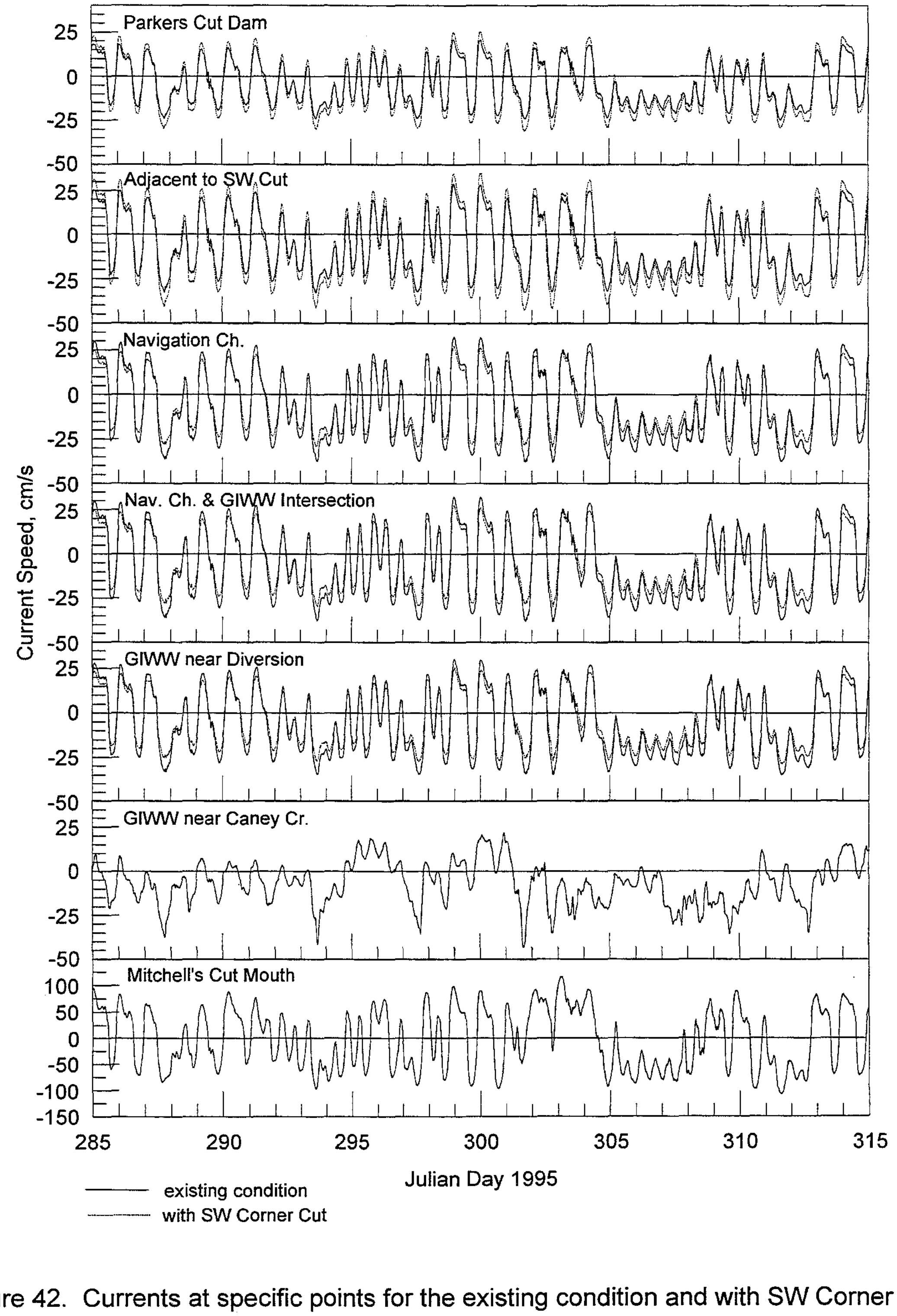

Figure 42. Currents at specific points for the existing condition and with SW Corner Cut.

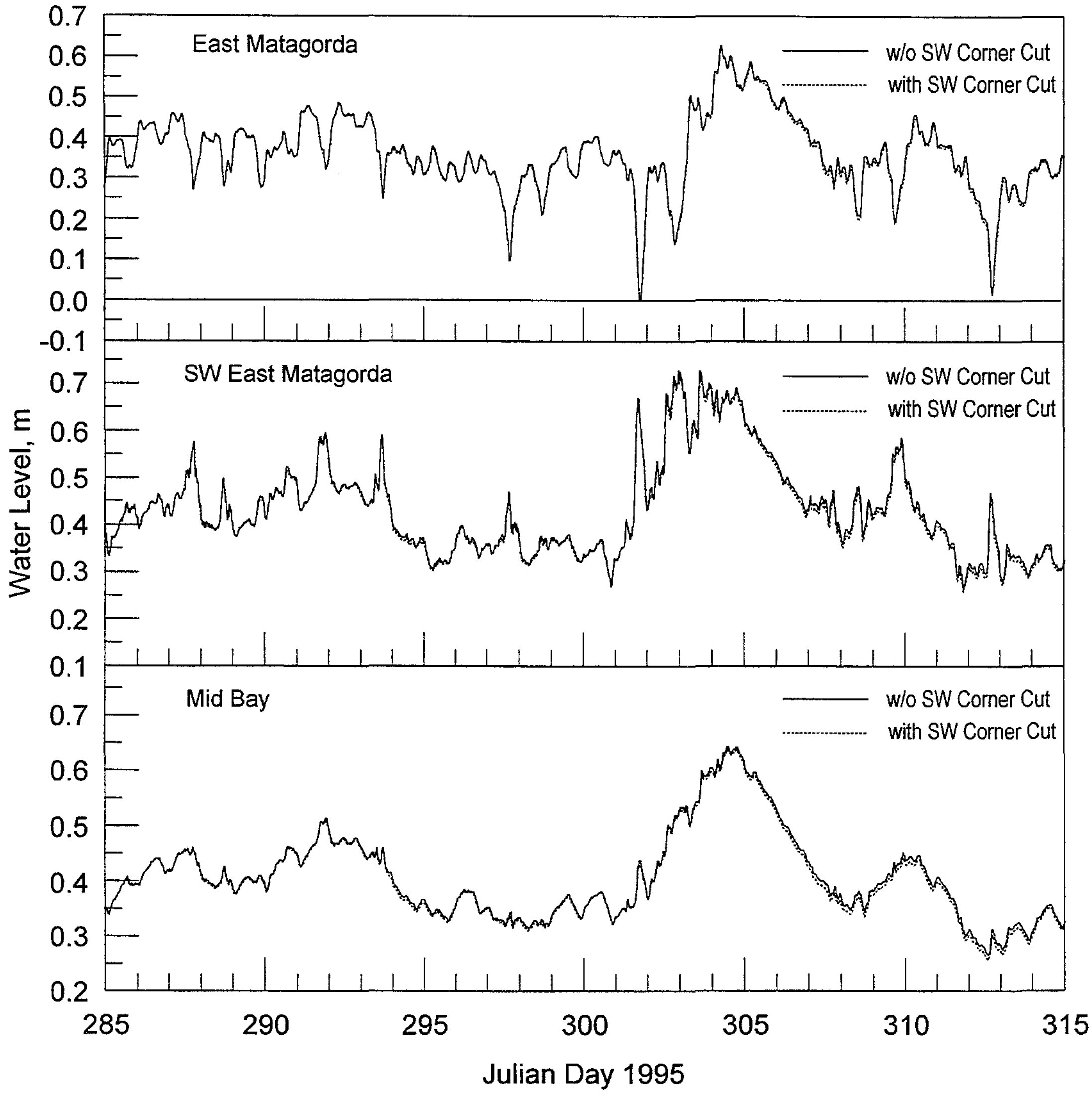

Figure 43. Water-level at specific points in East Matagorda Bay for the existing condition and with SW Corner Cut.

upstream of the SW Corner Cut location. On average, the diverted discharge is 30% of the total flow rate through the CR Navigation Channel south of the Cut for the month-long simulation period for the Cut at design depth of 5 ft MLLW. The reduction in flow occurs for both flood and ebb tide. This reduction in current speed of peak flows will contribute to improved navigation safety in the GIWW in the vicinity of the locks.

The rate of water movement through the SW Corner Cut has implications for scour or deposition in the Cut and for exchange of water between East Matagorda Bay and the CR Navigation Channel. Figure 45 shows the discharge and current speed in the middle of the

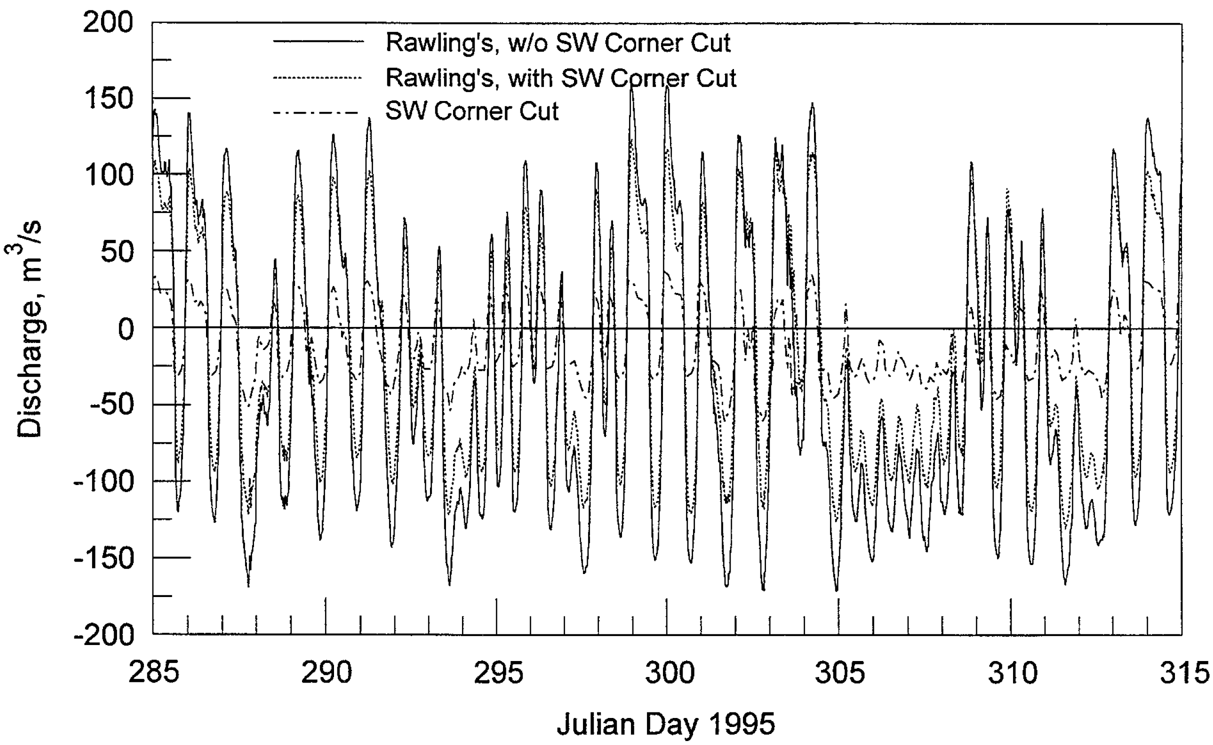

Figure 44. Comparison of discharge at Rawling's and in the SW Corner Cut.

confined portion of the SW Corner Cut for Case 2 (constant friction coefficient in the Cut) and Case 3 (higher friction coefficient on the ends of the Cut) as described in Table 2 and the section on calibration. Positive values of discharge and current speed indicate flow toward East Matagorda Bay from the CR Navigation Channel. Increasing the friction on the ends of the Cut decreased the calculated discharge and current speed by 20-25% during periods of peak flow, as seen in Figure 45. The net discharge is directed out of East Matagorda Bay and is 9 m^3/s and 11 m^3/s for Cases 2 and 3, respectively. The net outward flow is expected because the wind causes setup on the western end of East Matagorda Bay and would induce a water elevation gradient between the bay and the CR Navigation Channel. Figure 46 shows the water levels in the SW Corner Cut for Case 2. The curves represent water levels at the two end cells of the confined portion of the Cut. A water level gradient inducing flow out of the bay occurs when the water level on the bay end of the Cut is higher than the water level on the CR Navigation Channel side of the cut. When the gradient is reversed, water will flow into East Matagorda Bay from the CR Navigation Channel. Because of the nearly constant wind-induced setup on the western side of the bay, the mean discharge through the Cut is expected to be directed out of the bay for most of the year. The outflow through the Cut would be balanced by increased flow into the system through Mitchell's Cut and possibly the GIWW.

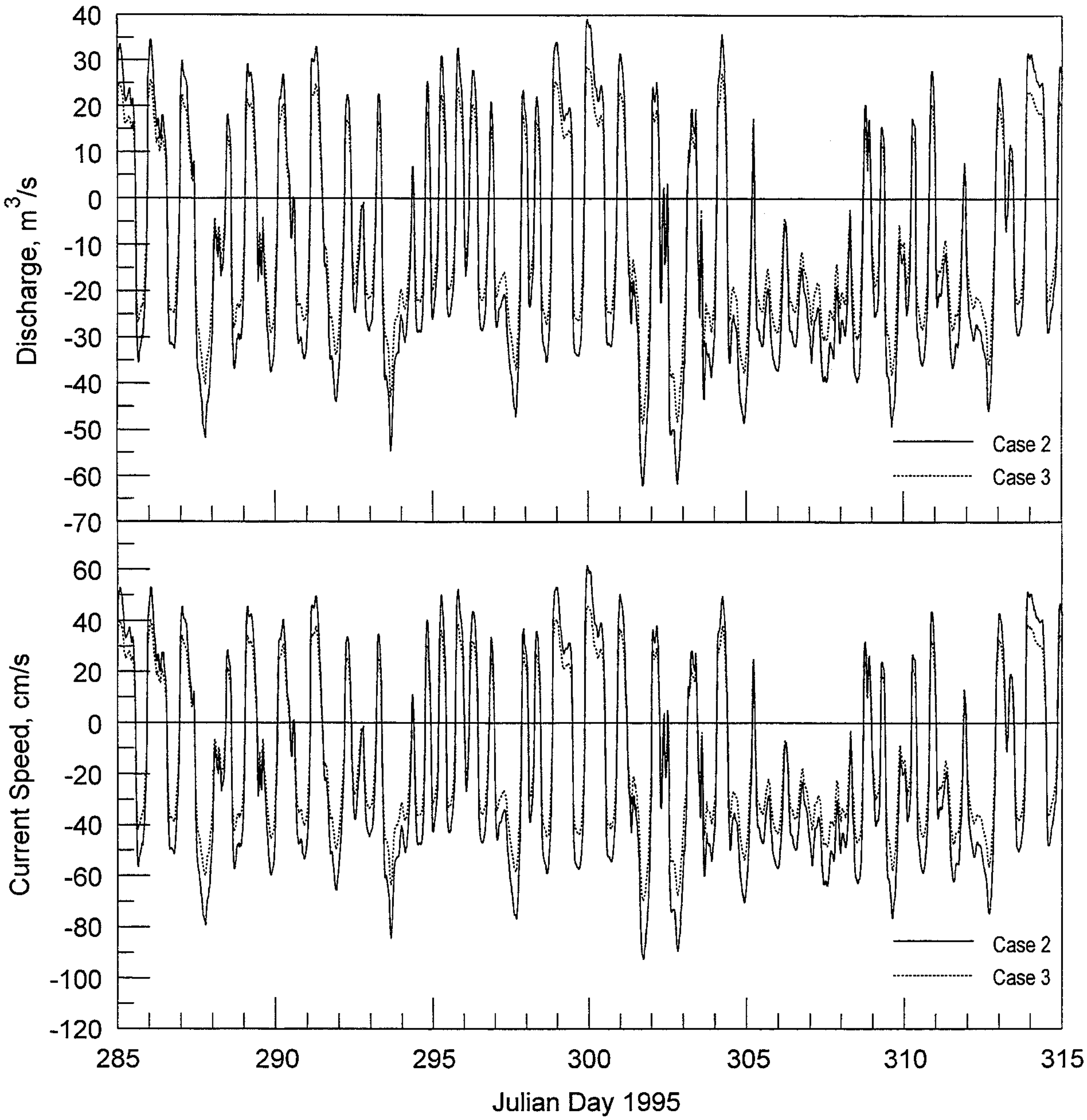

Figure 45. Discharge and current speed in SW Corner Cut.

A simulation was performed with a 0.76-m (2.5-ft) high weir placed in the middle of the SW Corner Cut (Case 8) to determine the change in flow rate and current in the Cut in comparison to the condition without the weir. Comparison of results with and without the weir showed no significant change in discharge or current through the Cut with the weir emplaced. Thus, a higher weir would be required to impede flow in the Cut.

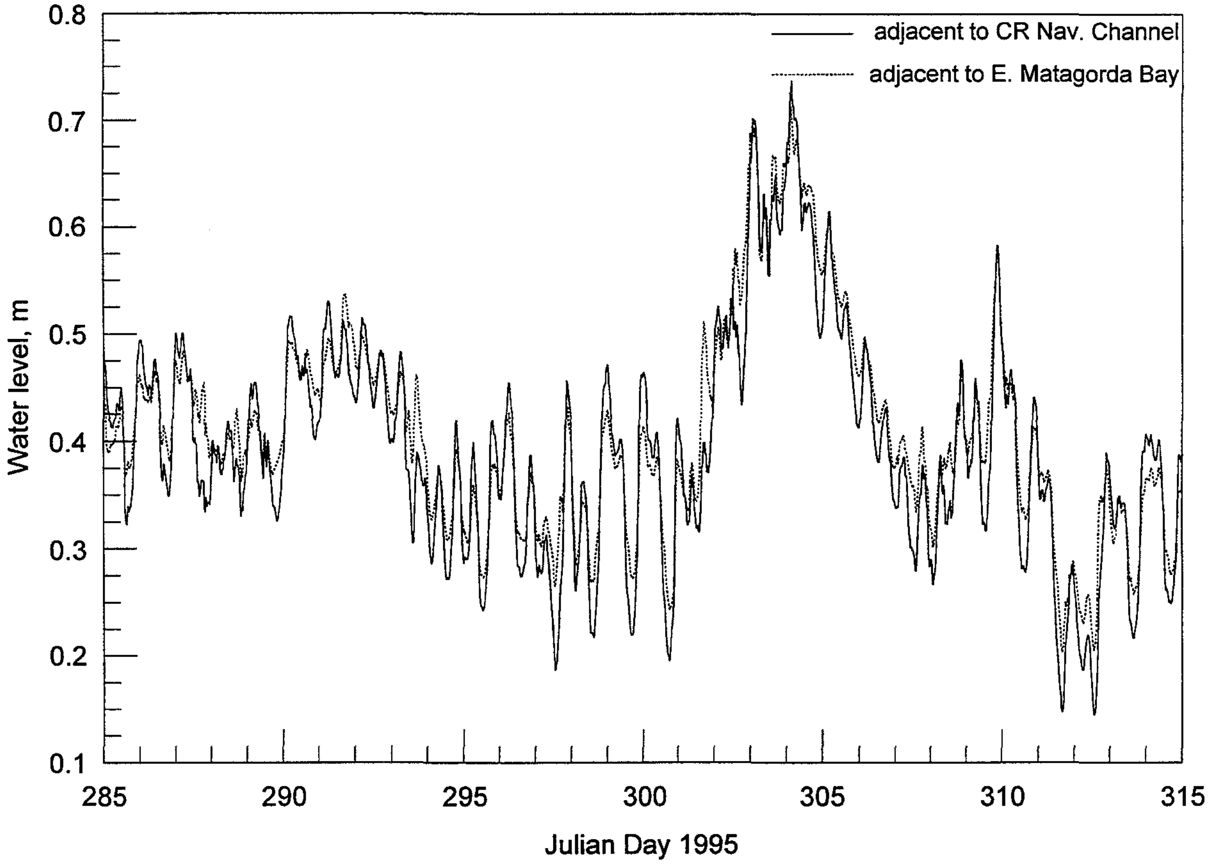

Figure 46. Water levels in SW Corner Cut.

Response of Mitchell's Cut to Installation of the SW Corner Cut

Change in discharge at Mitchell's Cut with installation of the SW Corner Cut is of concern for stability of Mitchell's Cut. The difference in discharge Δq at Mitchell's Cut was calculated from simulations performed with and without the SW Corner Cut, and is given as

$$\Delta q = q_w - q_{w/o} \tag{10}$$

where q is the discharge, the subscript w indicates presence of the SW Corner Cut, and the subscript w/o indicates the existing condition. Figure 47 shows the discharge for the existing condition plotted with the change in discharge if the Cut were installed. The plot shows calculations from Cases 1 and 2. Positive values indicate flooding. The net discharge will increase (landward) with installation of the Cut, but the increase will be slight and typically occurs when the tide is flooding. The change in discharge with the Cut installed is usually negligible during ebb tide. Over the simulation period, the average change in discharge is approximately 3 m^3/s landward, which is less than 2% of the daily peak discharge, which is typically about 200 m^3/s. The increased flow into Mitchell's Cut is a response to water flowing out of East Matagorda Bay through the SW Corner Cut. As water exits East Matagorda Bay on the western side, the wind pushes more water into the southwestern corner of the bay to replace the outflowing water. Water then flows into East Matagorda Bay from openings on its eastern side to replace water that flows out through the SW Corner Cut.

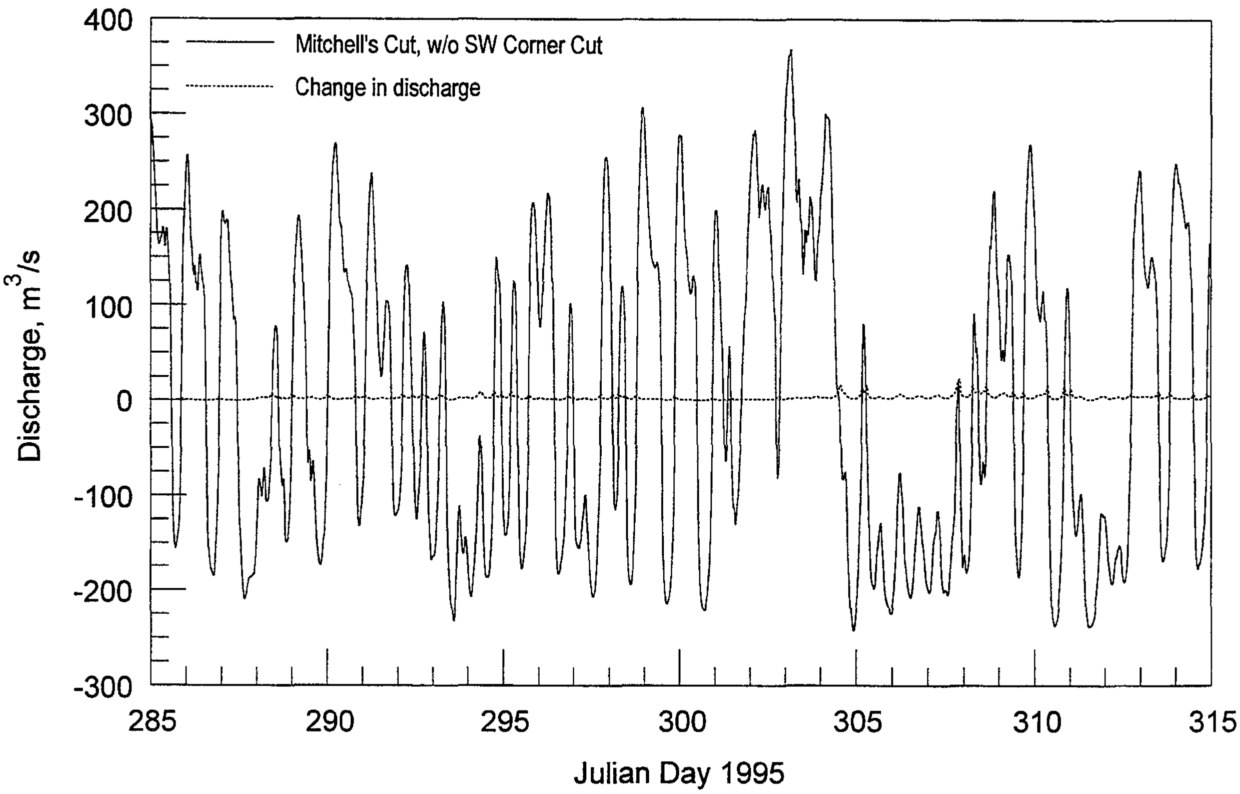

Figure 47. Discharge at Mitchell's Cut for the existing condition and the change in discharge at Mitchell's Cut with SW Corner Cut.

Influence of Wind on Circulation

Wind is a strong driving force on the water movement in East Matagorda Bay. Because of the strong wind that typically has an easterly component as SE or NE, circulation and water level are influenced to a great extent by wind forcing. Figure 48 shows the water level at EMAT and SWEMAT for simulations with and without the wind. Fluctuations on a daily time scale are seen to be diminished without wind forcing. The small daily fluctuations without the wind illustrate that East Matagorda Bay is microtidal. Additionally, the along-axis setup and setdown within the bay do not exist without the wind. The longer-period fluctuations (order of days) exist with and without the wind and are a response to Gulf water-level fluctuations. Even without the wind applying direct stress to the water level in the grid domain, the Gulf forcing data contains wind-forced fluctuations because the measurements were made under real conditions, i.e., with the wind. Thus, some portion or all of the longer-period fluctuations seen in Figure 48 for the curve without wind may actually be wind-induced, embedded within the water-level driving data in the Gulf.

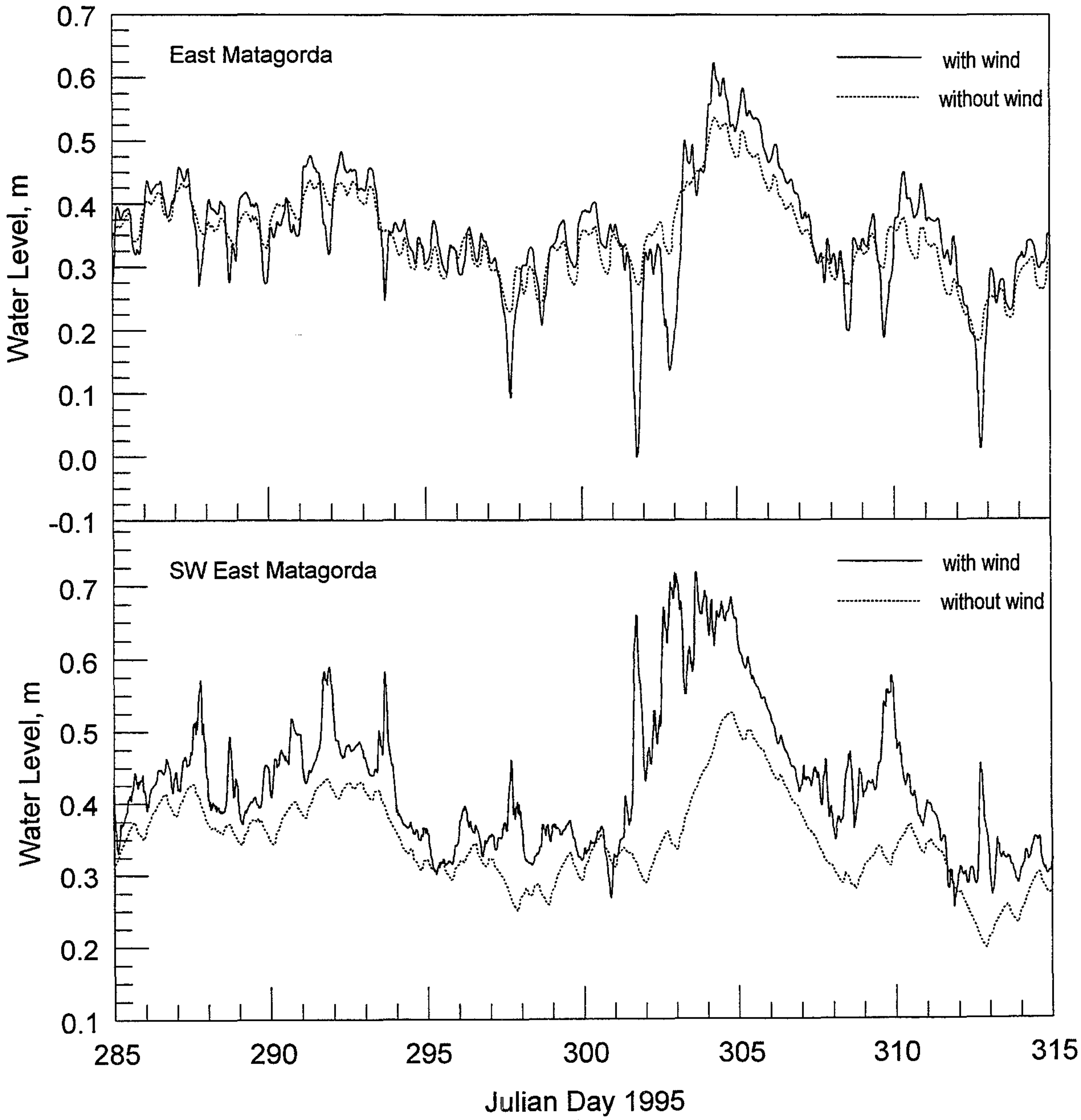

Figure 48. Calculated water levels at the EMAT and SWEMAT sites with and without wind for the existing condition.

The overall water level at EMAT and SWEMAT is lower without the wind than with the wind (see Figure 48). The lower water level may be due to the lack of water pushed against the Gulf shore (setup) during the predominant easterly wind conditions. Setup along the shore causes water to flow into the bay and increases the water level. Persistence of onshore wind keeps water levels elevated in the bay.

The difference in water levels between simulations run with and without the wind for EMAT and SWEMAT were computed and are shown in Figure 49. The difference in water level $\Delta\eta$ was computed as

$$\Delta\eta = \eta_{wind} - \eta_{nowind} \tag{11}$$

Positive values of $\Delta\eta$ indicate elevated water levels with the wind (setup) and negative values indicate depressed water levels with the wind (setdown). Figure 49 clearly shows the nearly constant setup at SWEMAT which, during the simulation period, reached more than 39 cm (1.3 ft). Individual wind events can be seen as spikes in the difference in water level. The water level at EMAT is seen to be set down in individual events corresponding to the setup events that occur at SWEMAT. Setdown at EMAT is expected during winds that have an easterly component. The peak setdown at EMAT during the simulation period was 27 cm (0.89 ft).

Figure 49 shows a persistent setup of approximately 3 cm (1 in) for both EMAT and SWEMAT. This setup is persistent throughout the simulation period and may be induced through low frequency wind setup along the Gulf shore. Thus, the wind may be responsible not only for daily and frontal scale water-level fluctuations, but also for maintaining water levels in the bay over long-period time scales.

Role of Mitchell's Cut

Mitchell's Cut is the most direct opening through which water can be exchanged between the Gulf and East Matagorda Bay. Simulations were performed without Mitchell's Cut for two reasons: (1) to understand the role that the cut plays in the hydrodynamics of East Matagorda Bay; and (2) to examine the consequence of closing Mitchell's Cut. Results of these simulations are presented here.

Water level in East Matagorda Bay for the existing condition, but with Mitchell's Cut closed (Case 6), is shown in Figure 50. The mean water level in the bay remains nearly constant. The small long-period fluctuations are a response to Gulf forcing that makes its way into East Matagorda Bay via the CR Navigation Channel and the GIWW. The wind causes the dominant

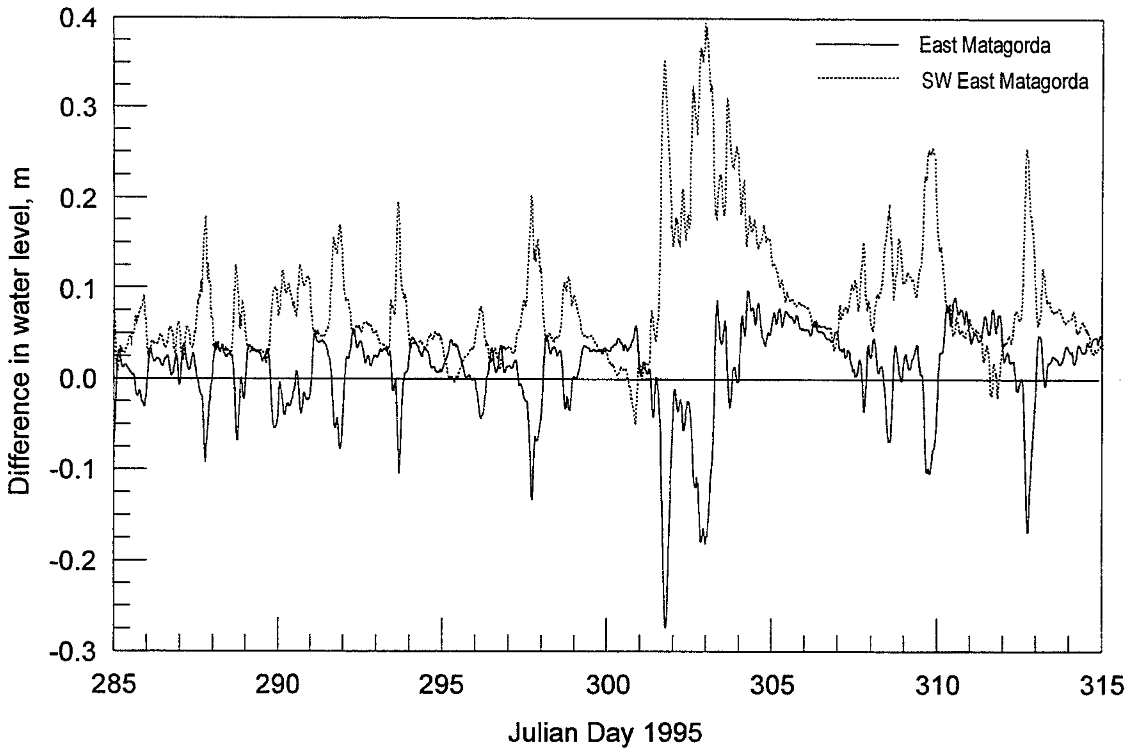

Figure 49. Calculated difference in water level between simulations runs with and without the wind for the existing condition.

water level changes, and the tilted water surface is readily apparent for most of the modeling period. The reduction in the long-period water-level fluctuations that are evident in Figure 43 is a direct result of closing Mitchell's Cut because exchange between the bay and the Gulf was effectively eliminated.

Installation of the SW Corner Cut would provide a conduit for flow between the bay and the Gulf, and results of a simulation with the Cut in place and with Mitchell's Cut closed are shown in Figure 50 as Case 7. The water level at both EMAT and SWEMAT are seen to decrease over the period of the simulation. Results for Case 7 are over a shorter time period than other model results because the decrease in water level became so severe that areas of the grid became dry and the calculations were halted. The decrease in water level is expected for the conditions imposed because the nearly persistent winds cause setup along the western end of the bay and water flows out of the bay via the SW Corner Cut, as described earlier. With Mitchell's Cut closed, water cannot enter the bay fast enough to replace that lost through the SW Corner Cut, and the net result is a severe decrease in water level. It is expected that if Mitchell's Cut were to close, the water level in the bay would drop to an equilibrium level in which water exchange

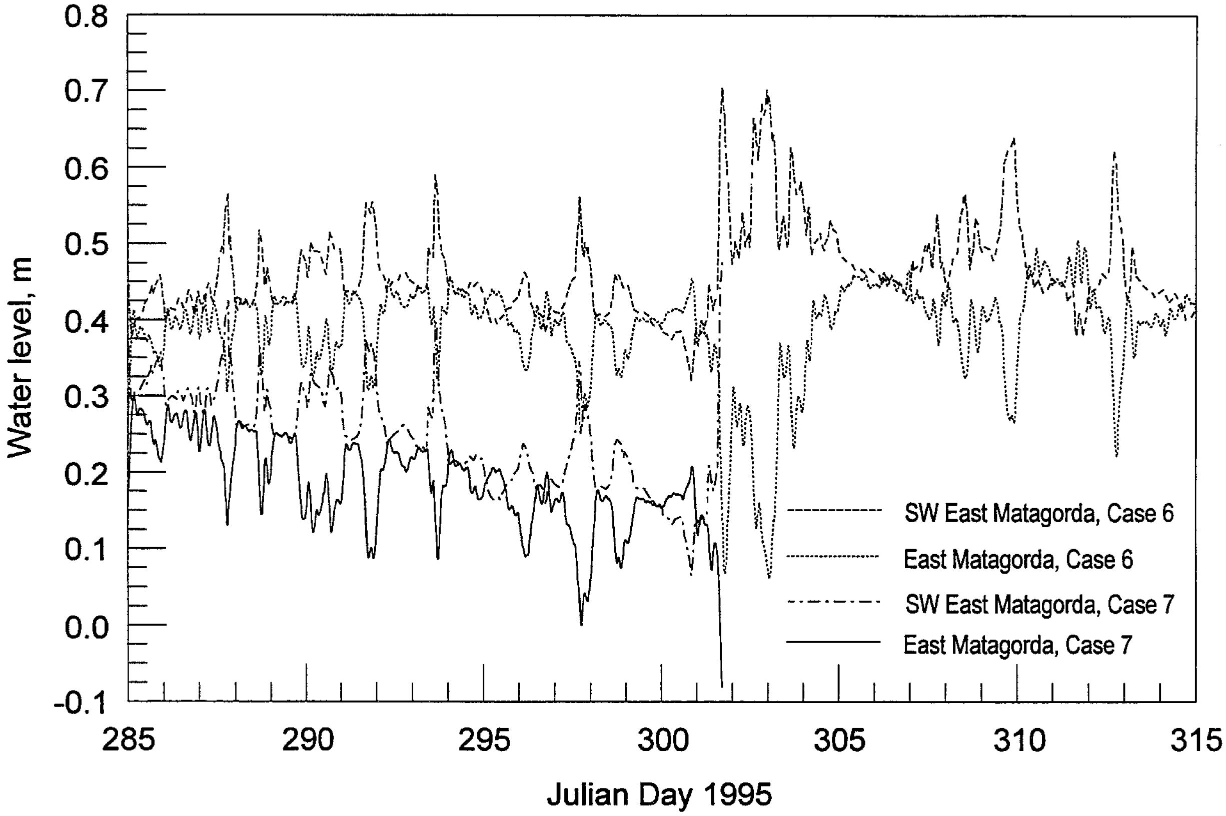

Figure 50. Water level at EMAT and SWEMAT with Mitchell's Cut open and closed.

through the SW Corner Cut would be balanced by the water level and tide in the CR Navigation Channel and the wind setup in the bay.

Scour of the SW Corner Cut

Strong currents in the SW Corner Cut could cause scouring, leading to change in the current speed and discharge in the Cut, CR Navigation Channel, and GIWW. A simulation (Case 9) was performed to determine the discharge and current speed in the Cut if it were scoured uniformly to a depth of 12 ft (3.66 m) MLLW. Figure 51 shows the discharge and current speed in the SW Corner Cut for the design depth (Case 3) and for the 12-ft depth. For the 1-month long simulation period, the discharge through the scoured Cut increased an average of 313% over the discharge in the Cut with the design depth. Discharge through the scoured Cut was calculated to be 72%, on average, of that through the CR Navigation Channel south of the Cut location for the simulation period. Currents in the vicinity of the intersection of the CR Navigation Channel and the GIWW were calculated to be reduced by approximately 10% with deepening of the Cut to 12-ft from 5-ft depth.

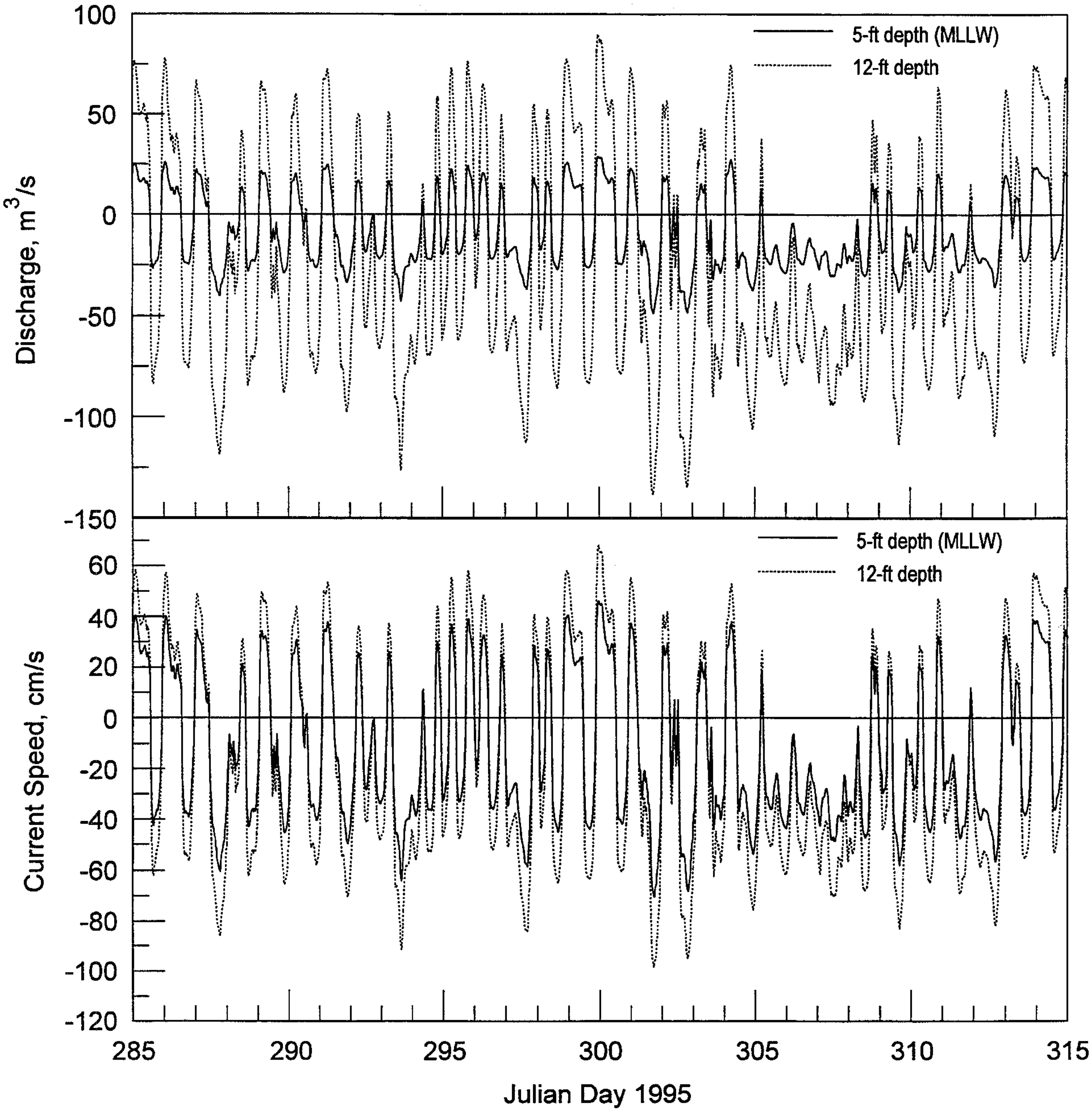

Figure 51. Discharge and current speed in the SW Corner Cut for depths of 5 ft and 12 ft.

Summary

Numerical modeling of the East Matagorda Bay and adjacent channels was performed to investigate changes in the hydrodynamics of the system if the SW Corner Cut were installed in the bay. Substantial water level and current velocity data were available to calibrate the model unambiguously and with confidence.

Installation of the SW Corner Cut will cause a reduction of discharge in the CR Navigation Channel north of the Cut because about 30% of the flow would be diverted from the CR Navigation Channel into the Cut. This reduction in discharge will be associated with a reduction in current speed north of the Cut that could be as much as 25% during times of peak velocities. The change in current speed and discharge decreases to the east along the GIWW. Currents in the GIWW in the vicinity of Caney Creek are not expected to change with installation of the Cut.

Installation of the SW Corner Cut will alter the water level in the system with the dominant changes being in the CR Navigation Channel south of the Cut location. Water level fluctuations were reduced upstream of the Cut and increased seaward of the Cut. The maximum water level reduction was 12 cm in the CR Navigation Channel near the Parker's Cut Dam during the simulation period and occurred during ebb tide. North of the location of the Cut, the water level was calculated to be, on average, slightly higher than without the Cut in the CR Navigation Channel and the western reach of the GIWW. The maximum water level increase in the CR Navigation Channel for the simulation period was 6 cm at the channel bend and occurred during ebb tide. The water level is virtually unaffected by existence of the Cut in the vicinity of Caney Creek. In East Matagorda Bay, the water level decreased approximately 1 cm over the 1-month long calculation interval.

The existence of the SW Corner Cut is expected to cause negligible change in the discharge through Mitchell's Cut. The discharge through Mitchell's Cut would increase slightly in the flood direction, but the increase is expected to be less than approximately 2% of the existing daily peak discharge during typical conditions.

Discharges through the SW Corner Cut will vary with friction and transition losses, but are estimated to peak at approximately 60 m^3/s if it is maintained at its design dimensions. Currents in the Cut will reach 1 m/s (3 ft/s) during typical moderately strong wind (10-12 m/s wind speeds), but could be elevated above this speed during extreme events (tropical storms, hurricanes). Because of high current speeds calculated for the SW Corner Cut, the potential for scouring exists. Scouring would increase discharge and current speed in the Cut. For a scour depth of 12 ft, the estimated discharge would be 313%, on average, over the discharge in the Cut at design depth.

The wind is the dominant force in East Matagorda Bay. The long-period wind setup inside East Matagorda Bay was calculated to be approximately 3 cm. Results of the hydrodynamic simulations indicate that the water level in the bay is maintained by the long-period water level on the Gulf coast, which is in part, setup induced by the persistent winds of the region.

Mitchell's Cut is the main channel through which water can flow into and out of East Matagorda Bay. Exchange through small passes between the GIWW and the bay are small in comparison, as evidenced by the lack of inflow into the bay with Mitchell's Cut closed. Low-frequency water-level fluctuations that occur in the bay are the result of Gulf forcing that propagate through Mitchell's Cut and enter East Matagorda Bay via the old GIWW channel and the small channel located near the mouth of Mitchell's Cut.

If Mitchell's Cut closed after installation of the SW Corner Cut, the water level in the bay would decrease significantly to an as-yet undetermined level. Because exchange of water through the SW Corner Cut is substantially less than through Mitchell's Cut, the rate and volume of inflow of Gulf water would be diminished if the cut was closed, possibly altering the water quality and salinity in the bay.

4. Hydraulic Feasibility and Inlet Stability Analysis

As discussed in Chapter 1, a primary objective of this study is estimation of the stability of the proposed SW Corner Cut and of Mitchell's Cut in the presence of the SW Corner Cut should it be constructed. A non-stable cut would either (a) increase in cross-sectional area (width, depth) of its throat, as did McCabes Cut, or (b) decrease in size and shoal until closure. Mitchell's Cut is a tidal inlet, although with some qualifications discussed below, and the SW Corner Cut would function more as a river mouth in tending to be dominated by the westerly flow produced by the frequent southeast and northeast winds.

A strong current flowing through a restricted channel will tend to erode the bottom and banks to increase the channel area, thereby reducing the velocity of the flow for a system with a constant upstream discharge. Once the velocity decreases to a magnitude for which no further erosion can occur, the channel area becomes stable and is in dynamic equilibrium with the sediment-moving forces. In actuality, hydrodynamic forces in nature have a wide range of variability in strength, duration, and order of occurrence, making prediction of stability difficult. Also, channel stability is influenced in part as to whether the erosional process is reversible. On a sandy coast, inlet mouths without stabilization will migrate up and down the coast, changing dimensions and location, because of the plentiful supply of sand; they thus are free to respond to changes in the hydrodynamic forcing and can move through reversible cycles. Stabilized inlets, as through jetties and bulkheading, will either increase in cross-sectional channel area until equilibrium is reached or shoal if the inlet flow is too weak.

For the situation with weak current, an inlet or a river mouth would tend to close if the volume of sediment brought to it is greater than can be transported away by the hydraulic (tidal or river) flow. Sediment can be brought to the mouth by wave action (littoral or longshore transport), by transport from the back bay by the ebb current, by transport from the Gulf by the flood current, and by wind blowing on the beach.

Inlet and river mouth stability involves many factors, and the physical situation cannot be considered completely as one involving "steady-state," constant, or average flow and sediment supply conditions. For example, in Chapter 1 the blockage of the old Colorado River was discussed, with the river closure evidently occurring because of a log jam that trapped sediments. Both mild and strong storms will change the overall hydrodynamic conditions and cause either inlet mouth growth or closure. Heavy rain raising the estuarine water level will tend to cause stronger ebb currents and increase inlet and river mouth width, but the potential slug of sand deposited by the strong current might, in turn, promote mouth closure upon return of normal hydrodynamic conditions. The underlying material, which could be live or relic oyster reef, sand, clay, limestone, or rock, will also determine the potential equilibrium size of an inlet or river mouth and the time taken to approach the equilibrium size for the case of an artificially opened mouth.

In light of above and related considerations, inlet stability is approached here from an empirical perspective based on qualitative observation at the site and on results of the hydrodynamic analysis described in Chapter 3.

Stability of Inlets and Entrances

In this section, a short overview of the stability of inlets and river mouths is given. Comprehensive reviews can be found in technical reference books such as Bruun (1990), Herbich (1992), and USACE (1995).

Tidal inlets are narrow channels that connect a smaller body of water (a bay or estuary, for example) to a larger body of water (the sea, or the Gulf in the present situation) that undergoes periodic and predictable changes in water level accompanying the tide. When the water level rises in the Gulf, flow is directed into the estuary, and the resultant current is called a flood current. When the water level goes down in the Gulf, water flows from the estuary to the Gulf, and the resultant current is called an ebb current. This ideal situation is made complex by introduction of freshwater into the estuary or bay (which would tend to produce an ebb current), by flow brought through channels such as the GIWW, by flows produced by strong wind as discussed in Chapter 2 and Chapter 3, by seasonal and inter-annual changes in wave climate, and by wide-area meteorological phenomena, such as local weather fronts, pressure fronts offshore, and annual changes in the temperature of the oceans.

In classical tidal inlet stability analysis, a quantity called the "tidal prism" enters most developments. The tidal prism is defined as the change in total water volume in an estuary or bay between high and low water, or as the volume of water entering the estuary from the sea during the flood tide. During most of the year, the tide on the Texas coast is diurnal, meaning that there is one high water and one low water in a (lunar) day. Therefore, the tidal prism would be calculated over a time interval of about 24 hours. Sometimes the spring-tidal prism is used, which is the tidal prism associated with the spring tide, which occurs with maximum tidal range about twice a month.

In the present study, tidal prism is not a particularly relevant quantity because of the relative independence of Mitchell's Cut from East Matagorda Bay and because the wind setup at the SW corner of the bay would tend to produce a quasi-steady ebb current at the location of the proposed cut there. Mitchell's Cut is a tidal inlet in the strict sense that it is a narrow channel connecting a smaller body of water (confluence of eastern end of East Matagorda Bay, GIWW, and Caney Creek) with a larger body of water (the Gulf) through which a (periodic) tidal current flows. Mitchell's Cut deviates from the classical picture, however, in being isolated from the main body of East Matagorda Bay, by receiving water from Caney Creek during times of strong precipitation, and by receiving or supplying water to the GIWW depending on flow conditions that may be distant from the study site (for example, wind might blow water down the GIWW from the east, where the water could exit through Mitchell's Cut).

With this general background established, we proceed to discuss the stability and hydraulic feasibility of the SW Corner Cut and the stability of Mitchell's Cut.

Hydraulic Feasibility of the Proposed SW Corner Cut

Hydraulic feasibility will be discussed as the (1) hydrodynamics and (2) the stability and inferred sediment movement in the Cut and adjacent land areas. The two topics are related because of the feedback between channel dimensions and hydraulic efficiency.

Hydrodynamics

In a preliminary stability assessment of the proposed SW Corner Cut, Martin (1993) estimated the tidal current velocity expected at the location of the Cut "...to determine if the (SW Corner Cut) is likely to accumulate silt and sand or if it will be scoured by tidal flows." Martin obtained what he believed to be maximum overestimated velocities in the channel of about 2 to 2.3 ft/s (60 to 70 cm/s), which he stated were "more than sufficient to move silt and sand." However, he cautioned that the substrata of the area must be evaluated to determine the actual materials entering the channel. Because of the recognized limitation of not having results from a hydrodynamic model of the circulation, Martin could not definitively conclude whether the channel of the SW Corner Cut would either silt in or maintain itself. It is interesting to note that Martin's estimates of the current velocity agree well with the results found in the present study.

Current velocities in excess of 2 ft/s will readily erode clay and sand, and stable tidal inlet entrances are known to be those that possess maximum flows on the order of 3 ft/s (Bruun 1990). Velocities of this magnitude were measured in the synoptic survey performed in this study both at Mitchell's Cut and at the mouth of the CR Navigation Channel. A magnitude exceeding 2 ft/s was also calculated by the hydrodynamic model for the SW Corner Cut for its design depth of 5 ft MLLW, with a speed approaching and exceeding 3 ft/s occurring should the channel scour to a nominal depth of 12 ft MLLW (which is the approximate depth of the connection Navigation Channel). The SW Corner Cut is a hydraulically efficient location for a "pass" and the preferred route for water flow under northeasterly wind. The Cut would capture part of the flow presently directed along the GIWW and into the Navigation Channel Land Cut. This flow is known to be sufficiently strong as to pose occasional difficulties for navigation. Similarly, the flow in and out of Mitchell's Cut was measured and calculated to reach more than 3 ft/s under typical autumn and winter weather conditions, with stronger frontal winds and storm winds expected to produce even faster current. Therefore, quantitatively by modeling or by analogy, an ebb or exiting current on the order of 3 ft/s will be a typical condition at the mouth of the SW Corner Cut.

In summary, the current in the SW Corner Cut will be biased toward ebb under forcing by southeast and northeast winds. At its design dimensions, the current speed will exceed 3 ft/s under normal wind conditions and will flow faster in storm conditions. If the channel scours to depth on the order of 12 ft, the flow speed will routinely exceed 3 ft/s, and there will be a substantial discharge of water entering the CR Navigation Channel at almost a right angle to the Channel. The flow through the SW Corner Cut will reduce the peak currents experienced at the GIWW lock area by about 25% for the design condition, and considerably more if the SW Corner Cut scours.

Stability and Sedimentation

As opposed to a classical tidal inlet, the SW Corner Cut will act more as a tidal river mouth, with the river flow replaced by a quasi-steady ebb flow having tidal fluctuations superimposed on it. No flood tidal delta will form because of the ebb bias in the current, although fine material deposited by the N-S circulating current over the channel on the bay side may tend to create an area of sediment deposition along a restricted reach of the channel. This material would, however, tend to be flushed toward the CR Navigation Channel during times of strong westward directed flow in East Matagorda Bay that is diverted through the Navigation Channel Land Cut.

Information on the substrata for the SW Corner Cut is available from a soil boring made by Brown and Root (1979) at a location along the proposed channel (see Brown and Root (1979) Appendix B: Soils Investigation Report, Plate 1 and Plate 7). Boring No. CB-8, taken at the project location, contained "soft light gray and tan clay w/roots" to a depth of almost 5 ft below the bottom surface, and "medium dense light gray sand w/shell" from 5 to 17 ft below the bottom surface. This core reflects the composition of the area as a deltaic deposit composed of clastic sediments formed by opening of the log raft on the Colorado River in 1929. Such material is easily eroded and transported by moderate water flows, as noted by Martin (1993).

Concerning erosion of the wetland adjacent to the SW Corner Cut, the borders of the channel are expected to adjust similar to the wetland bordering the upper channel of Mitchell's Cut. At Mitchell's Cut, the channel width and location of wetland margins appear to have remained more or less constant since 1989. At the SW Corner Cut, the dredged channel with bottom width of 100 ft will extend some 4,000 ft through wetland before entering the open bay. If boat movement in the channel is restricted to a no-wake condition, then no significant impact of the wetland margins is anticipated if the channel segment in the bay does not scour beyond 5-ft design depth.

As a pseudo river mouth, material will be deposited as a shoal in the CR Navigation Channel. Considering Figure 52, the maintained depth in the CR Navigation Channel is approximately 14 ft MLLW. The design depth of the SW Corner Cut channel is 5 ft MLLW. Initially, the channel intersection will occupy its design cross section on the east bank of the CR Navigation Channel. With time, the depth of the SW Corner Cut channel will increase if the riprap and bulkheading along the sides of the cut channel remain in place (see Sheet 3/9 of the project permit contained in Appendix A). Numerical simulations of the current performed in this study with a deepened channel (to 12 ft MLLW) indicated that the current speed will be somewhat increased and have greater capacity for further eroding and transporting sand and finer particles. Therefore, the deepening of the channel mouth can be expected to take place over several years and not abate until the channel reaches a depth similar to that at the CR Navigation Channel, becoming morphologically and hydraulically a tributary feeding into the Channel.

In round numbers, we assume material may be removed along the approximate length of the channel cut from the culvert bridge to the east bank of the CR Navigation Channel, to a depth of 9 ft below the dredged depth of 5 ft and with a width of 100 ft. Therefore, over time, opening of the channel could potentially remove material from this area and deposit the approximately 4,000 cu yd of sediments in the Navigation Channel. This is a relatively small volume compared to quantities dredged as part of navigation maintenance. Expected deepening of the western side of the channel should be anticipated in design of the box culvert bridge to be constructed on FM 2031, for which sufficient depth of bridge piers and toe protection should be provided.

From the hydrodynamic analysis described in Chapter 3, the SW Corner Cut junction would almost daily and, certainly, weekly experience flows, particularly ebb flows, with speeds in excess of 2 to 3 ft/s. Therefore, we conclude that the SW Corner Cut would maintain itself and flush bay sediments into the CR Navigation Channel. The portion of the channel extending from the wetland into East Matagorda Bay to ambient depth of about 5 ft MLLW would receive fine-grained sediments from adjacent areas that are resuspended by waves and currents and transported to the channel by the tide- and wind-induced flows. This material would tend to be transported westward and discharged into the Navigation Channel during times of stronger flows, such as produced by stronger northeast winds and southeast winds. On a continuing basis, fine sand, silt, and clay will be transported out of the SW corner and into the Navigation Channel. The SW corner of the bay has the longest fetch (length over which wind can blow) for winds with an easterly component, and the largest waves in the bay are therefore expected in the SW corner. The portion of the channel extending from East Matagorda Bay to the culvert would experience flow speeds reaching 2 to 3 ft/s with approach to weaker flows on the adjacent

If the SW Corner Cut is allowed to scour to the depth of the CR Navigation Channel, appropriate consideration must be given to the bridge culvert and piling design and depths. Also, the bulkheading and riprap revetments along the Cut must also account for the anticipated greater depths. Finally, some concern should be given to the strong discharge that would enter the CR Navigation Channel at almost a right angle. In addition to creating turbulent water, eddies, and a cross current in the Channel, the jetted discharge might erode the opposite bank of the CR Navigation Channel.

Erosion and scour, as well as the associated increase in current velocity and discharge in the SW Corner Cut, should be closely monitored so that rapid instability does not occur. Provision should be made to implement scour-abatement strategies at the time the box culvert is installed and prior to occurrence of unstable channel bank conditions.

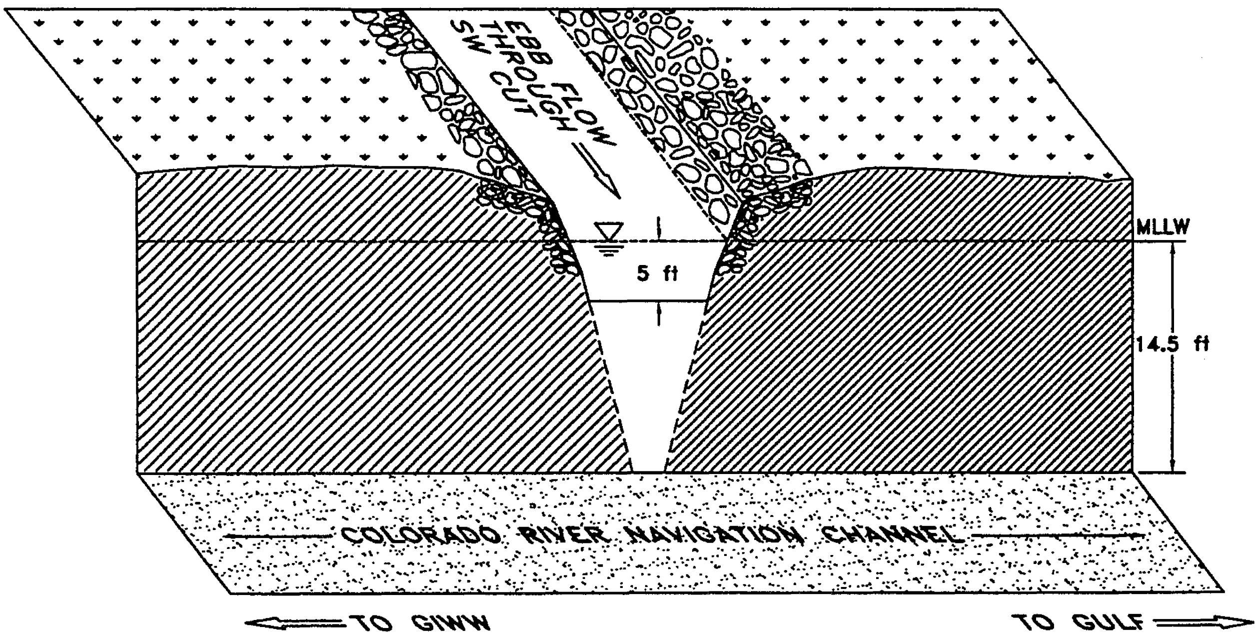

Figure 52. Schematic of intersection of SW Corner Cut and the CR Navigation Channel.

Mouth of Colorado River Navigation Channel

The volume of water entering or discharged from the mouth of the CR Navigation Channel will not change significantly because of the presence of the SW Corner Cut. The SW Corner Cut mainly changes the route of arrival between the mouth and East Matagorda Bay. Additional sediment will enter the CR Navigation Channel with opening of the SW Corner Cut. Suspended fine-grained sediment might increase water turbidity, and the additional material would eventually be deposited in shoals off the mouth of the Channel. The volume of additional material is ly be deposited in shoals off the mouth of the Channel. The volume of additional material is expected to be very small compared to the several hundreds of thousands of cubic yards a year dredged at the mouth (Heilman 1995) and not alter navigability of the Channel.

Stability of Mitchell's Cut

Modern Mitchell's Cut has remained open since it was created in May, 1989, and it evidently owes its longevity to the adequate flow from the GIWW and Caney Creek. McCabe's Cut was opened in 1983 and had to be closed (in May, 1989) because strong ebb and flood currents posed a hazard to navigation, as well as eroded the channel. In contrast to the physical situation of McCabe's Cut, which was located directly adjacent to the GIWW, the mouth of Mitchell's Cut is located approximately 1.2 miles (2 km) from the GIWW. This distance introduces sufficient resistance to reduce the current to a range that makes the cut dynamically stable; Mitchell's Cut has neither the strong flows that would excessively deepen and widen the channel, nor weak flows that would not be capable of clearing the mouth of littoral and estuarine sediments.

It is suspected, but was not verified in this study, that infrequent heavy precipitation and subsequent strong discharges from Caney Creek may be a significant factor in maintaining the stability of Mitchell's Cut. Therefore, a drought condition, as Texas is now experiencing, would tend to promote closure of the Cut.

In its present dynamically equilibrium state, and without the SW Corner Cut, it is possible that Mitchell's Cut will close for a variety of causes. The channel gorge in the Gulf, presently oriented to the south, might become narrowed and lengthened so that it closes. A storm might bring a slug of sand into the entrance, or the breaker bar could move onshore during a long duration of swell wave conditions as produced by a distant tropical storm or hurricane.

In the present study, the opening of the SW Corner Cut was shown to produce negligible change in the hydrodynamics at Mitchell's Cut. Therefore, the tendency of Mitchell's Cut to shoal or to remain open will not be altered by the SW Corner Cut under the present morphology of East Matagorda Bay. The reason for the lack of connectivity is that the GIWW and CR Navigation Channel are already hydraulically efficient in exchange of water through East Matagorda Bay. The opening of the SW Corner Cut would only change the path that the water would take in the Bay.

Mitchell's Cut is an ephemeral inlet; because it is not stabilized by structures, it has a finite life. If Mitchell's Cut were to close after opening of the SW Corner Cut, the results of the present study indicate that the closure process will be unrelated to the hydraulics in the SW corner of East Matagorda Bay.

Circulation in East Matagorda Bay

Opening of the SW Corner Cut will not change the magnitude of the flow through either the mouth of Mitchell's Cut or through the mouth of the CR Navigation Channel. Opening of the Cut will, however, change the distribution of the flow in East Matagorda Bay, increasing flushing of the bay.

5. CONCLUSIONS AND RECOMMENDATIONS

The following are main conclusions and recommendations of this study based on extensive monitoring and numerical modeling of the hydrodynamics in and around East Matagorda Bay:

Southwest Corner Cut

1. The SW Corner Cut, if opened, will remain open unless artificially closed. The flow in the Cut will be ebb dominated because of a bias introduced by the wind, and the flow speed will regularly reach 60 to 90 cm/s (2 to 3 ft/s) if the design dimensions of the Cut are maintained. The Cut will have a tendency to scour at its intersection with the CR Navigation Channel. If the flow in the Cut is not limited by some mechanism such as a weir, the reach of the Cut on the CR Navigation Channel side of FM 2031 will increase in depth until reaching the depth of the Navigation Channel. The flow speed will increase if the Cut scours. It is recommended that scour be anticipated and taken into account in both box culvert design of the bridge on FM 2031 and in any bulkheading and revetments placed in the channel. Provision for protecting the integrity of structures under scour and for reducing the flow in the Cut should be part of the design.

2. Scour in the wetland area adjacent to the channel of the SW Corner Cut is not expected to occur, because flow speeds in the Cut are similar in magnitude to those at Mitchell's Cut. The wetlands adjacent to channels at Mitchell's Cut have been effectively stable since its opening in 1989. It is recommended that a no-wake zone be established in regions of the channel of the SW Corner Cut that are directly adjacent to wetlands.

3. Opening of the SW Corner Cut to the CR Navigation Channel will create only a small cross current in the Channel if the design dimensions of the Cut cross section are maintained. If the Cut scours to reach the depth of the Navigation Channel, substantial turbulence and gyres are expected, similar to the situation occurring at the intersection of Caney Creek and Mitchell's Cut with the GIWW. Scour of the west bank of the Navigation Channel may occur if the discharge from the SW Corner Cut increases beyond that expected with its design dimensions maintained.

GIWW

4. If the SW Corner Cut is opened, the peak flow speed and discharge will decrease at the intersection of the GIWW and the CR Navigation Channel Land Cut. A minimum of 25% decrease in peak flow speed is expected, and the decrease will be greater if the SW Corner

Cut scours beyond its design dimensions. The decrease in flow speed will improve navigability in the GIWW.

5. If the SW Corner Cut is opened, there will be a slight increase in both ebb and flood peak flow speed at the mouth of the CR Navigation Channel. The increase in flow speed and discharge will enhance the potential to move sediments away from the intersection of the SW Corner Cut that will drop into the Channel from the Cut. The increase in flow at the mouth of Navigation Channel will act in favor of maintaining the channel.

Mitchell's Cut

6. The stability of Mitchell's Cut will not change with opening of the SW Corner Cut.
7. Mitchell's Cut is necessary for promotion of maximum water exchange in East Matagorda Bay. Mitchell's Cut allows dynamic movement of water to take place between the Gulf and the Bay that accompanies weather fronts and large-scale forcing in the Gulf.
8. If the SW Corner Cut is constructed and Mitchell's Cut closes (closure being independent of the existence of the SW Corner Cut), then the presence of the SW Corner Cut and absence of replacement water that would otherwise enter through Mitchell's Cut would lead to a lowering of mean water level in East Matagorda Bay. Calculation of the amount of lowering was beyond the scope of this study but is believed that it would be appreciable.

Circulation in East Matagorda Bay

9. Wind is the dominant force for day-to-day water movement and exchange in East Matagorda Bay. The dominance over the tide occurs not only because of the strong and persistent wind in the area, but also because of the east-west orientation of the bay, which results in westerly movement of water driven by winds out of both the northeast and southeast. There is a mean tilt of approximately 3 cm (1 inch) in the water surface across the long axis of the bay, with the western side higher, due to persistent wind forcing. The tilt was measured and calculated to reach as much as 60 cm (2 ft) under typical winter frontal movement and is expected to be greater under stronger winds.
10. Circulation in East Matagorda Bay will be increased with opening of the SW Corner Cut.

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Appendix A : Corps of Engineers Permit for the Southwest Corner Cut

This appendix contains a copy of the November 29, 1995, modification and time extension by the U.S. Army Corps of Engineers, Galveston District, of Permit No. 19091(01) for proposed channel development on East Matagorda Bay. The permit extends the time limit for completing approved work to December 31, 1998. The modification "...provides for authorization to place culverts under FM 2031 and to construct a boat ramp adjacent to the authorized channel for recreational purposes." The permit contains two additional special conditions (see letter of Dolan Dunn on page A-9 of this appendix).

In examination of the typical cross section (Sheet 2 of 9 in the permit application), some ambiguity in depth is evident. Although apparent water levels of "MLT" and "MHT" appear as labels on the cross section, the value of 1.4 ft is inconsistent with the position of, for example, a mean water level as an elevation zero. The engineering company that conducted the survey for the permit application, Baker & Lawson, Inc., of Angleton, Texas, was contacted by telephone, and Mr. Joe Ward of that firm kindly provided an explanation. Acting on and interpreting instructions from Mr. George Deshotel, Commissioner of Precinct 2, Matagorda County, a land-level survey was run from a National Geodetic Survey bench mark denoted as V 51 to the project site. Marker V 51 is located three blocks southeast of the high school in Matagorda City. The bench mark provides the elevation of the National Geodetic Vertical Datum (datum of 1929) called "NGVD," and Marker V 51 is at an adjusted datum (adjustments through 1959 and 1973) of 12.969 ft (with reference to NGVD).

The leveling was run by Baker & Lawson, Inc., from Marker V 21, down FM 2031, and out into East Matagorda Bay until a depth of 4 ft NGVD was reached. This depth was encountered some 11,200 ft from the road and thus determined the length of the proposed channel. The depth of 4 ft had been selected by the County as representative of the deeper portions of the bay. The design calls for an additional 1 ft of dredging identified as "undercut" in the cross section. The undercut would function as advance dredging to reduce the possible return interval for maintenance of the channel to a design depth of 4 ft, as well as assure that a 4-ft depth was provided for in the construction.

The datum NGVD is sometimes employed interchangeably with mean sea level (MSL), but is not necessarily (and typically is not) equal to MSL. Also, NGVD is not a tidal datum (not defined in terms of any phase of the tide). To the knowledge of the authors of this report, tidal datums available at the Rawlings water-level station (see main text of this report) have not been related to NGVD. In general, subsidence is a concern on estuarine deposits and is another factor that could confound the determination of the relation between local NGVD and tidal datums. In the area of the Colorado River Locks, the USACE, Galveston District, navigation datum of mean low tide is expected to lie 1.43 ft (0.43 m) below NGVD of 1929. The value of 1.4 ft shown in the permit cross-section thereby refers to 1.4 ft below NGVD; the labeling and value associated with "MHT" shown in the cross section is a probably a misprint.

TEXAS NATURAL RESOURCE CONSERVATION COMMISSION

Protecting Texas by Reducing and Preventing Pollution

November 7, 1995

Galveston District SWGCO-RP
Corps of Engineers
P.O. Box 1229
Galveston, Texas 77553-1229

ATTN: Robert Heinly

RE: USCOE Permit Application No. 19091(01)

Dear Mr. Heinly:

Matagorda County is requesting an extension of time for Permit 19091 which authorized the construction of a channel between the lower reach of the Colorado River and East Matagorda Bay on FM 2031, five miles south of Matagorda, Matagorda County, Texas. No portion of the project has been constructed to date. The channel will be approximately 100 feet wide and 10,800 feet long, dredged to a depth of -5 feet mean low tide. The applicant is proposing that the dredged material be deposited by jet spray in thin layers on low-lying areas in order to support the growth of marsh grasses. Approximately 1,400 feet of bulkhead will be constructed in the Colorado River and along the proposed channel. The applicant proposes to modify the proposal with the incorporation of culverts under FM 2031 and a boat ramp to be constructed on the east side of FM 2031 to facilitate recreational access to East Matagorda Bay via the proposed channel. The purpose of the channel is stated to be the creation of sufficient water exchange between East Matagorda Bay and the Gulf of Mexico in an effort to promote ecological vitality and enhance the fisheries served by East Matagorda Bay.

In letter dated August 28, 1995 the TNRCC identified concerns about this project being consistent with the Texas Water Quality Standards. TNRCC's certifications are required by Section 401 of the Federal Clean Water Act and are reviewed pursuant to Title 30 Texas Administrative Code Chapter 279. We were particularly concerned that the alteration of circulation and salinity had not been analyzed in any quantitative manner, and that no success criteria had been established to determine if the project "promotes ecological vitality or enhances the fisheries" of East Matagorda Bay. Also, concerns about the Total Suspended Solids (TSS) impacts from the jet spray disposal, and the need for a disposal plan for the maintenance of the project were identified.

P.O. Box 13087 • Austin, Texas 78711-3087 • 512/239-1000

Because the State of Texas Water Quality Inventory (305B), 12th Edition indicates that the average salinity in East Matagorda Bay (Texas Classified Segment Number 2441) averages 24 parts per thousand (ppt) with a range from 4 ppt to 35 ppt, we are concerned with impacts to the existing salinity gradients, particularly since the stated purpose of this project is to create sufficient water exchange between East Matagorda Bay and the Gulf of Mexico. However, the Texas Water Commission (TWC) previously certified the project and the Texas Parks and Wildlife Department (TPWD), the agency with primary responsibility for managing the fishery resources of the state, is a cosponsor of the project. So despite these concerns the TNRCC defers addressing them in this certification.

A study has been initiated by the TPWD and the Texas Department of Transportation to evaluate the impacts of circulation changes from this project. The applicant has indicated that if the results of the study indicate potential negative impacts to the ecological vitality and fisheries of East Matagorda Bay, they will not construct the channel. Futhermore, the applicant has also indicated they are willing to terminate the water exchange project if unexpected degradation does occurs. In order to make such a determination clearly defined success criteria will be needed. These criteria should include the target species that are expected to benefit from the project/and baseline data documenting the existing community for comparison with future monitoring results. Any monitoring plans to evaluate the success of the project should be identified. Additionally, there is a need for a binding commitment from the applicant that in the event the project needs to be terminated, adequate funding has been secured to finance the restoration of the existing conditions.

The public notice states the material from the construction of the channel will be deposited by jet spray in thin layers on low lying areas in order to support the growth of marsh grasses. While TNRCC strongly supports the beneficial use of dredged material, we are concerned that the material be retained in the disposal area to prevent violations of established water quality standards for TSS impacts, and that estimates of the volume of material to be disposed meets the design criteria for establishing the desired marsh elevations. If the jet spray disposal results in the desired elevations and marsh vegetation is established, there is a need to establish a disposal plan for maintenance dredging so that the adjacent wetland areas will not be impacted in the future.

In response to the Joint Public Notice dated March 7, 1995 and the previous certification by the TWC, we waive certification that the activity should not result in a violation of established Texas Water Quality Standards as required by Section 401 of the Federal Clean Water Act and pursuant to Title 30 Texas Administrative Code, Chapter 279.

Wetlands are protected by the Texas Surface Water Quality Standards and they play a major role in maintaining water quality standards. We support a goal of no net loss of wetlands. To this end, we believe that wetland impacts/losses can be avoided, minimized, or mitigated when personnel follow their Section 404 Guidelines in determining whether to issue a Section 404 permit.

If we may be of further assistance, please contact Mark Fisher, Research and Environmental Assessment Section, Water Planning and Assessment Division at (512) 239-4586.

Sincerely,

Dan Pearson, Executive Director
Texas Natural Resource Conservation Commission

Attachment 1

ccs: Mr. George Deshotels
Matagorda County Commissioner
Precinct No. 2
P. O. Box 571
Matagorda, Texas 77457

Mr. Herbert S. Smith, P.E.
Baker and Lawson, Inc.
300 E. Cedar
Angleton, Texas 77515

Attachment 1 - Dredge and Fill Certification
USCOE Permit No. 19091(01)
November 7, 1995
Page 1 of 3

WORK DESCRIPTION: As described in public notice dated March 7, 1995

SPECIAL PROVISIONS: None

GENERAL: **This waiver, issued pursuant to the requirements of Title 30, Texas Administrative Code, Chapter 279, is restricted to the work described in the application or joint public notice and shall expire 5 years from the date of issuance of the Corps of Engineer (COE) permit.** This waiver may be extended to any minor revision of the COE permit when such change(s) would not result in an impact on water quality. The TNRCC reserves the right to require full joint public notice on a request for minor revision. If this application is a modification of an original permit or any modification thereof for which a special condition was cited by the Commission or a predecessor agency, such conditions shall remain valid. The applicant is hereby placed on notice that any activity conducted pursuant to the COE permit which results in a violation of the state's surface water quality standards may result in an enforcement proceeding being initiated by the TNRCC or a successor agency.

STANDARD PROVISIONS: These following provisions attach to any permit issued by the Corps of Engineers and shall be followed by the permittee or any employee, agent, contractor or subcontractor of the permittee during any phase of work authorized by a Corps permit.

1. The water quality of wetlands shall be maintained in accordance with all applicable provisions of the Texas Surface Water Quality Standards including the General, Narrative and Numerical Criteria.

2. The applicant shall not engage in any activity which will cause surface waters to be toxic to man, aquatic life or to terrestrial life.

3. Permittee shall employ measures to control spills of fuels, lubricants, or any other materials to prevent them from entering a watercourse. All spills shall be promptly reported to the TNRCC, Emergency Spill Response, at (512) 463-7727.

4. Sanitary wastes shall be retained for disposal in some legal manner. Marinas and similar operations which harbor boats equipped with marine sanitation devices shall provide state/federal permitted treatment facilities or pump out facilities for ultimate transfer to a permitted treatment facility. Additionally, marinas shall display signs in appropriate locations advising boat owners that the discharge of sewage from a marine sanitation device to waters in the state is a violation of state and federal law.

5. Materials resulting from the destruction of existing structures shall be removed from the water or areas adjacent to the water and disposed of in some legal manner.

6. A discharge shall not cause substantial and persistent changes from ambient conditions of turbidity or color. The use of silt screens or other appropriate methods is encouraged to confine suspended particulates.

7. The placement of any material in a watercourse or wetlands shall be avoided and placed there only with the approval of the Corps when no other reasonable alternative is available. If work within a wetland is unavoidable, gouging or rutting of the substrate is prohibited. Heavy equipment shall be placed on mats to protect the substrate from gouging and rutting if necessary.

8. Dredge Material Placement: Dredged sediments shall be placed in such a manner as to prevent any sediment runoff onto any adjacent property not owned by the applicant. Liquid runoff from the disposal area shall be retained on-site or shall be filtered and returned to the watercourse from which the dredged materials were removed. Except for material placement authorized by this permit, sediments from the project shall be placed in such a manner as to prevent any sediment runoff into waters in the state, including wetlands.

9. If contaminated spoil that was not anticipated or provided for in the permit application is encountered during dredging, dredging operations shall be immediately terminated and the TNRCC, Emergency Spill Response, shall be contacted at (512) 463-7727. Dredging activities shall not be resumed until authorized by the Commission.

10. Contaminated water, soil or any other material shall not be allowed to enter a watercourse. Noncontaminated stormwater from impervious surfaces shall be controlled to prevent the washing of debris into the waterway.

11. Stormwater runoff from construction activities (US EPA Category X) are governed by the requirements of the US Environmental Protection Agency. Applications to apply for a general permit are to obtained from Region 6, US EPA at (214) 665-7185.

12. Upon completion of earthwork operations all temporary fills shall be removed from the watercourse/wetland and areas disturbed during construction shall be seeded, riprapped, or given some other type of protection to minimize subsequent soil erosion. Any fill material shall be clean and of such composition that it will not adversely effect the biological, chemical or physical properties of the receiving waters.

13. Disturbance to vegetation will be limited to only what is absolutely necessary. After construction, all disturbed areas will be revegetated to approximate the pre-disturbance native plant assemblage.

14. Where the control of weeds, insects and other undesirable species is deemed necessary by the permittee, control methods which are nontoxic to aquatic life or human health shall be employed when the activity is located in or in close proximity to water, including wetlands.

15. Concentrations of taste and odor producing substances shall not interfere with the production of potable water by reasonable water treatment methods, impart unpalatable flavor to food fish including shellfish, result in offensive odors arising from the water, or otherwise interfere with reasonable use of the water in the state.

16. Surface water shall be essentially free of floating debris and suspended solids that are conducive to producing adverse responses in aquatic organisms or putrescible sludge deposits or sediment layers which adversely affect benthic biota or any lawful uses.

17. Surface waters shall be essentially free of settleable solids conducive to changes in flow characteristics of stream channels or the untimely filling of reservoirs, lakes and bays.

18. The work of the applicant shall be conducted such that surface waters are maintained in an aesthetically attractive condition, foaming or frothing of a persistent nature is avoided and surface waters shall be maintained so that oil, grease, or related residue will not produce a visible film of oil or globules of grease on the surface or coat the banks or bottoms of the watercourse.

19. This waiver shall not be deemed as fulfilling the applicant's permittee's responsibility to obtain additional authorization/approval from other local, state or federal regulatory agencies having special/specific authority to preserve and/or protect resources within the area where the work will occur.

DEPARTMENT OF THE ARMY
GALVESTON DISTRICT. CORPS OF ENGINEERS
P.O. BOX 1229
GALVESTON. TEXAS 77553-1229

REPLY TO
ATTENTION OF

November 29, 1995

Policy Analysis Section

SUBJECT: Permit No. 19091(01); Extension of Time

Mr. George Deshotels
Matagorda County Commissioner
P.O. Box 571
Matagorda. Texas 77457

Dear Mr. Deshotels:

Your request to modify and extend the time to complete your project is approved. The time for completing the approved work is extended to December 31, 1998. The permit now provides authorization to place culverts under FM 2031 and to construct a boat ramp adjacent to the authorized channel for recreational access.

The enclosed plans in nine sheets are approved to supersede the plans of the original permit. All conditions to which the work is made subject, except for the time limit, remain in full force and effect including the following special conditions:

> The applicant shall submit a survey of the disposal area delineating vegetated and unvegetated areas to the Corps of Engineers 1 month prior to initiation of dredging.
>
> Spray dredged material shall be placed only on those areas exhibiting no vegetation.

FOR THE DISTRICT ENGINEER:

Dolan Dunn
Chief, Policy Analysis Section

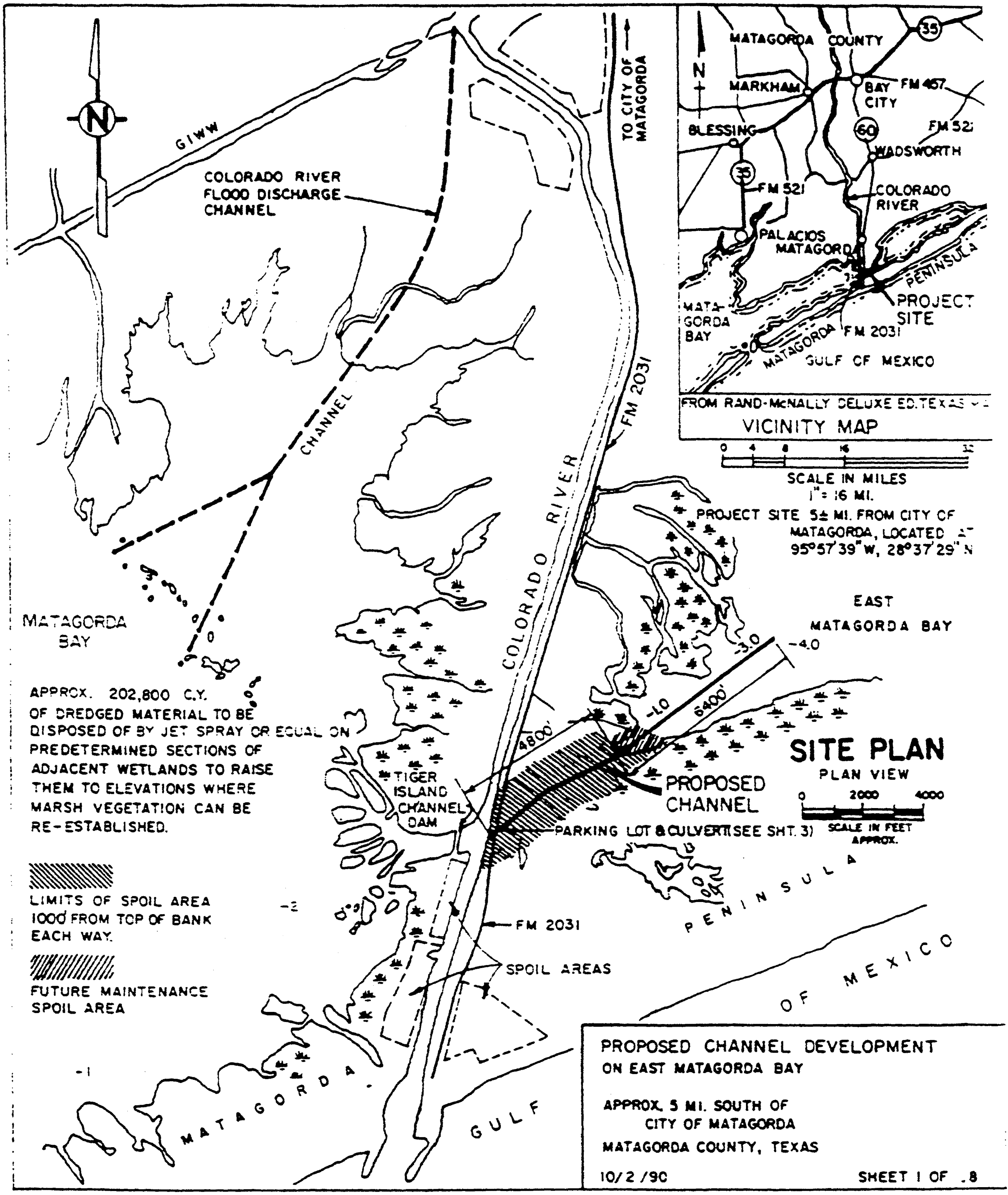
Copies Furnished:
Eighth Coast Guard District, New Orleans, La.

NOAA/NOS, Coast & Geodetic Survey, Silver Spring, Md.

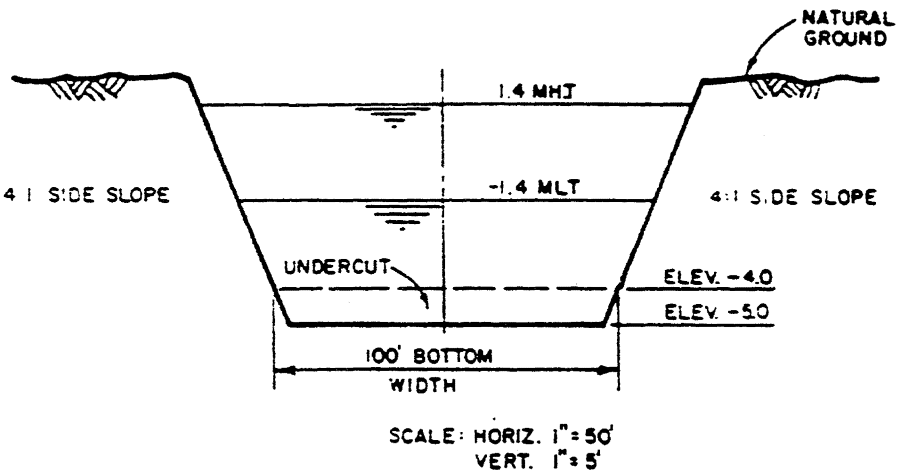
Texas General Land Office, Austin, Tx.

Texas General Land Office, La Porte, Tx.

Area Engineer, Southern Area Office, Corpus Christi, Tx.



N
GIWW
COLORADO RIVER
FLOOD DISCHARGE
CHANNEL
CHANNEL
TO CITY OF
MATAGORDA
MATAGORDA COUNTY
MARKHAM
BAY
CITY
FM 457
BLESSING
FM 52
WADSWORTH
FM 521
COLORADO
RIVER
PALACIOS
MATAGORDA
PENINSULA
PROJECT
SITE
MATA-
GORDA
BAY
MATAGORDA
FM 2031
GULF OF MEXICO
FROM RAND-McNALLY DELUXE ED. TEXAS
VICINITY MAP
0 4 8 16 32
SCALE IN MILES
1" = 16 MI.
FM 2031
COLORADO RIVER
PROJECT SITE 5± MI. FROM CITY OF
MATAGORDA, LOCATED AT
95°57'39" W, 28°37'29" N
EAST
MATAGORDA BAY
MATAGORDA
BAY
-3.0
-4.0
-1.0
6400'
4800'
APPROX. 202,800 C.Y.
OF DREDGED MATERIAL TO BE
DISPOSED OF BY JET SPRAY OR EQUAL ON
PREDETERMINED SECTIONS OF
ADJACENT WETLANDS TO RAISE
THEM TO ELEVATIONS WHERE
MARSH VEGETATION CAN BE
RE-ESTABLISHED.
SITE PLAN
PLAN VIEW
0 2000 4000
SCALE IN FEET
APPROX.
TIGER
ISLAND
CHANNEL
DAM
PROPOSED
CHANNEL
PARKING LOT & CULVERT (SEE SHT. 3)
LIMITS OF SPOIL AREA
1000' FROM TOP OF BANK
EACH WAY.
FUTURE MAINTENANCE
SPOIL AREA
-2
FM 2031
SPOIL AREAS
PENINSULA
OF MEXICO
-1
MATAGORDA
GULF
PROPOSED CHANNEL DEVELOPMENT
ON EAST MATAGORDA BAY
APPROX. 5 MI. SOUTH OF
CITY OF MATAGORDA
MATAGORDA COUNTY, TEXAS
10/2/90
SHEET 1 OF 8

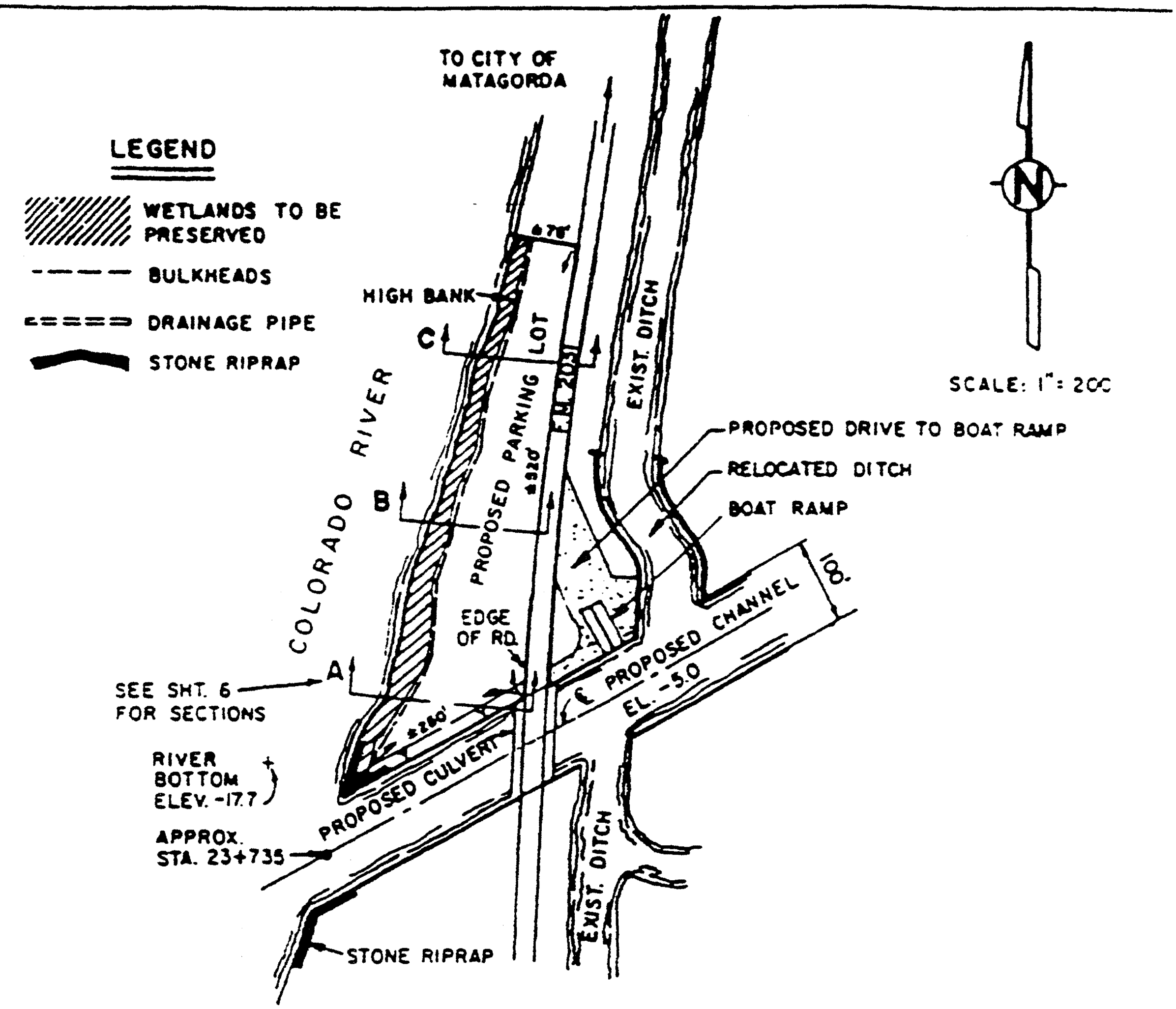


TYPICAL CROSS SECTION

PROPOSED CHANNEL DEVELOPEMENT
ON EAST MATAGORDA BAY

MATAGORDA COUNTY, TEXAS

10/2/90 SHEET 2 OF 8

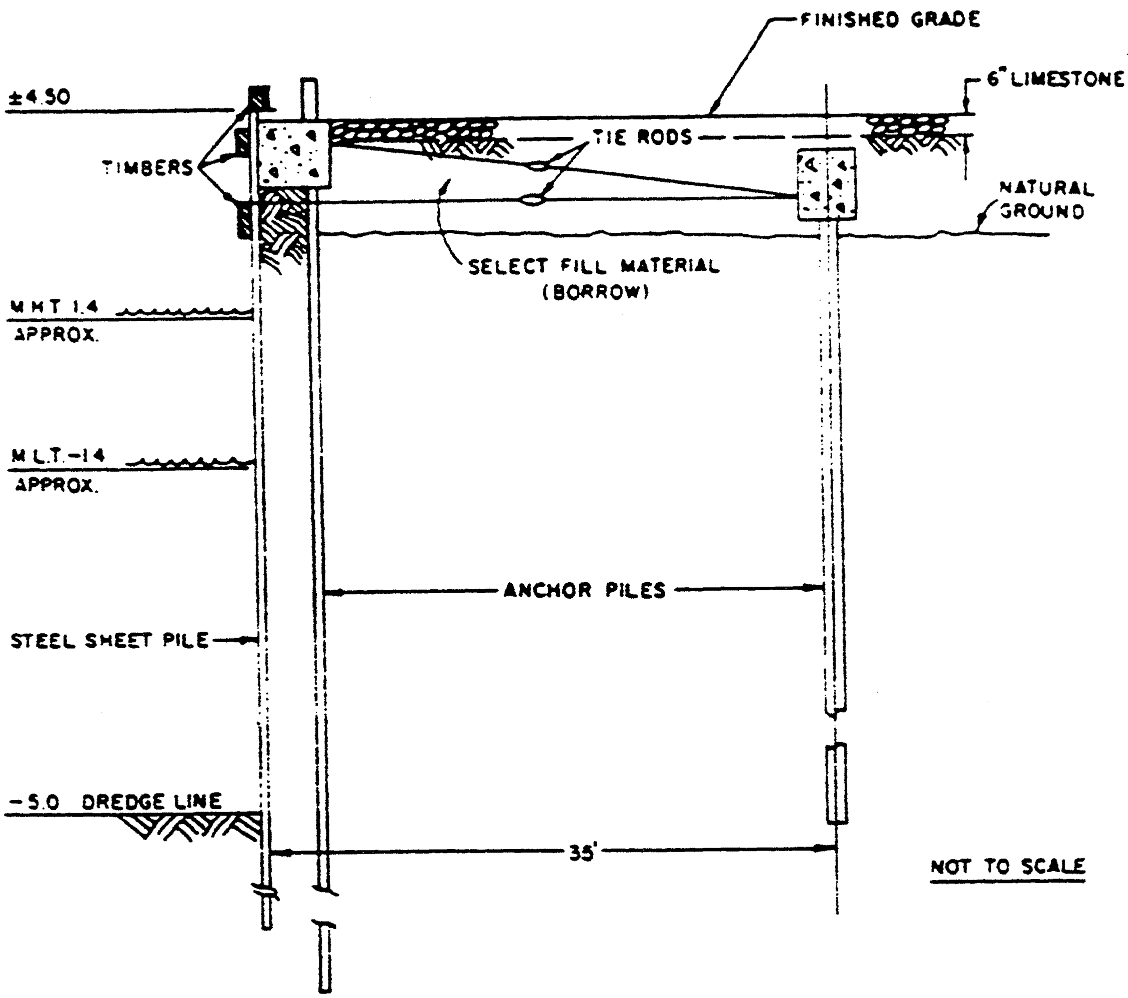


PROPOSED CHANNEL DEVELOPMENT
ON EAST MATAGORDA BAY

MATAGORDA COUNTY, TEXAS

10/2/90 SHEET 3 OF 8

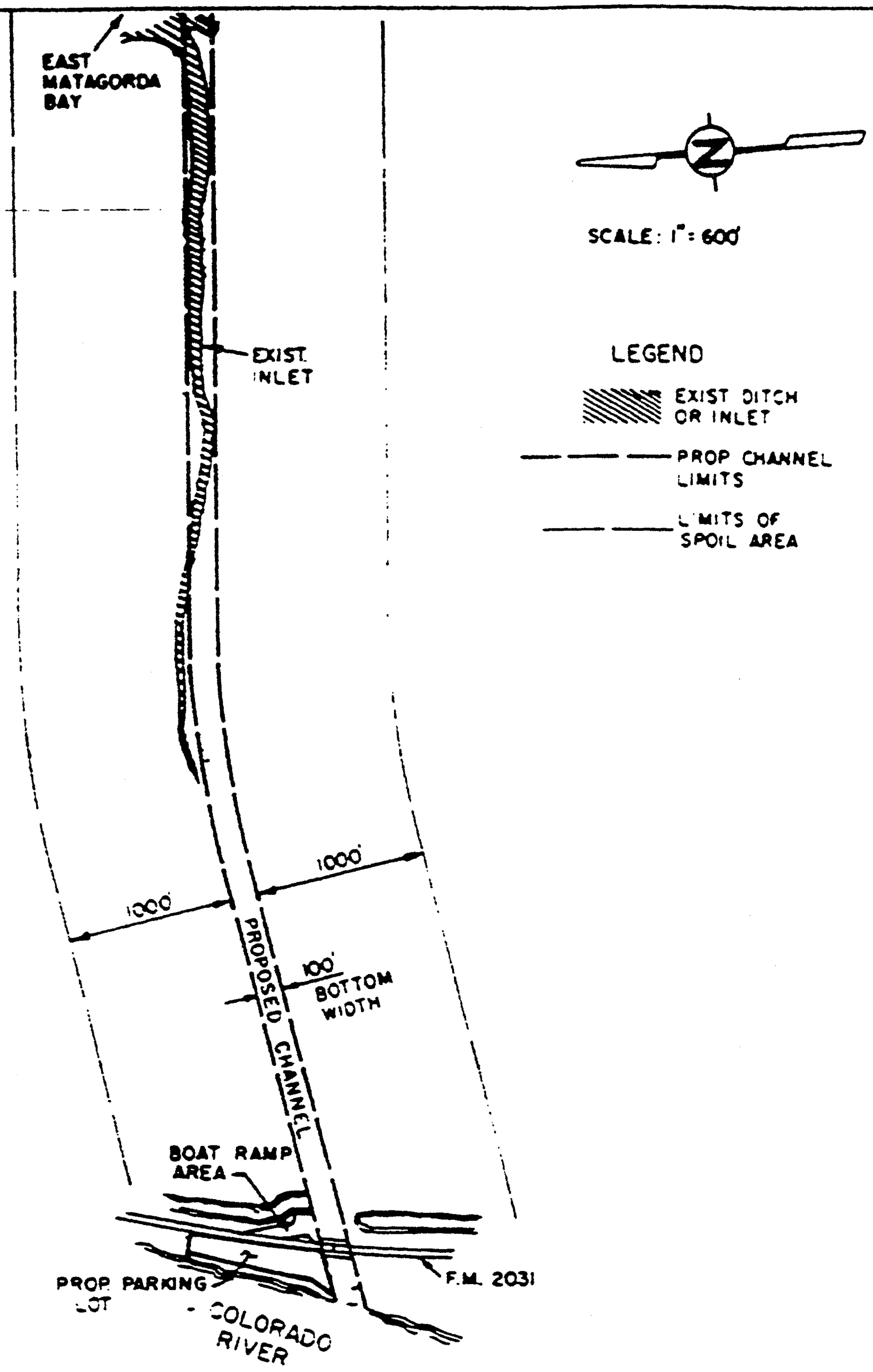
TYPICAL BULKHEAD CROSS SECTION



PROPOSED CHANNEL DEVELOPMENT
ON EAST MATAGORDA BAY

MATAGORDA COUNTY, TEXAS

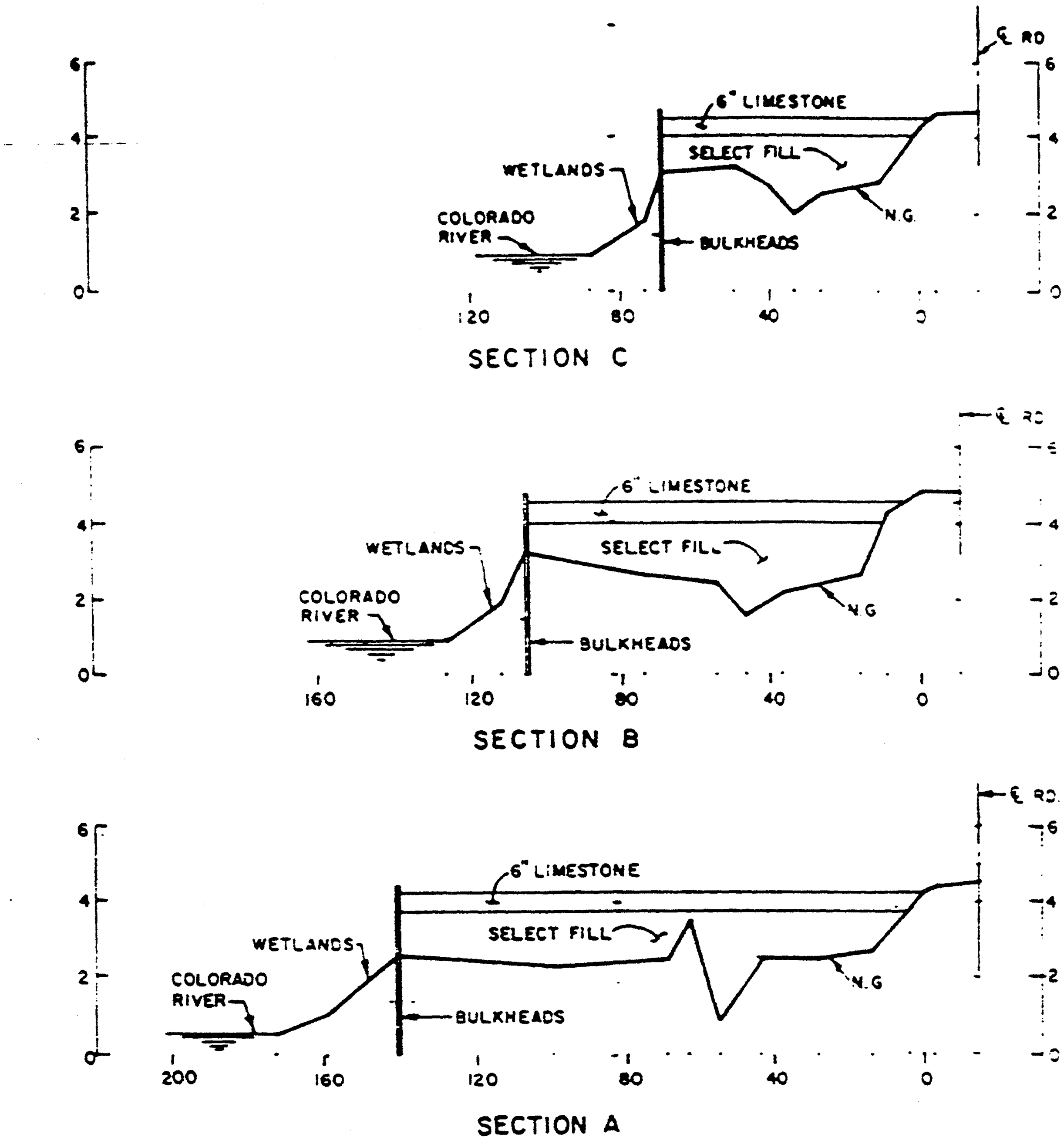
10/2/90 SHEET 4 OF 8



PROPOSED CHANNEL DEVELOPMENT
ON EAST MATAGORDA BAY

MATAGORDA COUNTY, TEXAS

10/2/90 SHEET 5 OF 8

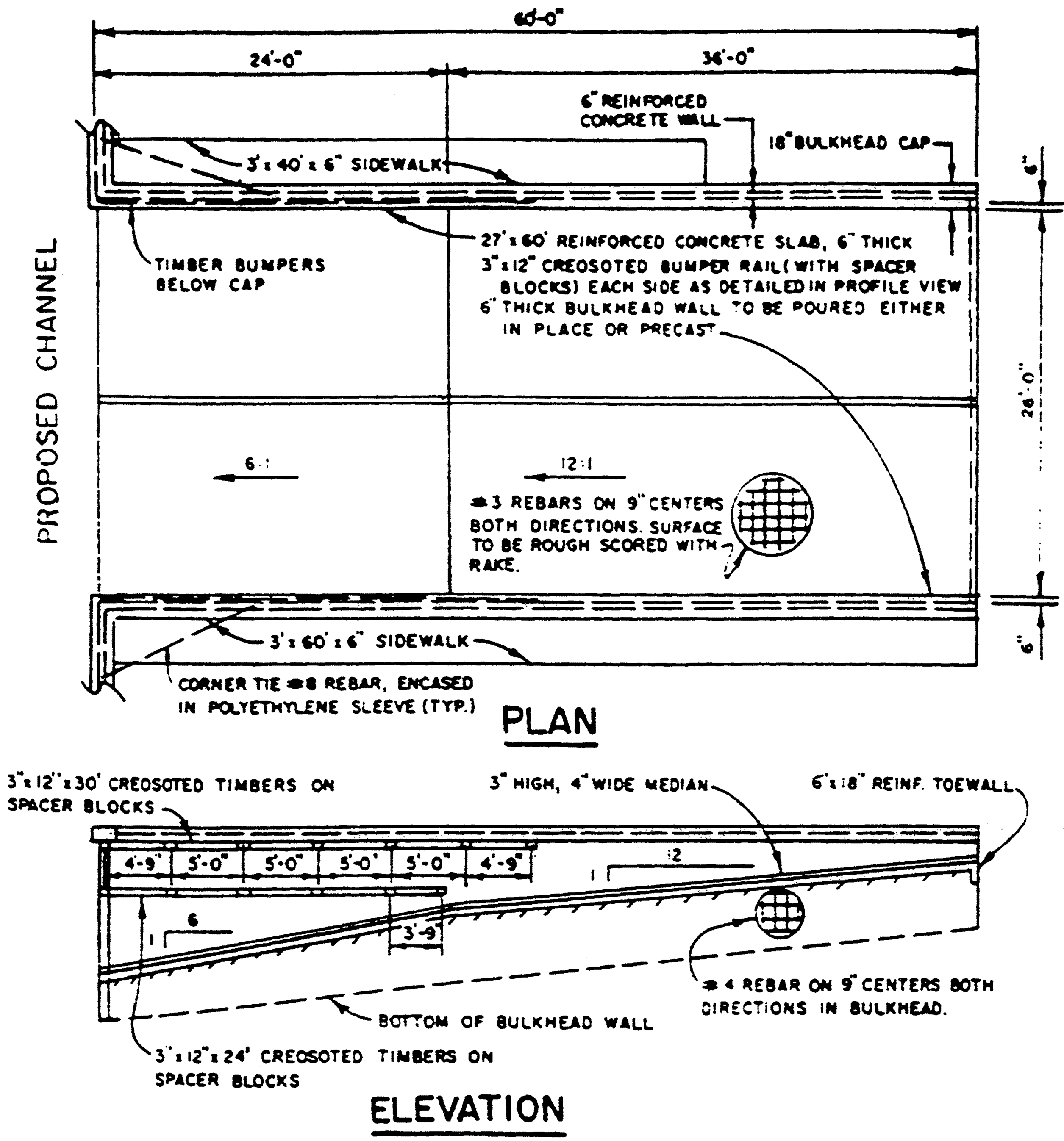


SCALE: HORIZ. 1"=40'
VERT. 1"=4'

PROPOSED CHANNEL DEVELOPMENT
ON EAST MATAGORDA BAY

MATAGORDA COUNTY, TEXAS

10/2/90 SHEET 6 OF 8

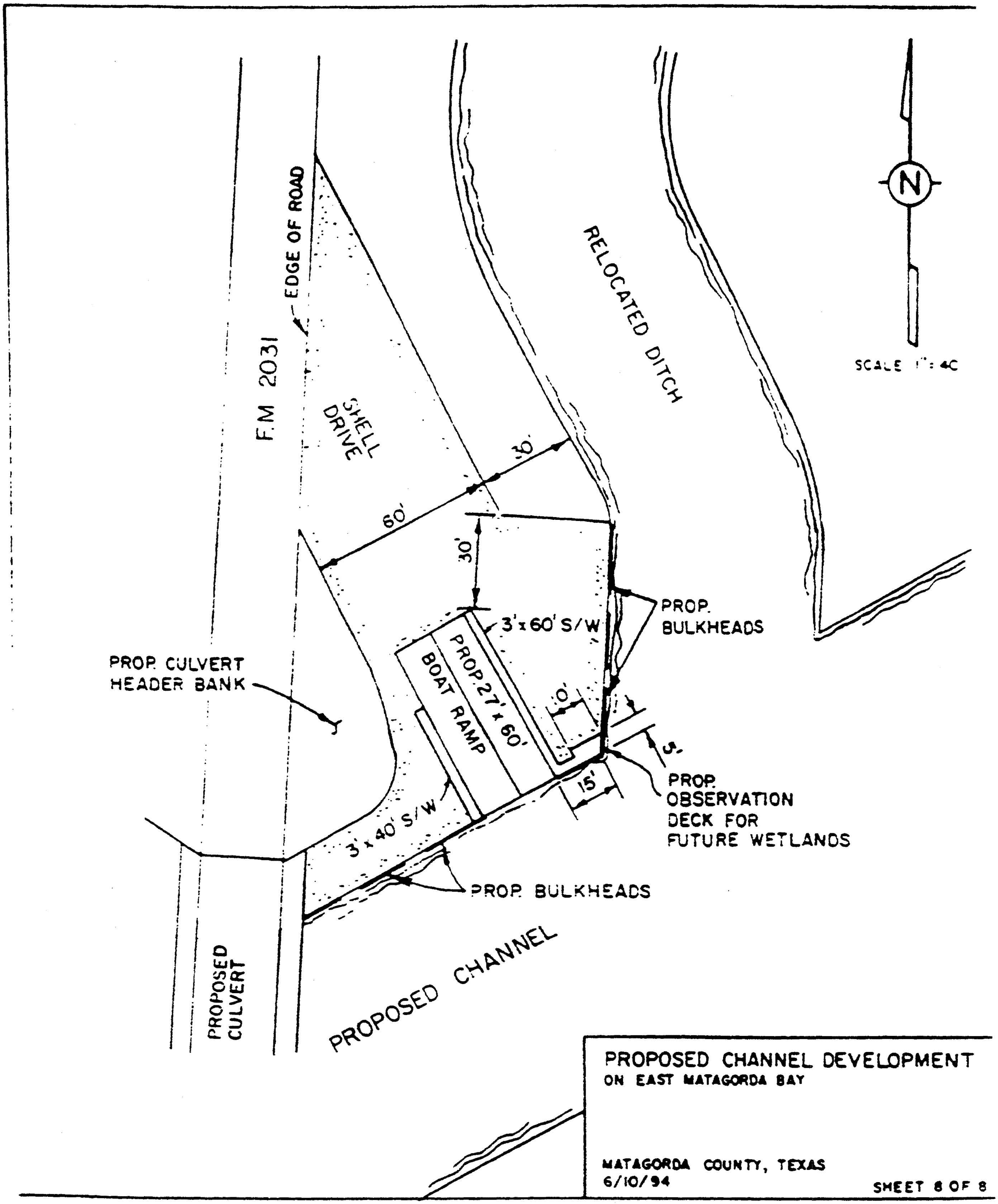


BOAT RAMP PLAN

PROPOSED CHANNEL DEVELOPMENT
ON EAST MATAGORDA BAY

MATAGORDA COUNTY, TEXAS
6/6/94

SHEET 7 OF 8


EDGE OF ROAD
F.M 2031
SHELL DRIVE
RELOCATED DITCH
SCALE 1":40
N
30'
60'
30'
3'x 60' S/W
PROP. BULKHEADS
PROP. CULVERT
HEADER BANK
PROP. 27' x 60'
BOAT RAMP
10'
5'
15'
PROP. OBSERVATION DECK FOR FUTURE WETLANDS
3' x 40' S/W
PROP. BULKHEADS
PROPOSED CULVERT
PROPOSED CHANNEL
PROPOSED CHANNEL DEVELOPMENT
ON EAST MATAGORDA BAY
MATAGORDA COUNTY, TEXAS
6/10/94
SHEET 8 OF 8

Appendix B : Chronology of Field Data-Collection Activities

This appendix contains detailed summaries, mainly in the form of tables, of the field data-collection activities performed in this study over the period August 25, 1995, through March 20, 1996. Sustained hydrodynamic data collection took place over October 10, 1995, to January 26, 1996. An intensive or synoptic survey was conducted by three boats on November 7, 1995, and by two boats on November 8, 1995. Information on equipment servicing, types of parameters measured, locations of measurements, and tabulation of selected measurements are contained in the tables. Figure B1 shows the locations at which measurements were made during the synoptic survey, as well as locations of the sampling stations.

Table B1. Chronology of field data-collection activities.

	1995
Aug 25	SWEMAT platform installed POLE1 installed (28°43.024N, 95°53.206 W) POLE2 installed (28°41.802N, 95°49.826 W)
Aug 26	Installed deck, handrail, fiberglass box, water level gauge, and connected radio to TCOON communication systems
Aug 29	Added self-logging HU to POLE2
Aug 30	Installed ADV, HU, solar panel, and radio antenna on SWEMAT Self-logging HU installed on EMAT platform
Aug 30 - Sep 8	HU failed; data missing
Aug 30 - Sep 8	EMAT water level recorder malfunctioned
Aug 31	Installed self-logging HU at EMAT Removed HU from SWEMAT
Sep 8	Serviced HU at POLE2 Exchanged HU at SWEMAT Serviced ADV at SWEMAT Serviced HU at EMAT
Sep 18	Installed second solar panel and battery on SWEMAT WL gauge Retrieved data from SWEMAT Cleaned HU and ADV Surveyed SWEMAT WL gauge
Sep 19	Serviced instruments at POLE2 and SWEMAT
Sep 28 -29	EMAT Leveled Routine instrument service Replaced WL gauge at SWEMAT (previous unit failed to operate)

Oct 10 - 11	Routine service trip Unable to safely redeploy self-logging HU at POLE2. Repaired WL gauge at SWEMAT platform. Data from this unit now acquired automatically via satellite
Oct 19	Added ADV at EMAT platform. Changed HU from self-recording type to standard field logging type Moved self-logger to POLE1 at the Gulf Cut (2-Mile Cut)
Nov 7 - 8	Synoptic survey of currents and salinity by three boats Routine instrument service
Nov 17	Retrieved data from POLE1 and POLE2 Downloaded ADV data and exchanged HUs at EMAT and SWEMAT Routine instrument service
Nov 28	Retrieved data from POLE1 and POLE2 Downloaded ADV and HUs at EMAT and SWEMAT Routine instrument service
Dec 11	Retrieved data from POLE1 and POLE2 Replaced self-logging HU at POLE2 Replaced data logger and exchanged HU at SWEMAT Retrieved data from SWEMAT Cleaned ADV and exchanged HU at EMAT Restored backup WL gauge to service and repaired temperature sensors at EMAT Retrieved data from EMAT
Dec 21	Removed data logger and exchanged HU at EMAT Downloaded data logger and exchanged HUs at SWEMAT Downloaded HU at POLE1 Downloaded the HU and changed batteries at POLE2
Dec 28	Replaced data logger and lowered the ADV probe pipe six inches at EMAT Exchanged the HU at SWEMAT
	1996
Jan 8	Downloaded data logger and exchanged HU, cleaned ADV at EMAT Lowered HU and ADV at SWEMAT Downloaded HU at POLE1 Downloaded HU at POLE2
Jan 16	Downloaded data logger at SWEMAT
Jan 26	RAM card, two solar panels, HU, ADV, data logger, batteries, and enclosure box were removed from EMAT All instruments removed from SWEMAT, the platform remains in the event of reoccupation. Reflectors were added to ensure boater safety HU was removed from POLE1 HU was removed from POLE2
Feb 23	Installed HU at EMAT and SWEMAT
Mar 8	Serviced, cleaned and downloaded HUs at EMAT and SWEMAT
Mar 20	Removed HUs at EMAT and SWEMAT

Table B2. Data available from September 1, 1995, collected in this study.				
Measured Parameter	**EMAT**	**SWEMAT**	**POLE 1**	**POLE 2**
Water Level	9/1/95 - 3/18/96	9/10/95 - 9/21 10/10 - 1/26/96	- -	- -
Current *u,v*	10/19/95 - 12/17 12/28 - 1/22/96	9/1/95 - 9/10 9/18 - 9/22 9/28 - 1/26/96	- -	- -
Wind Speed	9/1/95 - 3/18/96	- -	--	--
Salinity	10/19/95 - 11/17 11/23 11/28 - 12/17 12/28 - 1/06/96	9/8/95 - 9/12 9/18 - 1/26/96	11/1795 - 1/26/96	9/19/95 - 10/11 11/17 - 1/26/96
Water Temperature	9/1/95 - 3/18/96	9/8/95 - 12/21 12/28 - 1/26/96	11/17/95 - 1/26/96	9/19/95 - 10/11 11/17 - 1/26/96
pH	10/19/95 - 11/17 11/23 11/28 - 12/17 12/28 - 1/8/96	9/8/95 - 10/19 11/17 - 12/21 12/28 - 1/26/96	11/17/95 - 1/26/96	9/19/95 - 10/11 11/17 - 1/26/96
Dissolved Oxygen	11/11/95 - 11/17 11/28 - 12/17 12/28 - 1/08/96	11/17/95 - 1/26/96	11/17/95 - 1/26/96	9/19/95 - 10/11 11/17 - 1/26/96

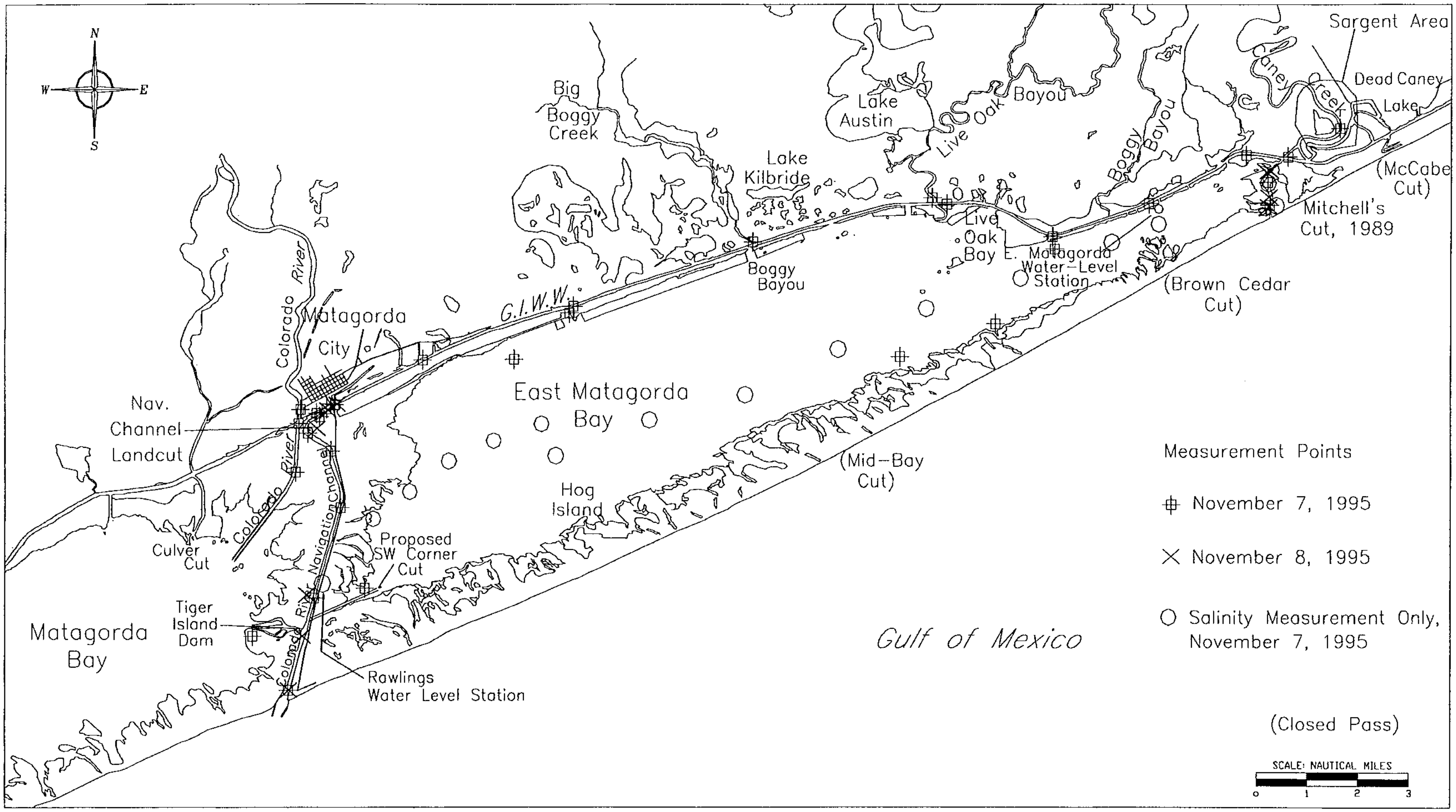


Figure B-1. Location of sampling station for the synoptic survey.

Table B3. East Matagorda Bay intensive survey current meter log, Boat 1.			
November 7, 1995			
Latitude 28° N Longitude 95° W	**General Location**	**Time, GMT**	**Length of Record min**
44.9429, 39.4800	Mouth of Mitchell's Cut	20:44	22
45.3563, 39.5430	Inside Mitchell's Cut, near first fork	21:45	17.6
45.3666, 39.5176	Moved to shallow area on N side inside Mitchell's Cut	22:15	14.4
45.7045, 39.2737	Mouth of Caney Creek	22:32	4.2
November 8, 1995			
44.9342, 39.4713	Mouth of Mitchell's Cut	15:54	4.6
45.1127, 39.4830	Just inside Mitchell's Cut	16:25	20
45.5386, 39.5600	Fork from GIWW to Mitchell's Cut channel	16:59	24
45.5752, 39.5613	GIWW Southwest of Caney Creek	17:34	25.1
45.6839, 39.3000	Inside Caney Creek on GIWW intersection	18:07	22.9
45.7672, 39.2197	In GIWW at crossing of Caney Creek	18:39	18.1
45.0415, 39.4788	Mitchell's Cut and GIWW	19:22	39.0

Table B4. Water-quality measurements made by Blucher Institute, Boat 1.						
Time GMT	Latitude 28° N	Longitude 95° W	Salinity ppt	Temp. C	pH	DO mg/L
November 7, 1995						
15:58	39.1061	57.1953	26.8	15.6	7.88	6.25
16:21	39.6373	56.3839	26.7	15.7	7.87	6.20
16:32	40.1504	55.5899	26.8	15.5	7.94	6.66
16:47	40.5529	54.7146	26.9	15.8	7.96	6.55
17:00	40.8731	53.7859	26.8	16.0	8.01	6.75
17:16	40.2826	53.5014	26.8	16.2	8.04	6.54
17:30	40.9291	51.6411	27.0	16.0	8.08	7.17
17:45	41.4187	49.7432	26.9	16.2	8.05	6.56
17:57	42.2507	47.9547	26.2	16.1	8.05	6.81
18:07	42.9877	46.2003	25.6	16.3	8.06	6.73
18:17	43.5880	44.3534	24.9	17.0	8.04	6.82
18:27	44.2435	42.5684	24.5	18.2	8.08	7.03
18:47	44.6069	41.6271	24.1	18.6	8.07	6.89
20:43	44.9429	39.4800	24.0	19.1	8.06	6.99
21:44	45.3563	39.5430	24.1	19.2	8.05	7.23
November 8, 1995						
15:54	44.9342	39.4713	23.1	17.7	8.03	6.91
16:25	45.1127	39.4830	22.8	17.8	8.03	6.85
16:59	45.5386	39.5600	21.1	18.0	8.01	6.63
17:34	45.5752	39.5613	21.8	18.1	8.02	6.47
18:07	45.6839	39.3000	19.9	18.3	8.01	7.10
18:39	45.7672	39.2197	20.4	18.5	8.00	6.75
19:22	45.0415	39.4788	28.7	19.3	8.10	6.71

Table B5. East Matagorda Bay intensive survey current meter log, Boat 2.			
November 7, 1995			
Latitude 28^{O} N Longitude 95^{O} W	**General Location**	**Time, GMT**	**Length of Record min**
35.9164, 58.8147	CRNC across channel from Marker 4, 4/5 of the way across channel.	16:59	19.4
36.9239, 59.5245	Approximately where proposed cut will be.	17:58	19.6
37.6293, 58.2922	Across channel from Rawlings tide gauge.	18:40	8.5
39.3062, 57.7560	At CRNC 11 & 12 (just down channel from a bend in the river).	19:20	21.2
40.3646, 57.9563	CRNC 13 & 14, positioned at mid-channel	19:55	5.2
40.6973, 58.4199	Channel marker 15 at location where old river channel has been cut off and diverted.	20:21	17.4
41.0035, 58.1841	Near junction of CRNC & GIWW.	20:50	4.8
41:0714, 58.2451	100 ft. downstream of last station, more at mid-channel.	21:16	7.1
41.1412, 58.5682	Between locks, tied up on South side.	22:01	20.9
39.9697, 58.6675	CRNC, N of GIWW.	22:31	17.1
40.8779, 58.6050	CRNC that runs into West Matagorda Bay.	22:56	18.1
41.153, 58.0436W	Confluence of CRNC, GIWW, and between locks	29:00	17.9
November 8, 1995			
35.9163, 58.8039	Mouth of CRNC, anchored in mouth (very constricted due to spits)	15:30	20.4
36.8933, 58.5257	Opposite Parker's Cut	16:03	21.3
37.6618, 58.2858	Opposite Rawling's gauge (current stronger because constricted)	16:29	19.3
40.7733, 58.2420	North of CRNC Channel Markers 15 & 16	17:00	19.4
41.1806, 57.9690	Behind swing bridge.	17:22	6.1
41.1499, 58.0258	Relocated near east bank due to arrival of barge	17:29	11.5
41.2448, 57.8386	East side of Pontoon Bridge	18:58	13.1

Table B6. Water-quality measurements made by the Blucher Institute, Boat 2.						
Time GMT	Latitude 28° N	Longitude 95° W	Salinity ppt	Temp °C	pH	DO mg/L
			November 7, 1995			
17:40	35.9164	58.8147	25.7	15.8	7.90	7.20
18:18	36.9239	59.5245	26.4	16.0	7.95	7.30
18:40	37.6293	58.2922	26.3	16.1	7.98	6.86
19:20	39.3062	57.7560	26.4	16.3	7.97	7.10
19:55	40.3646	57.9563	26.3	16.5	7.97	6.73
20:21	40.6973	58.4199	26.3	16.7	7.98	7.02
20:50	41.0035	58.1841	26.3	16.8	7.99	6.79
21:16	41.0714	58.2451	26.3	16.8	7.98	7.08
21:58	41.1412	58.5682	19.9	16.2	7.92	6.10
22:31	39.9697	58.6675	21.2	15.7	7.93	5.68
22:56	40.8779	58.6050	15.7	17.1	7.95	6.62
29:00	41.1536	58.0436	26.2	17.2	7.99	7.24
			November 8, 1995			
15:30	35.9163	58.8039	25.9	17.5	8.08	6.84
16:03	36.8933	58.5257	26.0	17.5	8.11	6.33
16:28	37.6618	58.2858	26.0	17.6	8.12	6.55
17:00	40.7733	58.2420	26.0	17.2	8.14	6.88
17:23	41.1806	57.9690	26.1	17.2	8.14	6.55
17:53	41.1499	58.0258	26.1	17.2	8.15	6.85
18:58	41.2448	57.8386	25.5	17.2	8.14	6.49

Table B7. Water-quality measurements made by the Texas Parks and Wildlife Department.						
Time GMT	Latitude 28° N	Longitude 95° W	Salinity ppt	Temp °C	pH	DO mg/L
			November 7, 1995			
13:56	41.226	57.871	27.8	15.4	8.04	7.23
14:38	41.235	57.882	27.8	15.4	8.05	7.13
15:00	42.061	56.120	27.8	15.7	8.06	6.70
15:39	42.726	54.304	27.8	15.9	8.07	7.73
16:02	42.927	53.212	27.9	16.1	8.07	7.83
16:37	43.052	53.136	27.4	15.9	8.06	7.72
17:26	44.129	43.678	27.8	16.5	8.10	8.31
17:50	44.253	49.610	22.4	8.7	7.89	7.88
18:28	44.239	49.422	26.9	16.4	8.04	8.21
18:51	44.704	47.720	26.4	16.6	8.06	8.38
19:15	45.073	46.091	10.7	18.1	8.13	9.23
19:27	44.955	45.810	24.9	16.2	8.00	7.90
19:57	44.358	43.722	24.9	17.2	8.03	8.36
20:17	44.975	41.841	26.0	17.9	8.11	8.41
20:30	45.863	39.934	26.1	17.3	8.08	8.07
20:51	46.367	38.091	8.8	20.0	8.22	10.00
21:30	43.594	43.593	25.4	19.1	8.12	8.37
21:49	42.731	44.842	26.5	18.8	8.14	8.50
22:04	42.120	46.711	27.2	17.6	8.15	9.03
22:19	41.523	48.500	27.8	17.6	8.15	8.65
22:30	40.560	50.183	28.5	18.9	8.12	8.70
22:40	39.781	51.921	28.3	17.8	8.14	8.73
22:55	38.841	53.592	28.2	18.7	8.15	8.64
23:07	38.265	55.424	28.1	18.9	8.22	8.30

Table B7. Water-quality measurements made by the Texas Parks and Wildlife Department.						
Time GMT	Latitude 28° N	Longitude 95° W	Salinity ppt	Temp °C	pH	DO mg/L
23:18	37.728	57.324	28.3	18.7	8.17	9.22
November 8, 1995						
14:09	41.699	55.959	27.8	16.6	8.11	7.43
14:24	42.239	54.057	28.0	16.2	8.08	7.67
15:38	45.051	40.268	25.6	17.2	8.16	7.74
15:52	44.982	40.711	25.7	17.2	8.14	7.45
16:32	45.902	39.084	10.8	18.4	7.95	7.19
16:38	45.685	39.334	21.8	17.7	8.08	7.69
16:56	44.435	42.475	24.8	18.4	8.20	7.67
17:08	43.933	44.310	26.0	17.4	8.14	7.40
17:20	44.471	46.466	24.1	17.2	8.12	8.10
17:31	44.154	48.566	28.0	17.0	8.17	8.08
17:41	43.585	50.450	27.8	17.7	8.16	7.85

Table B8. Texas Parks and Wildlife Department, current meter survey, November 7, 1995.

Time, GMT	Latitude 28° N Longitude 95°W	General Location	Direction in Deg	Depth, ft	Current cm/s
13:56	41.226 57.871	GIWW near diversion	45	18 11.5 5	61.5 62.5 67.9
14:38	41.235 57.882	GIWW	45	12 7.5 3	43.3 50.6 52.7
15:00	42.061 56.12	GIWW east of diversion	45	13 8.5 3.4	45.1 46.3 45.7
15:39	42.726 54.304	In bay on north side	60	13 8.5 3.4	44.8 51.2 58.2
16:02	42.927 53.212	Inside Gulf Cut	180	8 5 2	35.7 39.6 44.8
16:37	43.052 53.136	Near Gulf Cut	60	13 8 3.2	32.3 39.3 40.5
17:26	44.129 43.678	GIWW	180	5 3 1	28.3 22.5 21.9
17:50	44.253, 49.610	GIWW just inside from Boggy Creek	300	2	37.5
19:15	45.073, 46.091	Live Oak Bayou	300	2	18.6
19:27	44.955 45.81	In GIWW at Live Oak Bayou	270	13 8.5 3.4	3.0 4.3 6.1
19:57	44.358 43.722	At bend in GIWW, west of EMAT gauge	300	13 8.5 3.4	4.6 5.2 14.0
20:17	44.975 41.841	West of Brown Cedar Cut	270	13 8.5 3.4	17.7 20.7 25.6
20:30	45.863 39.934	In GIWW, near EMAT gauge	290	13 8 3.2	36.3 35.4 39.6
20:51	46.367 38.091	In cut between GIWW and Bay near EMAT gauge	360	5.6 3.5 1.4	2.1 12.2 10.1
21:49	42.731, 44.842	Near southeast shore, south of Live Oak Bayou	120	1	0.3
22:04	42.120, 46.711	Southeast shore near old Mid-Bay Cut	270	2	6.1

Table B9. Intensive current meter survey, Blucher Institute, Boat 1.

Filename	Location	Duration min	N-S / SD cm/s	E-W / SD cm/s
November 7, 1995				
31115	Mitchell's Cut	22.0	49.6 / 6.7	2.9 / 3.6
31117a	Inside Mitchell's Cut, near first fork	17.6	18.1 / 59.3	6.2 / 34.2
31117b	moved to shallow area on North side	14.4	30.8 / 4.5	3.2 / 3.3
31117c	at mouth of Caney Creek	4.2	-6.5 / 5.9	13.7 / 4.6
31118	same location as last station	7.6	3.0 / 3.4	-5.8 / 5.1
November 8, 1995				
31210	Entrance of Mitchell's Cut (current meter rotated so we used only 4.6 minutes)	4.6	-38.4 / 8.5	-25.1 / 8.0
31211a	same location as last station	15.0		
31211b	just inside entrance of Mitchell's Cut (just down stream from what might be a source of flow)	20.0	-15.4 / 6.5	-3.0 / 4.7
31211c	fork from GIWW to Mitchell's Cut channel	23.9	19.2 / 8.7	9.3 / 9.2
31212a	same location as last station	25.1		
31212b	GIWW Southwest of Caney Creek	25.1	-3.0 / 11.8	2.0 / 7.8
31213a	Inside Caney Creek on GIWW intersection	22.9	11.1 / 13.7	-23.1 / 11.8
31213b	In GIWW at crossing of Caney Creek	18.1	-3.7 / 4.3	33.6 / 5.7
31214	Mitchell's Cut, tide has turned, now flooding strong current flowing into Caney Creek	39.0	110.6 / 17.1	-4.8 / 7.3
31215	same location as last station	36.0		

In Table B10, the symbol "SD" denotes the standard deviation in the current over the period of record. The values in the fourth and fifth columns of the table give the mean and standard deviation for the N-S and the E-W components of the current, respectively.

Table B10. Intensive current meter survey, Blucher Institute, Boat 2.

File Name	General Location	Duration min	N-S / SD cm/s	E-W / SD cm/s
	November 7, 1995			
E31112	CRNC mouth across channel from Marker 4	19.4	-80.0 / 5.6	-6.7 / 3.7
E31113a	same location	13.2		
E31113b	approximately where proposed cut will be	19.6	-42.7 / 4.1	-2.1 / 3.3
E31113c	anchored in middle of channel	12.5	-36.2 / 4.1	2.9 / 3.9
E31114a	across channel from Rawling's tide gauge, boat swinging around slowly, adjusted current meter orientation	8.5	-38.2 / 3.6	-2.4 / 2.7
E31114b	arrive at channel markers 11 and 12 (just down channel from a bend in the river)	21.2	-43.7 / 6.7	-10.9 / 3.4
E31114c	arrive at channel markers 13 and 14, positioned at mid-channel	5.2	-36.3 / 8.0	-19.9 / 4.5
E31115a	same location	13.0		
E31115b	channel marker 15 in CRNC	17.4	-32.0 / 6.0	-7.9 / 3.9
E31115c	near junction of CRNC and GIWW (wind is moving boat)	4.8	-25.2 / 5.7	12.4 / 3.6
E31115d	100 ft. downstream of last station, more at mid-channel	7.1	-26.3 / 5.0	15.3 / 3.3
E31116a	same location as last station	9.2		
E31116b	between locks, tied up on the South side	20.9	-5.2 / 18.3	1.9 / 20.2
E31117a	CRNC, North of GIWW	17.1	-34.0 / 6.7	-2.0 / 2.9
E31117b	CRNC channel that runs into West Matagorda Bay	18.1	-19.1 / 4.2	2.4 / 2.6
E31117c	Confluence of CRNC, GIWW and between locks	3.2	-3.3 / 8.8	-1.5 / 8.0
E31118a	same location as last station	14.7		
E31118b	at location between lock and CRNC and Gate	6.8	-44.2 / 7.1	6.6 / 3.6
	November 8, 1995			
E31210	CRNC, anchored in mouth (very constricted due to spits)	20.4	-86.7 / 6.8	2.2 / 2.8

Table B10. Intensive current meter survey, Blucher Institute, Boat 2.				
File Name	**General Location**	**Duration min**	**N-S / SD cm/s**	**E-W / SD cm/s**
E31211a	Parker's Cut	21.3	-46.4 / 6.1	6.6 / 8.2
E31211b	opposite Rawling's bait stand (stronger current because restricted)	19.3	-55.3 / 7.4	9.3 / 4.1
E31212a	bend above Channel Markers 15 and 16	19.4	-67.7 / 7.6	8.6 / 4.1
E31212b	behind swing bridge (had to relocate because of barges)	6.1	-22.5 / 10.1	33.4 / 9.7

Appendix C : Historic Salinity Regime For East Matagorda Bay, Texas (1983 - 1995)[1]

Abstract

The Blucher Institute for Surveying and Science at Texas A&M University-Corpus Christi is conducting a hydraulic feasibility analysis to determine the stability of the proposed pass and to predict possible physical changes in East Matagorda Bay resulting from installation of the pass. Although not directly part of the hydraulic feasibility analysis, understanding the historical salinity regime in East Matagorda Bay is central to evaluating environmental changes should the water exchange pass be installed. The purpose of this appendix is to document the existing condition of East Matagorda Bay by assessing the historical salinity regime from 1983 to the present. In East Matagorda Bay, the overall average salinity from 1983 to 1995 was found to be 21.3 ppt (SE = 0.09 ppt) based on 6,827 observations. There is a long-term seasonal trend of higher salinities in late summer through fall (August - November) averaging 23.4 ppt, and lower salinities from late winter through spring (February - July), averaging 19.8 ppt. The seasonal fluctuation in salinity is undoubtedly tied to seasonal patterns in freshwater inflows. The Texas Department of Health data from 1983 to 1995 ranged from 0.5 to 33.9 ppt and averaged 16.8 ppt (SE = 0.23 ppt) based on 732 observations. The Texas Parks and Wildlife Department data ranged from 0 to 40 ppt and averaged 21.8 ppt (SE = 0.09 ppt) based on 6,046 observations. The Lower Colorado River Authority (LCRA) salinity data ranged from 7 to 28.8 ppt and averaged 18.8 ppt (SE = 0.61 ppt) based on 49 observations. A poor correlation observed between daily rainfall and salinity may reflect the inadequacy of inland monitoring sites for portraying actual direct precipitation on the bay. A salinity gradient greater than 5 ppt in the long axis of East Matagorda Bay was observed 18.5 % of the sampling days, and a gradient greater then 10 ppt occurred only three times. Although tidal influence from Mitchell's Cut seems to be evident in the LCRA data, comparison of all salinity values collected throughout the bay pre- and post- pass opening, after accounting for differences in rainfall, revealed no significant difference.

[1] Written by Beau Hardegree, Center for Coastal Studies, Texas A&M University-Corpus Christi.

Introduction

Matagorda County, Texas, has proposed installation of a water exchange pass between East Matagorda Bay and the Colorado River Navigation Channel. The location of the proposed cut is in the southwest corner of East Matagorda Bay and approximately 3.2 km upstream from the Gulf of Mexico in the Colorado River Channel. The Blucher Institute for Surveying and Science at Texas A&M University-Corpus Christi is conducting a hydraulic feasibility analysis to determine the stability of the proposed pass and to predict possible physical changes in East Matagorda Bay resulting from installation of the proposed pass. Although not directly part of the hydraulic feasibility analysis, understanding the historical salinity regime in East Matagorda Bay is central to evaluating environmental changes should the water exchange pass be installed.

The triple role of salinity as a water-quality indicator, as well as a hydrodynamic and ecological parameter, make it one of the most significant hydrologic variables to be considered in an estuarine system (Ward et al. 1980). Correlations between species diversity and salinity have been made by many authors (e.g., Gunter 1967, Copeland 1967, Copeland and Jones 1963, Copeland and Bechtel 1974, Parker 1959). Parker (1959) found fewer invertebrate species present but in high abundance when estuaries were either consistently hypersaline or had very low salinity waters. As salinities approach normal Gulf of Mexico values (35 ppt), the number of species increases, and the number of individuals decreases (Parker 1959). Many commercially harvested estuarine and oceanic species have larval stages which require specific salinity regimes for survival; therefore, study of changes in salinity before and after the proposed "Southwest Corner Cut" will aid in evaluating the effectiveness of the pass in terms of increases or decreases in production.

Salinity within a bay system is controlled by many factors; direct precipitation on the bay, sheet flow runoff from adjacent upland areas, freshwater input from rivers and creeks, evapotranspiration from the bay, intrusion from fresh ground water, and direct tidal exchange with Gulf waters. Unfortunately, only two of these (direct precipitation, and freshwater input from rivers and creeks) can be accurately and easily measured. This problem is compounded in East Matagorda Bay because none of the freshwater inflows has been gauged with sufficient regularity to be used in predictive modeling of salinity.

Only a limited number of technical reports were found which discuss salinity in the Matagorda Bay system (McGowen et al. 1976, Texas Department of Water Resources 1980, Ward and Armstrong 1980, Ward et al. 1982, Wiersema et al. 1982, Mueller and Matthews 1987, White et al. 1988, Boyd et al. 1995). For the most part, these reports with the exception of Ward and Armstrong (1980) do not present information on East Matagorda Bay. Only one paper was found which specifically addressed salinity in East Matagorda Bay (Kimura 1993). In a Policy Research project class report (University of Texas at Austin), Kimura developed a predictive salinity model for East Matagorda Bay based on precipitation and Colorado River flow data. Kimura's model used running 7-day precipitation totals to correlate with salinity.

The purpose of this appendix is to document the existing condition of East Matagorda Bay by assessing the historical salinity regime from 1983 to the present; to determine what correlation exists between local precipitation and salinity in East Matagorda Bay; to determine if a salinity gradient regularly occurs in East Matagorda Bay; and to determine if the opening of Mitchell's Cut in May, 1987, produced detectable changes in the salinity of East Matagorda Bay.

Study Area

East Matagorda Bay, located in Matagorda County on the mid-Texas coast (Figure C1), has a surface area of 140 km^2 and a volume of approximately 1.5 x 10^8 m^3 (Ward and Armstrong 1980). Matagorda County is subhumid (Thornthwaite, 1948) receiving an average of 103 cm of precipitation annually (McGowen et al. 1976). Temperatures in the area average between 8°C and 9°C for winter minimums to near 32°C for summer maximums (White et al. 1988). Two principal wind regimes dominate the East Matagorda Bay area - persistent, southeasterly winds from March through November and short lived but strong northerly winds from December through February (McGowen et al. 1976). Ward and Armstrong (1980) report salinity in East Matagorda Bay averaging between 15 and 17.4 ppt on measurements dating back to 1958; unfortunately, the number of measurements, as well as the temporal and spatial distribution of this data were not indicated.

East Matagorda Bay was effectively isolated from the rest of Matagorda Bay between 1929 and 1941 after removal of more than an 80-km long log jam in the Colorado River released large amounts of sediment, greatly accelerating river delta formation (Ward and Armstrong, 1980). The river delta rapidly prograded across Matagorda Bay and ultimately emptied directly into the Gulf of Mexico. Recently, the Colorado River was diverted back into Matagorda Bay. A series of locks installed on the Gulf Intracoastal Waterway (GIWW) for all practical purposes eliminates connection of the Colorado River with East Matagorda Bay. East Matagorda Bay now receives freshwater input only from Caney Creek at the extreme northeastern end of the bay, and, following local rainfall events, from several small stream courses (Big Boggy Creek, Live Oak Bayou, and Boggy Bayou).

Tidal exchange in East Matagorda Bay historically has been restricted to storm washover passes along Matagorda Peninsula. The most permanent of these passes was Brown Cedar Cut located in the northeastern end of East Matagorda Bay. The permanence of this cut was a result of the isolation of East Matagorda Bay by the Colorado River Delta; consequently, Brown Cedar Cut carried a tidal prism (Ward and Armstrong 1980). Brown Cedar Cut shoaled to closure in

September, 1977, and was briefly reopened in July, 1979, by floodwaters (Ward and Armstrong 1980). To afford relief from flood waters attributed to Caney Creek, McCabe Cut was constructed in 1983. McCabe Cut was located east of East Matagorda Bay near the pontoon swing bridge across the GIWW on FM 457 (U.S. Army Corps of Engineers 1987). Because natural processes widened and deepened McCabe Cut, it became a hazard to navigation in the GIWW. McCabe Cut was closed in May, 1987. Also in May 1987, Mitchell's Cut was opened to restore relief from Caney Creek flood waters (U.S. Army Corps of Engineers 1992). Mitchell's Cut is located in the northeastern corner of East Matagorda Bay and presently represents the only direct connection with the Gulf of Mexico.

Methods

Salinity data, together with sample site location (latitude and longitude), for East Matagorda Bay were obtained from the following four agencies: Texas Parks and Wildlife (TPWD), Texas Department of Health (TDH), Texas Water Development Board (TWDB), and the Lower Colorado River Authority (LCRA). Daily precipitation totals for the time period 1972 through 1992 were obtained from the Texas Natural Resources Information System (TNRIS) for two stations in Matagorda County, Texas; one at each of the towns of Bay City and Matagorda. Monthly rainfall totals were obtained from 14 stations east of the Colorado River in Matagorda County, Texas, from the Matagorda County Soil and Water Conservation District (MCSWCD) for the time period of 1991 through September, 1995. All salinity data obtained from resource agencies (TPWD, TDH, and TWDB) were combined prior to calculations of daily, monthly, and annual means with standard errors (salinity in parts per thousand = ppt; mean salinity = $\bar{y}$; and standard error of mean = SE, defined as the standard deviation divided by the square root of the number of samples).

To determine the extent of correlation between local precipitation and salinity, Pearson correlation coefficients were calculated for daily rainfall totals and daily average salinity, monthly rainfall totals and average monthly salinity, and annual rainfall totals with average annual salinities. To determine the optimum amount of prior rainfall data necessary to produce the highest possible correlation, running totals were calculated for time periods of 7, 14, 30, 60, 90, 180, 365, 550, 730, 1095, and 1460 days and then correlated with salinity on a given day.

To determine the extent and stability of a salinity gradient in East Matagorda Bay, TDH and LCRA salinity data were used because their stations were fixed and sampled over time. Four TDH stations (3, 5, 8, and 10) and three LCRA stations (1, 2, and 3) were chosen because of their central location in the bay relative to its long axis (Figure C2). For each sampling day, the mean and range of salinity were calculated for the four stations. The data were examined for gradient trends if ranges exhibiting greater than 5 ppt were observed. The criterion for gradient determination was a linear relationship ($R^2 > 0.6$) between salinity and site position in the bay, which resulted in progressively increasing or decreasing salinity.

To determine if opening Mitchell's Cut in May, 1989, produced detectable changes in salinity in East Matagorda Bay the data were first divided into pre- and post-pass opening observations. To account for possible differences in salinity due to differences in rainfall occurring pre- and post-pass opening, a Factorial ANOVA with rainfall as a covariate in the model was used for analyses. Although autocorrelation in salinity data is inherent, that is, the observed salinity on a given day is somewhat dependent on what it was during previous days, it was not accounted for in the model. Because the TPWD employs a stratified sampling protocol with the intent of collecting samples uniformly throughout the bay, the same amount of autocorrelation should be assignable to both the pre- and post-Mitchell's Cut Data; therefore, autocorrelation was disregarded.

Results and Discussion

General

Examination of the salinity data revealed at least one salinity measurement was recorded each month from January 1983, to April 1995; therefore, this time period was treated in all subsequent analyses. The TDH and TPWD were the only agencies to systematically collect data throughout this time period. The LCRA collected monthly salinity data from November, 1992, through April, 1993, and June, August, and October 1993, as well as January, March, May, June, August, and December 1994. These three data sets (TDH, TPWD, and LCRA) were combined and assessed to calculate daily, monthly, and annual salinity averages. The TDH sampled primarily from January through April and in November (Figure C3). The TDH data from 1983 to 1995 ranged from 0.5 to 33.9 ppt and averaged 16.8 ppt (SE = 0.23 ppt) based on 732 observations (Figure C4). The TPWD sampled in all months (Figure C3). The TPWD data ranged from 0 to 40 ppt and averaged 21.8 ppt (SE = 0.09 ppt) based on 6,046 observations (Figure C5). The LCRA salinity data ranged from 7 to 28.8 ppt and averaged 18.8 ppt (SE = 0.61 ppt) based on 49 observations (Figure C6). Although a 5 ppt difference in the average salinity exists between the TDH and TPWD data, this difference is probably an artifact of differences in sampling seasons. The TDH sampled primarily in the winter and spring, whereas the TPWD sampled year round. Comparing daily average salinities between TDH and TPWD data on sampling days common to both agencies using a paired samples t-test revealed no significant ($P = 0.489$) differences in salinity (TDH - $\bar{y}$ = 15.7 ppt, SE = 1.2 ppt, TPWD - $\bar{y}$ = 16.4 ppt, SE = 1.5 ppt on 19 paired observations).

In East Matagorda Bay, the overall average salinity from 1983 to 1995 was 21.3 ppt (SE = 0.09 ppt) based on 6,827 observations that are nearly equally distributed over all months (Figure C3). Average salinities were lowest from February through July averaging 19.8 ppt and highest August through November averaging 23.4 ppt (Figure C7).

Correlation with Precipitation

Comparisons on days when measurable rainfall occurred revealed little correlation between salinity and precipitation (Pearson Correlation = - 0.09). The correlation was only slightly better on days when measurable rainfall was 2.54 cm or greater (Pearson Correlation = -2.57). Although large amounts of precipitation (> 25.4 cm/month) have a noticeable impact on salinity (Figure C8), in general, average monthly salinity and total monthly rainfall were also poorly correlated (Pearson Correlation = -0.249). A much stronger correlation between salinity and precipitation (Pearson Correlation = -0.716) was found by comparing annual rainfall totals with average annual salinity (Figure C9). The poor correlation between daily rainfall and salinity is not surprising considering salinity on a given day is a result, not only of rainfall on that day, but also of the amount of precipitation which had occurred for some time previous to making the salinity measurement. By using a series of progressively longer running totals beginning at 7 days and ending at 4 years and comparing correlation coefficients, it was apparent that salinity had its strongest negative correlation with rainfall using approximately 365 days of prior precipitation data (Figure C10), suggesting annual rainfall cycles would be better predictors of salinity in East Matagorda Bay than shorter time intervals. It is unfortunate that none of the streams delivering freshwater to East Matagorda Bay have been gauged. Daily inflow rates from gauged systems have been shown to be good predictors of salinity in other bay systems (Texas Department of Water Resources 1980).

Salinity Gradient Determination

The TDH sampled 81 days from January 1983, through March, 1995. For the most part, sampling by the TDH occurred in the months of January through April and in November. A salinity gradient (> 5 ppt) in the long axis of East Matagorda Bay was observed 18.5 % of the sampling days, and a gradient greater than 10 ppt occurred only three times. Salinity typically decreased at stations moving from southwest to northeast along observed gradients in East Matagorda Bay. On three occasions (April 9, 1984; February 10, 1987; and April 7, 1987) the salinity gradient was observed to run in the opposite direction (Table C1). Three of six salinity gradients greater than 5 ppt observed prior to May, 1989 (the date which Mitchell's Cut was established) decreased from northeast to southwest along East Matagorda Bay. Prior to May, 1989, when salinity was greater than 24 ppt, the observed salinity gradients decreased from southwest to northeast, but when salinity was less than 20 ppt the opposite was true. After May, 1989, all salinity gradients were observed to decrease from southwest to northeast.

The opening of McCabe Cut in 1983 probably resulted in most of the freshwater entering East Matagorda Bay via stream runoff to be carried through the GIWW and out into the Gulf of Mexico. With the closure of McCabe Cut between the GIWW and the Gulf of Mexico, and subsequent opening of Mitchell's Cut between East Matagorda Bay and the Gulf of Mexico in May 1989, freshwater from stream runoff more easily flowed across East Matagorda Bay and out Mitchell's Cut. Most of the possible freshwater inputs from stream discharges into East Matagorda Bay are located between Old Gulf Cut and Caney Creek along the northeastern shoreline; therefore, the influence of Mitchell's Cut on stream runoff causes any gradient in salinity to decrease from southwest to northeast.

The construction of a diversion dam in 1993 forced the Colorado River to empty into Matagorda Bay. This diversion dam also eliminated any prior overbank connection of the Colorado River with East Matagorda Bay during flood events. The reversals of salinity gradients observed prior to 1989 were probably a direct result of flood water entering the East Matagorda Bay from the Colorado River. In dry periods prior to 1989, the more typical salinity gradient decreasing southwest to northeast developed.

The tidal effect of Mitchell's Cut was evident in the LCRA data. Because LCRA Station 3 was closest to Mitchell's Cut, occasionally (3 out of 15 observation days), salinity was greater than 5 ppt higher than observations at Stations 1 and 2. Two of these three times, when salinity was greater than 5 ppt higher at Station 3, the similarity in salinity between LCRA Stations 1 and 2 eliminated these data from consideration of a true salinity gradient, and thus probably indicates tidal influence from Mitchell's Cut (Table C2). One of these three observations (March 17, 1993) might be considered a salinity gradient with increasing salinity moving from southwest to northeast along the bay. Because no evidence of this increasing gradient was observed in the TDH data from March 31, 1993, (approximately two weeks after the LCRA observation), and salinities at TDH stations were comparable to LCRA Stations 1 and 2 (< 15 ppt), the higher salinity observed at LCRA Station 3 (20.1 ppt) may be more evidence of tidal influence from Mitchell's Cut.

Effect of Mitchell's Cut on Salinity

Although possible tidal influence from Mitchell's Cut seems to be evident in the LCRA data, comparing all salinity values collected throughout the bay pre- and post- pass opening, after accounting for differences in rainfall, revealed no significant difference ($P = 0.281$, adjusted for rainfall pre-pass average salinity = 19.7 ppt, post-pass average salinity = 20.7 ppt). Even after limiting the data to those observations east of Latitude 95° 44', no significant difference in long-term average salinities could be detected (P = 0.920, adjusted for rainfall pre-pass averages salinity = 20.8 ppt, post- pass average salinity = 20.7 ppt). More evidence of a lack of significant long-term effect on salinity of East Matagorda Bay as a result of opening Mitchell's Cut is given by a homogeneity of variance test between pre- and post-pass construction (Bartlett - Box , P = 0.319) indicating that variation in salinity was equal over the two time periods.

Conclusion

Salinity in East Matagorda Bay is controlled by many factors; unfortunately, only rainfall data were available for inclusion in analyses of a data set ranging from 1983 to 1995. To compound this problem, the rainfall data were not collected in the bay but from various inland sites in Matagorda County, Texas (two sites prior to 1992, and fourteen sites from 1992 - 1995); therefore, these data sets may not accurately portray direct precipitation on the bay. The poor correlation observed between daily rainfall and salinity may reflect the inadequacy of inland monitoring sites for portraying actual direct precipitation on the bay. Large amounts of precipitation (> 10 inches) has an obvious impact, resulting in rapidly reduced salinities. Salinity can also be reduced substantially following several months with total monthly rainfall greater than 5 inches, as observed following December, 1991, to February, 1992 (Figure C8). McGowen et al. (1976) report average potential evapotranspiration in the East Matagorda Bay area as approximately zero. Because there is a lack of continuous riverine input of freshwater, the moderate overall average salinity of 21.3 ppt observed in East Matagorda Bay is probably indicative of an area where evaporation is nearly equal to precipitation.

There is a long-term seasonal trend in salinity resulting in higher salinities in late summer through fall (August - November) and lower salinities from late winter through spring (February - July). This seasonal trend was also observed by White et al. (1988) in Tres Palacious and Matagorda Bays. The seasonal fluctuation in salinity is undoubtedly tied to seasonal patterns in freshwater inflows. Orlando et al. (1991) defined April through June as a high flow period resulting in lower salinities and August through November as a low flow period associated with slightly higher salinities in the Lavaca-Colorado estuary.

Salinity gradients resulting in differences of greater than 5 ppt in the long axis of East Matagorda Bay are rare (< 20 % of the sampling days), but when they do occur are probably the result of freshwater entering the bay from Caney Creek and exiting through Mitchell's Cut. The resulting gradients in salinity decrease from southwest to northeast. Prior to the opening of Mitchell's Cut and construction of a water diversion dam in the Colorado River, overbanking during flood events caused salinity gradients to occasionally decrease from northeast to southwest.

Although no significant detectable changes in the long-term average salinity were found comparing pre- and post-Mitchell's Cut data for the whole bay, or after restricting the observations to those made only in the vicinity of the pass, some evidence of tidal influence may be observed in the LCRA data. The LCRA observed three out of 15 times that salinity was greater than 5 ppt higher at Station 3, near the cut, compared to salinity at Stations 1 and 2, at the southwest end and mid bay, respectively.

The fact that East Matagorda Bay produced the least commercial harvest of oysters, shrimp, crabs, and finfish of any other primary Texas bay from 1972 - 1993 (Robinson et al., 1994) is misleading and is undoubtedly an artifact of its small size and relative inaccessibility. Compared to other Texas bays in terms of total finfish (number/hour), East Matagorda Bay had the second highest average catch rate from TPWD gill net data from 1983 - 1992 (Boyd et al., 1995), and from TPWD trawl data from 1987 - 1992 produced the third and fourth highest average catch rates (number/hour) for brown shrimp and blue crabs, respectively; therefore, the bay is highly productive for its size. The high fish and shellfish production of East Matagorda Bay is a result of its long-term moderate salinity regime. Young fish and shellfish commonly utilize estuarine habitats that have salinities below 17.5 ppt, whereas adults seem to prefer slightly higher salinities (Texas Department of Water Resources 1980).

Because of the isolation of East Matagorda Bay and the lack of continuous riverine inputs, if this bay were in a more arid climate it would almost certainly be hypersaline. East Matagorda Bay is, therefore, a fragile ecosystem able to maintain important moderate salinities despite a lack of constant riverine input of freshwater. Alterations in bay circulation caused by additions of water exchange passes should be well understood prior to construction, and maintenance of a moderate salinity regime should be the central focus of such plans. Only through proper planning and management can alterations in this bay system's circulation take place and maintain its high level of productivity.

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Table C1. List of salinity measurements representing gradients found in the Texas Department of Health Data. (+ = increasing gradient from southwest to northeast, - = decreasing from southwest to northeast.

	Salinity (ppt)				
Date	Station 3	Station 5	Station 8	Station 10	SW-NE
9 April 1984	16.9	19.9	19.3	23.1	+
14 January 1986	32	28.9	20	20	-
10 February 1987	8.5	10	12.6	16	+
7 April 1987	10	11	15	15.1	+
16 January 1989	31.2	31	28.1	26.1	-
15 February 1989	28	24.3	22.9	22.2	-
24 April 1990	26	22.3	21.5	19.3	-
22 January 1991	23.2	20.1	17.8	13.1	-
22 April 1991	17.1	15.1	11.9	12.1	-
18 February 1992	12	10.1	5.5	7	-
26 April 1994	22.8	21.1	19	17.9	-
25 October 1994	26.1	21	14	11	-
16 March 1995	14	12	11	8.5	-
10 April 1995	11	10.5	7.9	3.5	-

Table C2. Salinity measurements collected by the Lower Colorado River Authority resulting in > 5 ppt difference between Stations. (+ = gradient increasing from southwest to northeast)

	Salinity (ppt)			
Date	Station 1	Station 2	Station 3	SW-NE
17 March 1993	12.5	14.3	20.1	+
26 April 1993	11.9	11.9	21.2	
30 August 1993	19.2	19.8	26.6	

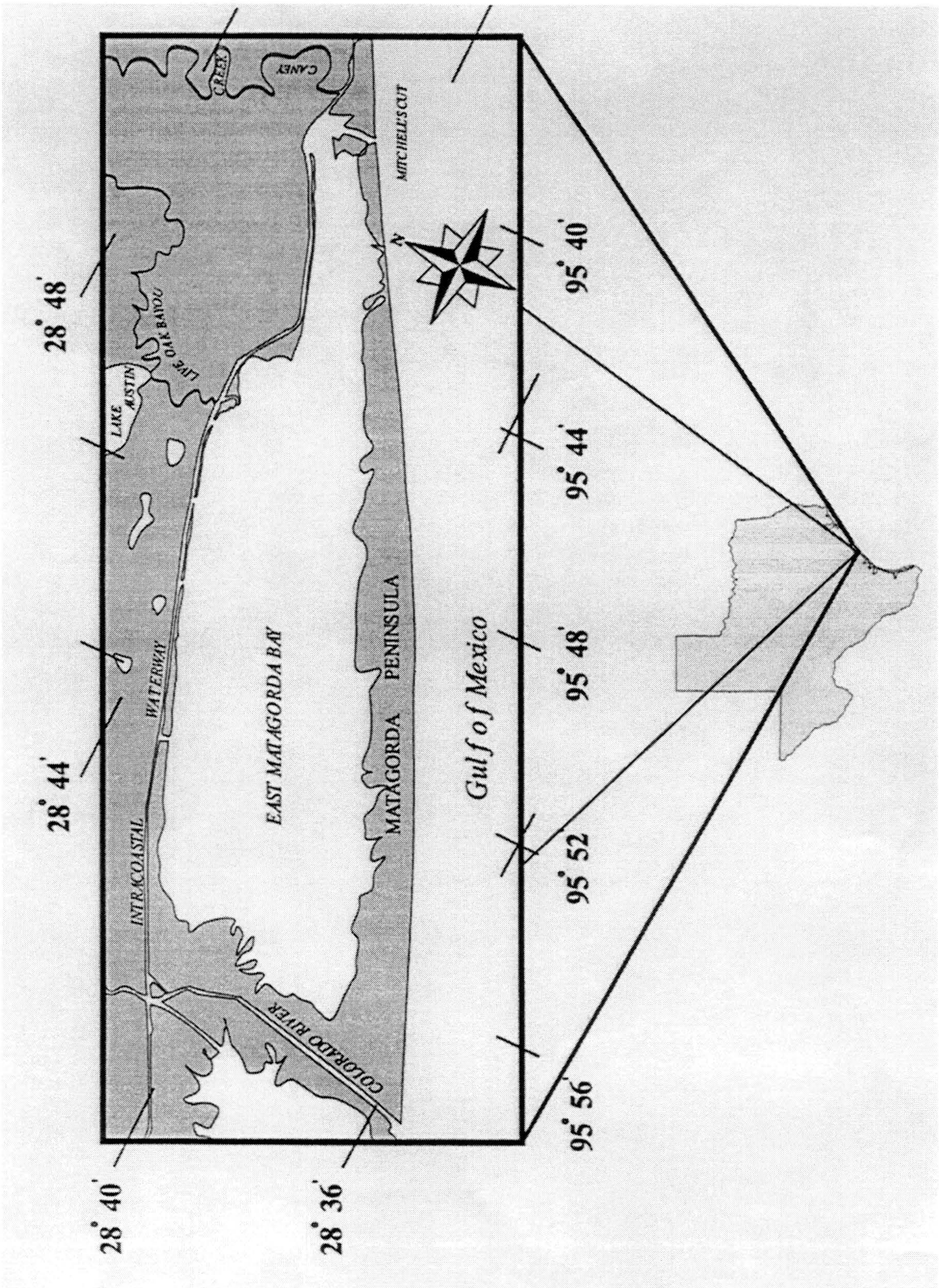


Figure C-1. Location of East Matagorda Bay on the Central Texas Coast.

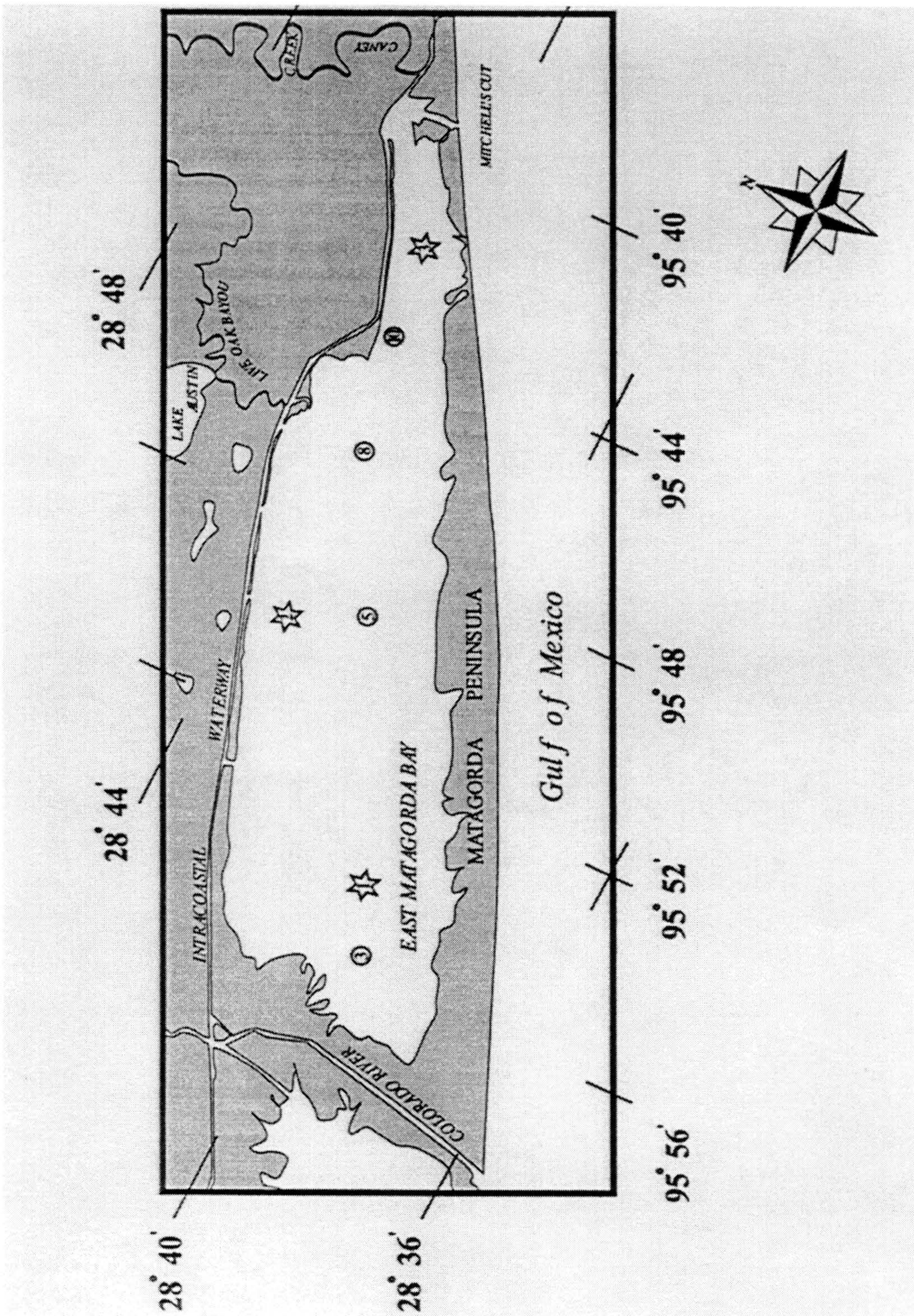


Figure C-2. Location of Texas Department of Health Stations (O), and Lower Colorado River Authority stations (✶) used in gradient analysis.

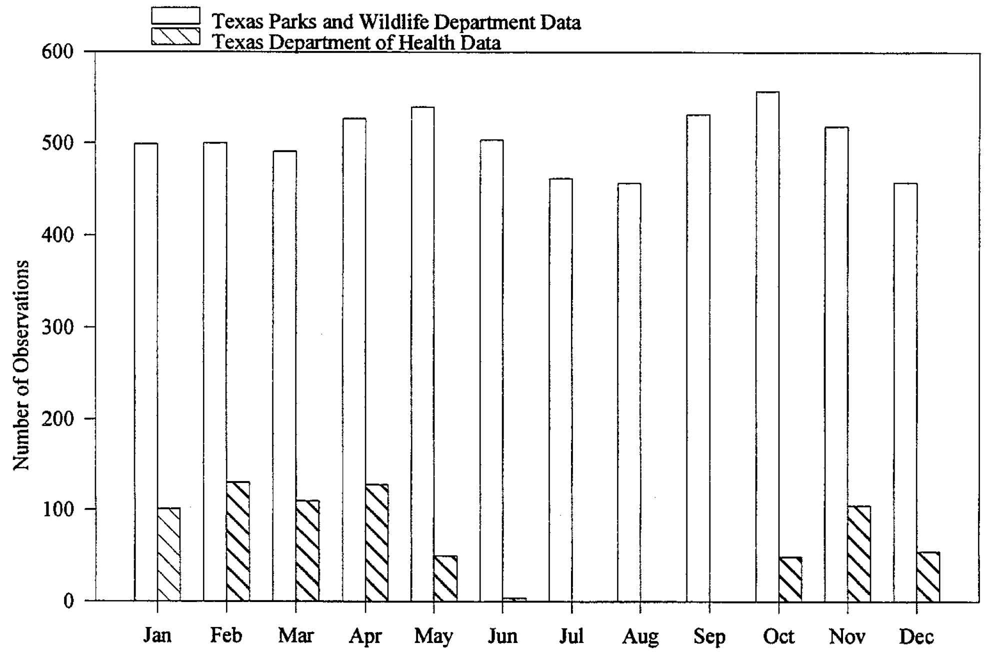


Figure C-3. Number of salinity observations made each month from 1989-April 1995 by the Texas Parks and Wildlife Department and the Texas Department of Health.

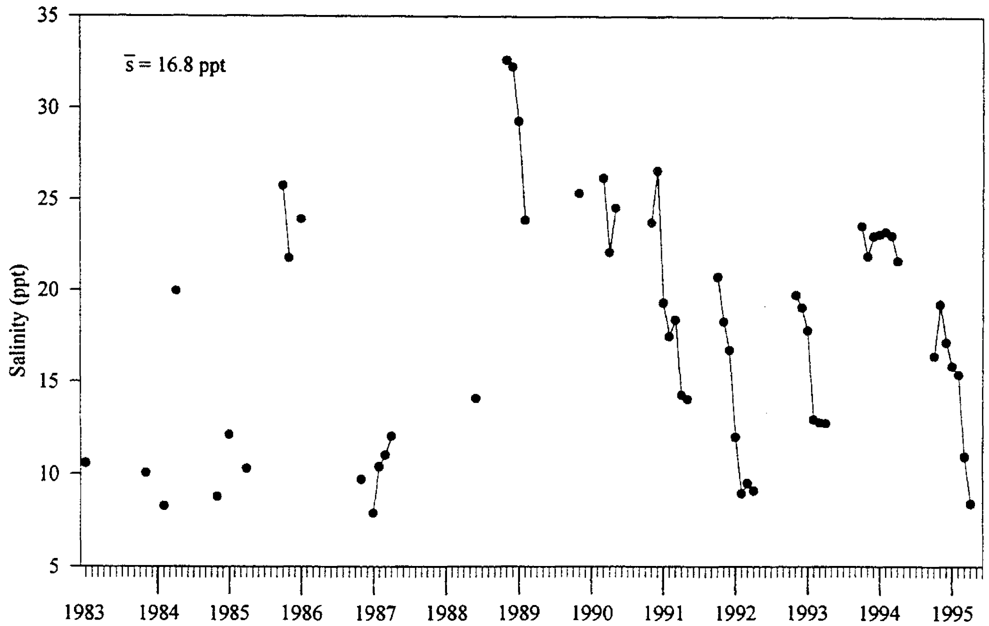


Figure C-4. Average monthly salinity data collected by the Texas Department of Health in East Matagorda Bay, Texas.

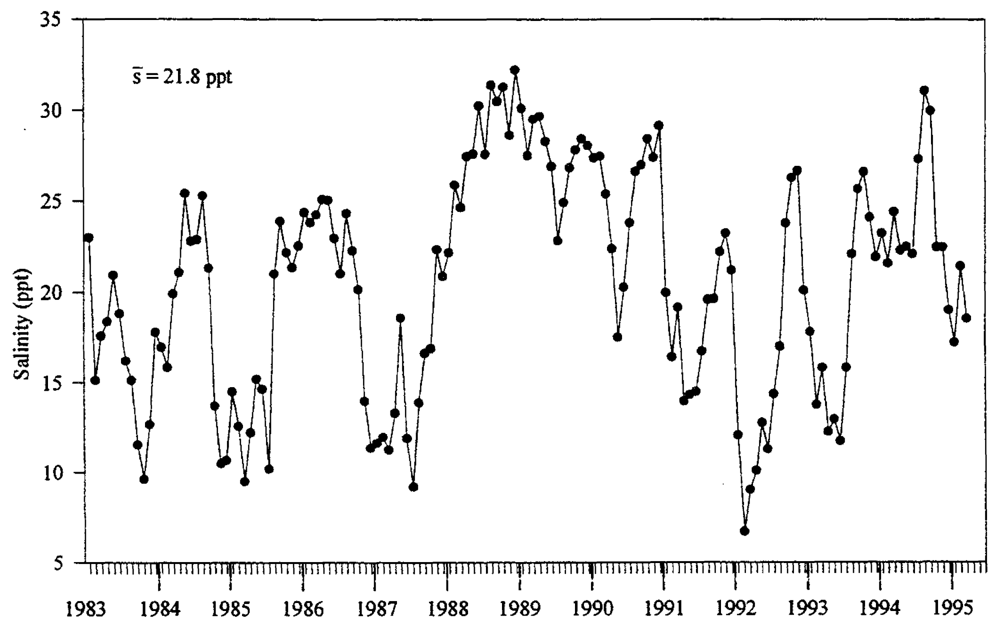


Figure C-5. Average monthly salinity data collected by the Texas Parks and Wildlife Department in East Matagorda Bay, Texas.

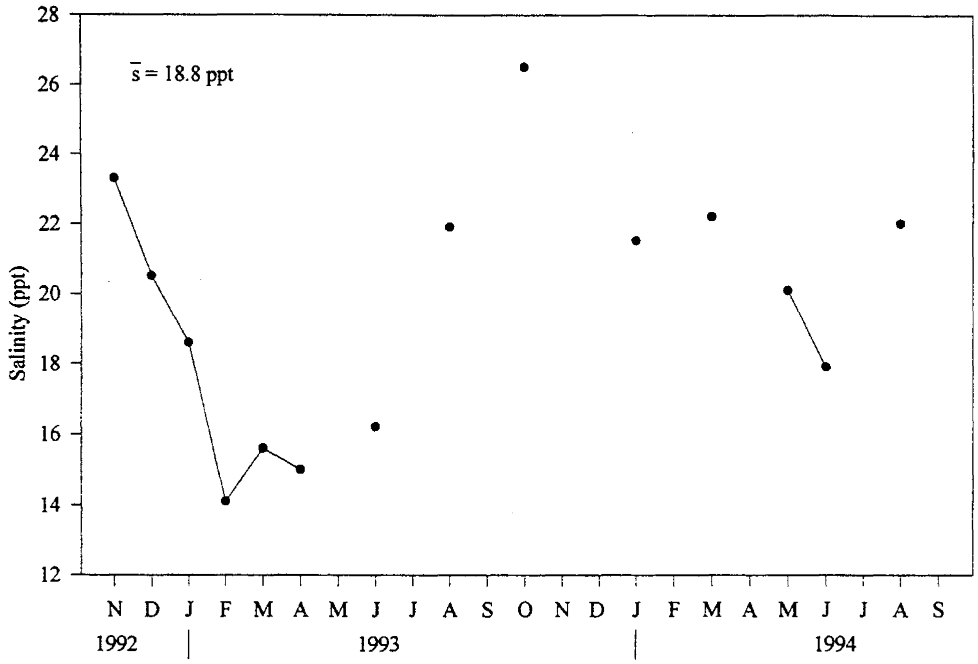


Figure C-6. Average monthly salinity data collected by the Lower Colorado River Authority in East Matagorda Bay, Texas.

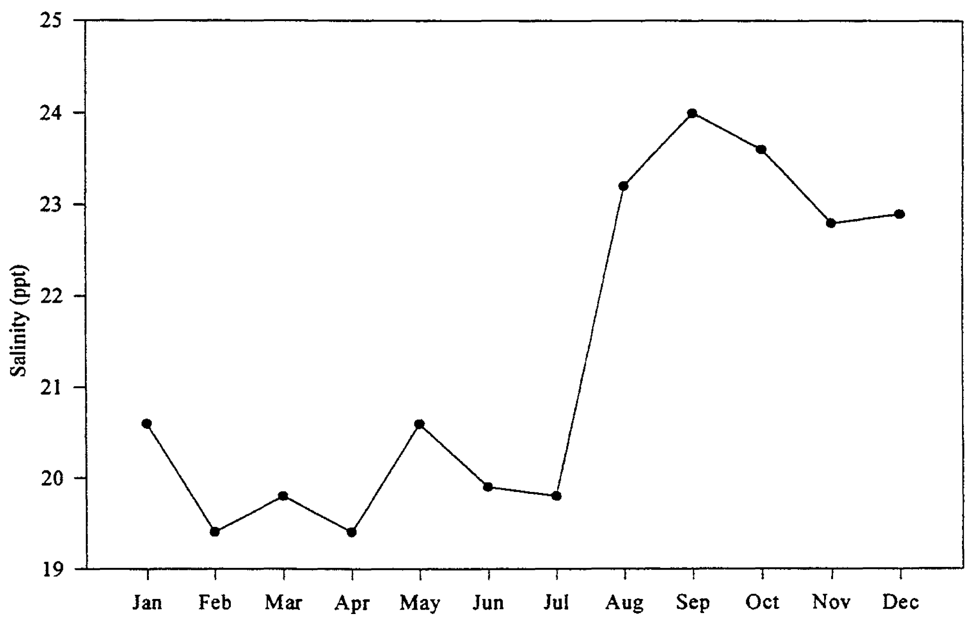


Figure C-7. Monthly average salinities for all data combined (TPWD, TDH, and LCRA) from 1983 - April 1995.

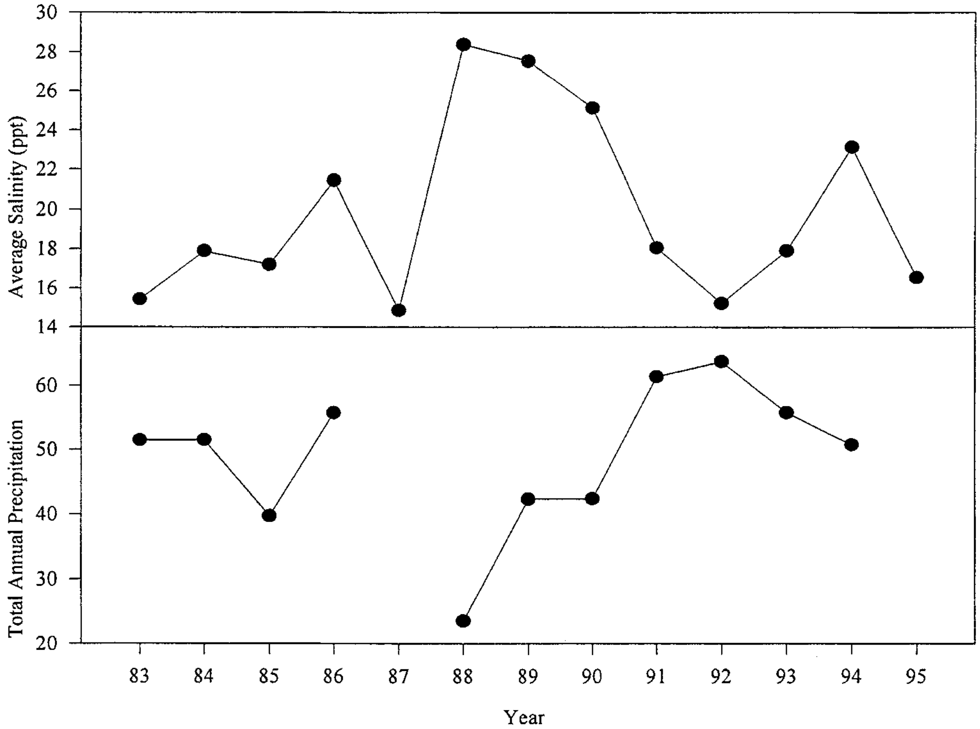


Figure C-8. Graph depicting strong correlation (Pearson Correlation Coefficient = -0.716) between average annual salinity and total annual precipitation in East Matagorda Bay, Texas.

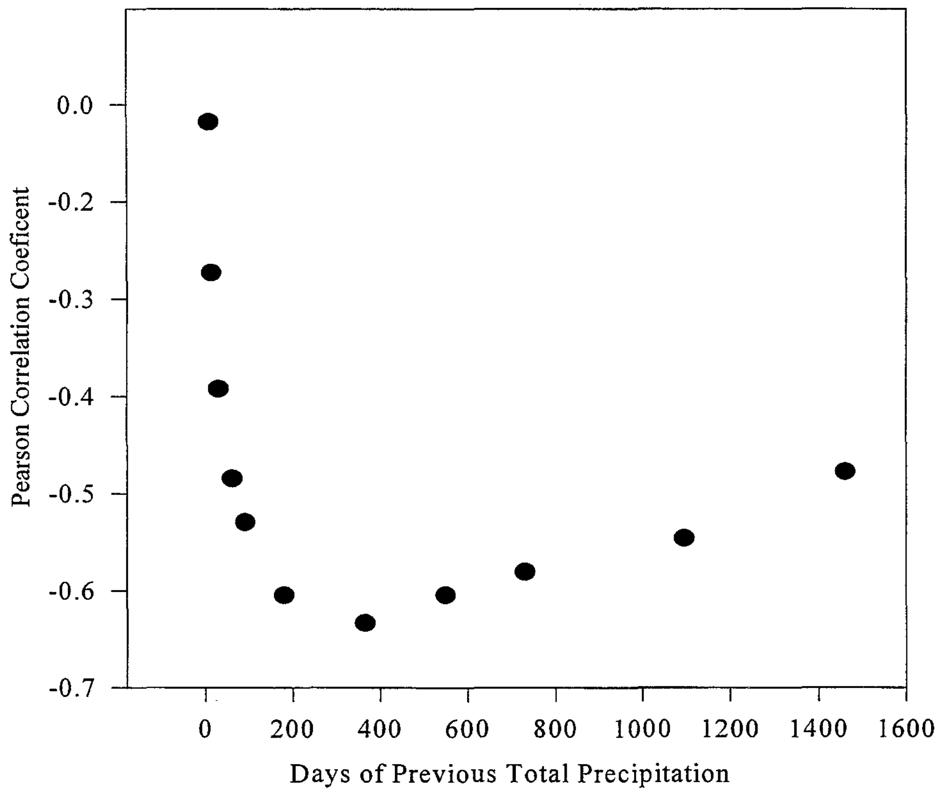
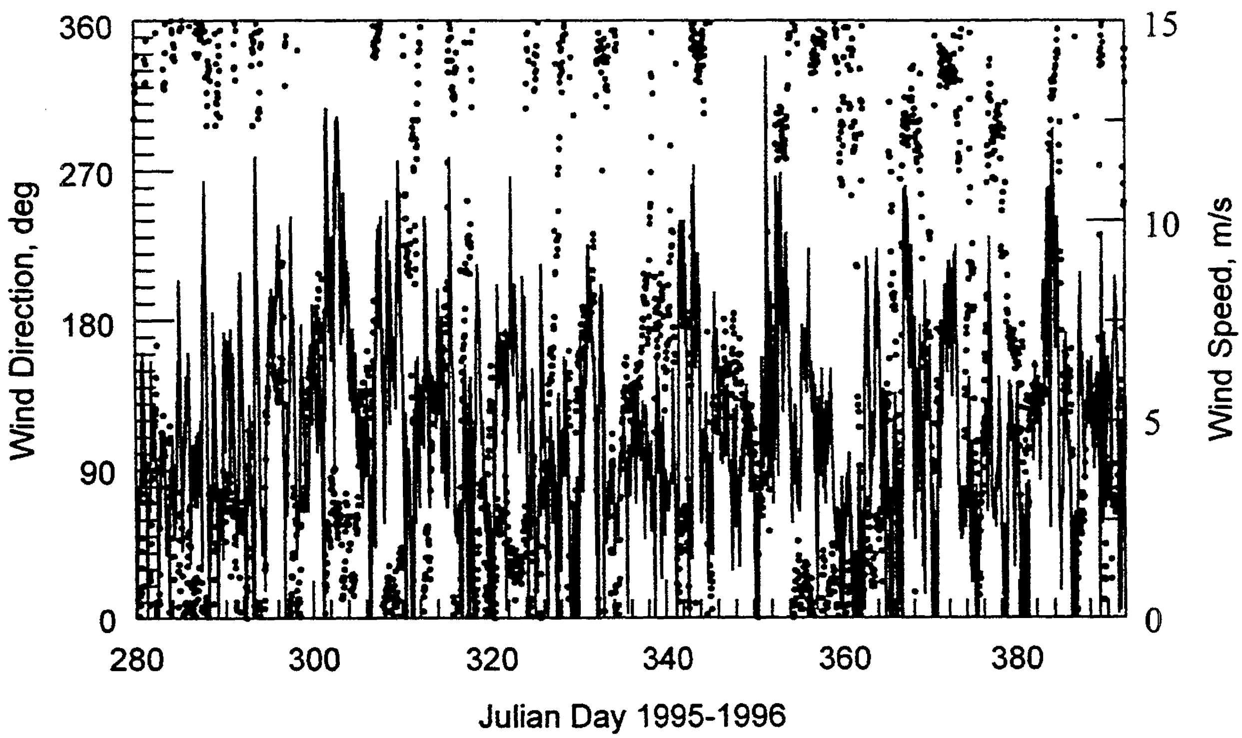


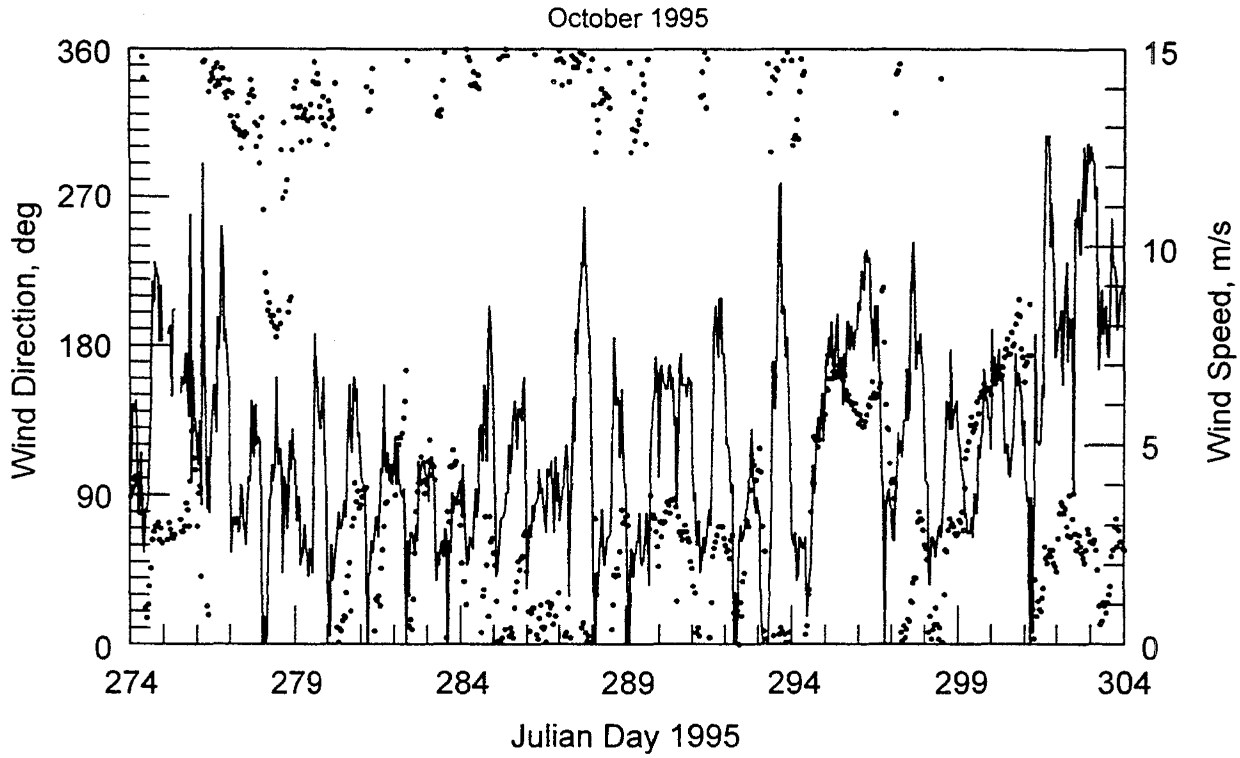
Figure C-9. Pearson Correlation Coefficients calculated between salinity on a given day and total rainfall for varying prior numbers of days. The strongest correlation is at approximately 365 days of total rainfall.

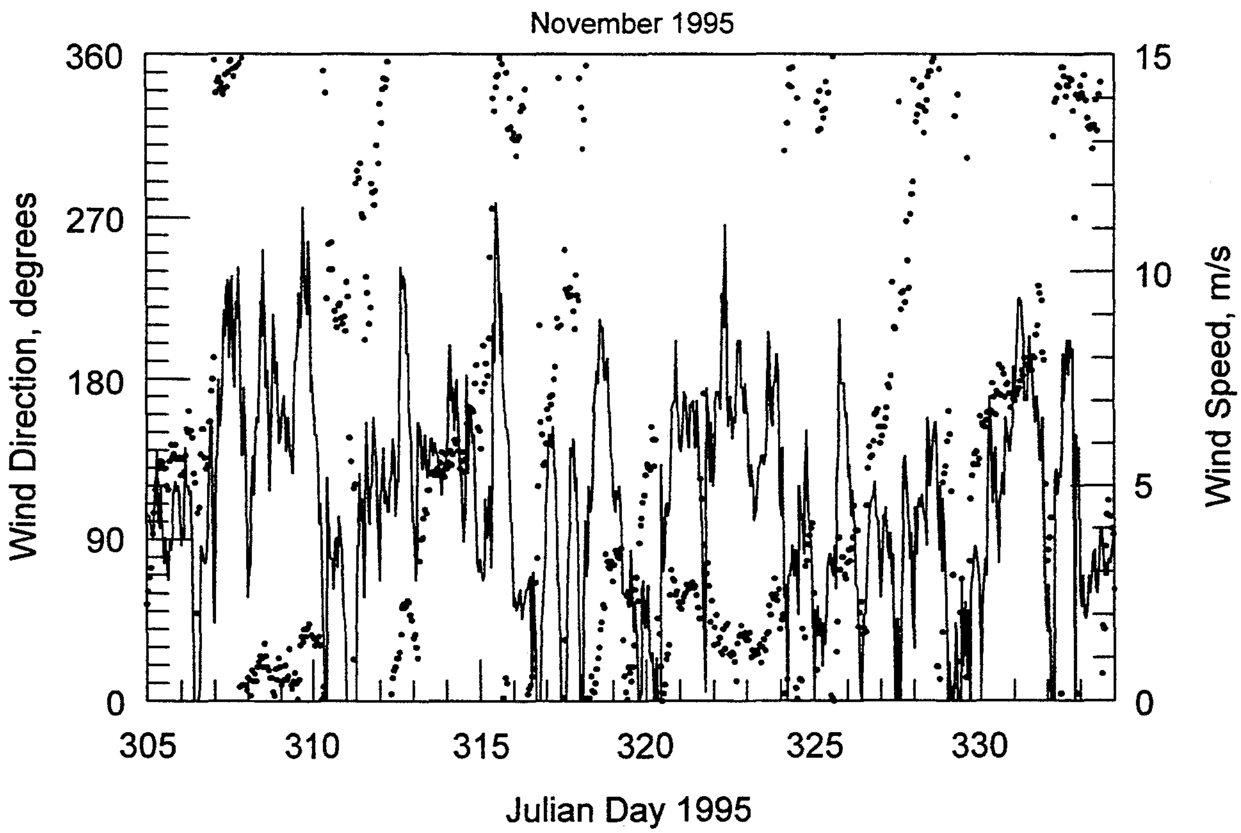
Appendix D : Compilation of Data Obtained in this Study

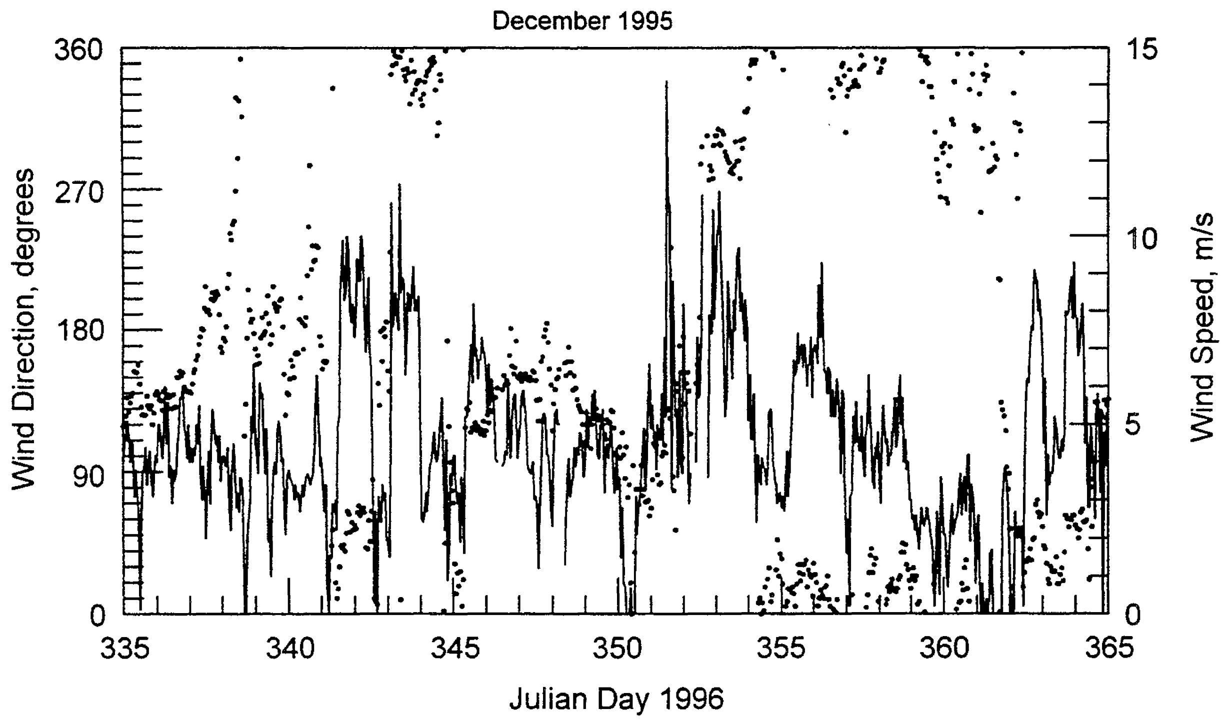
This appendix contains representative time series plots of data collected in this study. Plots are given for both the observation period, nominally Julian Day (JD) 280 to JD392 (October 7, 1995, to January 26, 1996), and for monthly intervals, if available, from October, 1995, through January, 1996. The plots are presented in chronological order for the wind (measured at the EMAT platform), water level at EMAT and SWEMAT, the horizontal current velocity components at EMAT and SWEMAT, and the water-quality parameters of salinity, water temperature, pH, and dissolved oxygen at EMAT, SWEMAT, POLE1, and POLE2. Locations of these measurement stations are given in Chapter 2 of the main text of this report. The data for the current were filtered to remove fluctuations less than 6 hr so that the general trend can be more clearly seen. Properties of the data are discussed in Chapter 2.

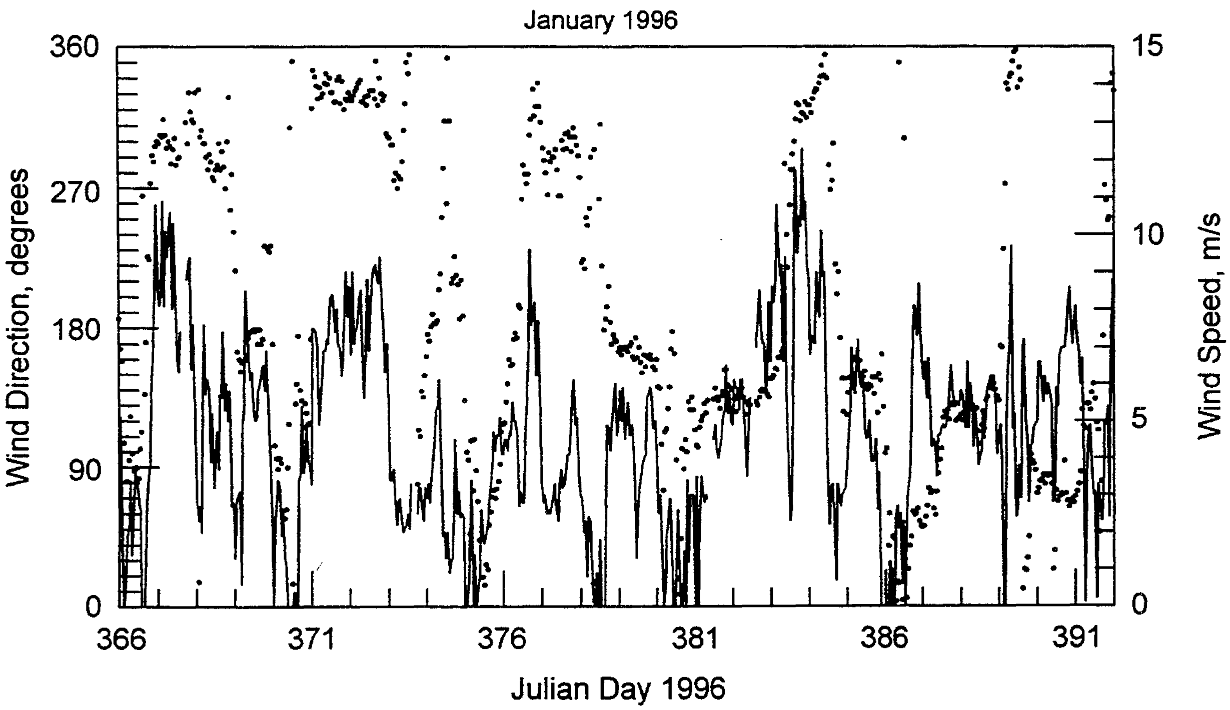
Wind



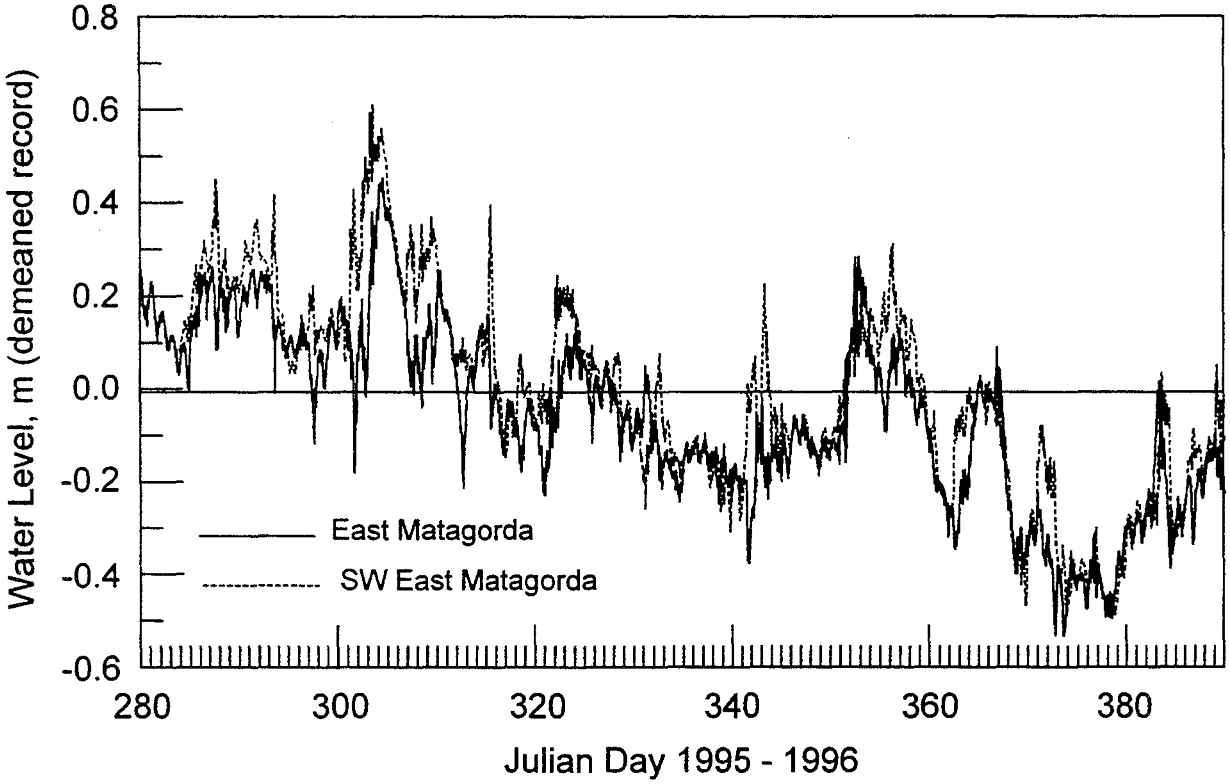

October 1995
Wind Direction, deg
Wind Speed, m/s
Julian Day 1995
360
270
180
90
0
15
10
5
0
274
279
284
289
294
299
304


November 1995
Wind Direction, degrees
Wind Speed, m/s
Julian Day 1995
360
270
180
90
0
15
10
5
0
305
310
315
320
325
330

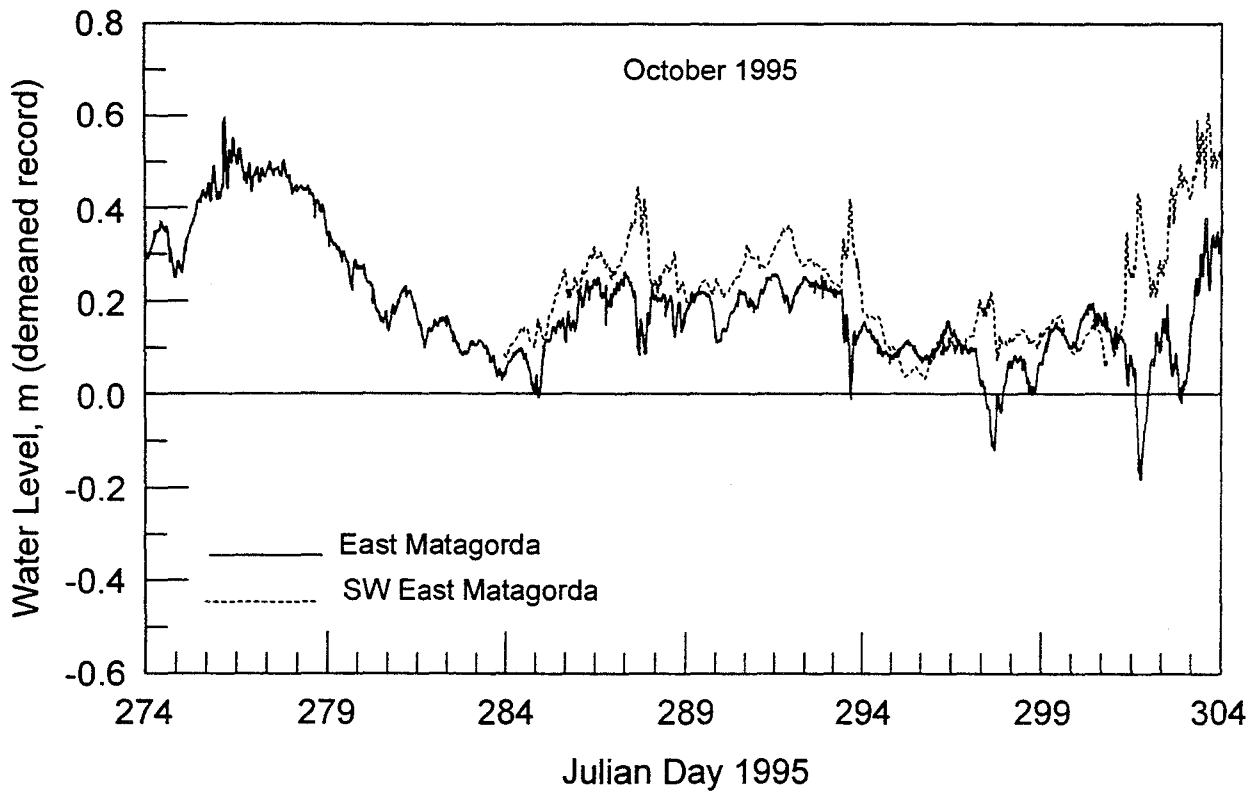

December 1995
Wind Direction, degrees
360
270
180
90
0
Wind Speed, m/s
15
10
5
0
335
340
345
350
355
360
365
Julian Day 1996

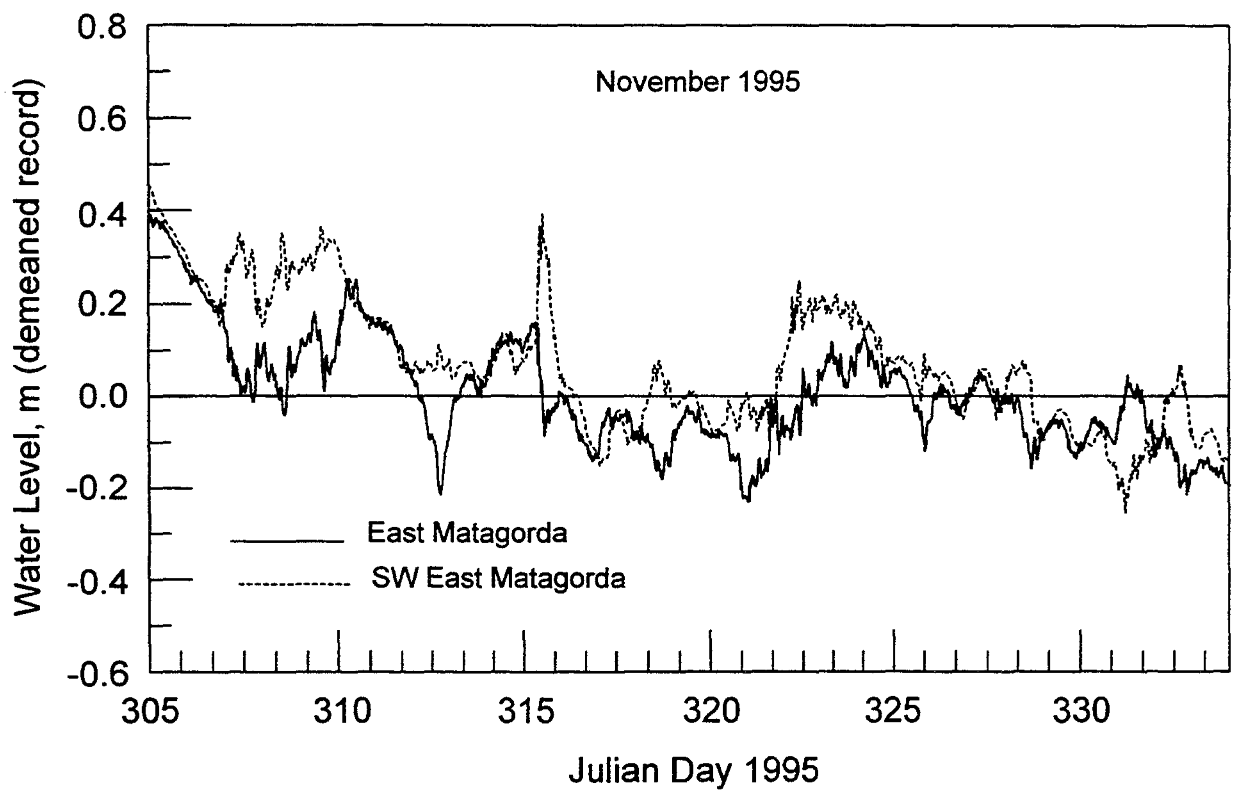

January 1996
Wind Direction, degrees
360
270
180
90
0
Wind Speed, m/s
15
10
5
0
366
371
376
381
386
391
Julian Day 1996

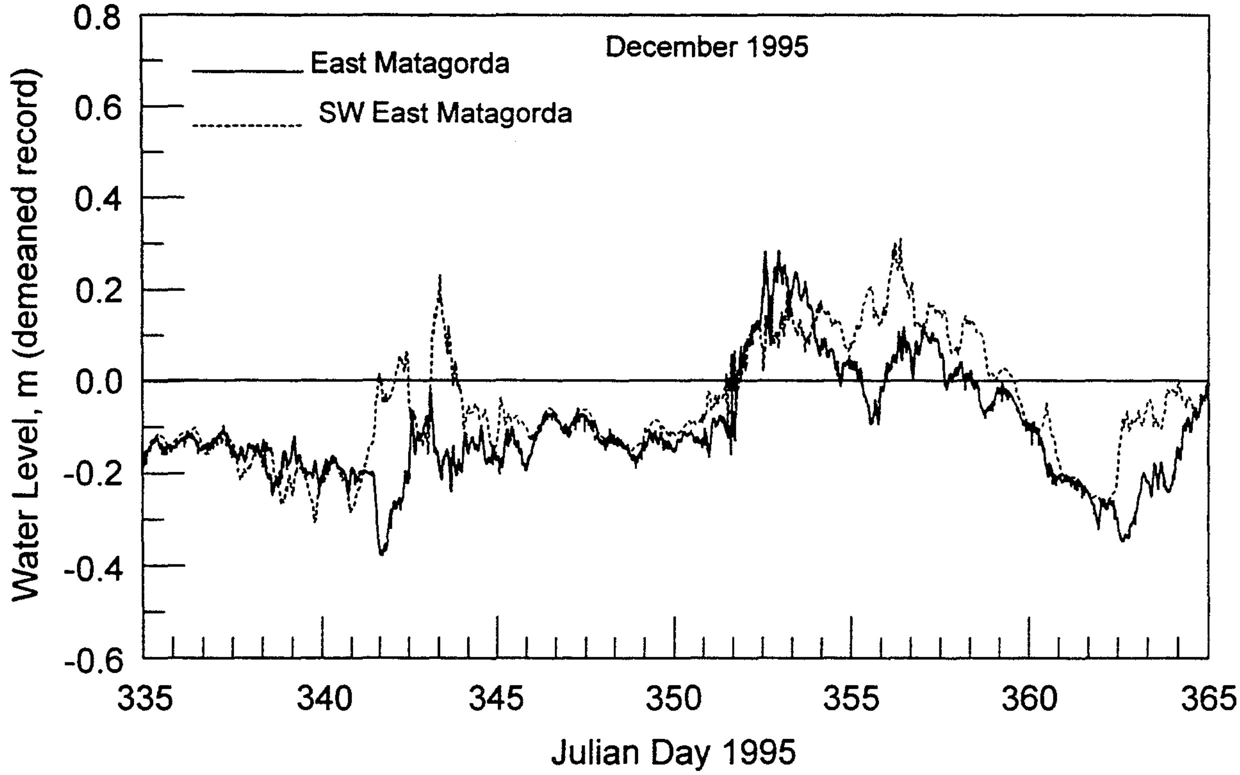
Water Level

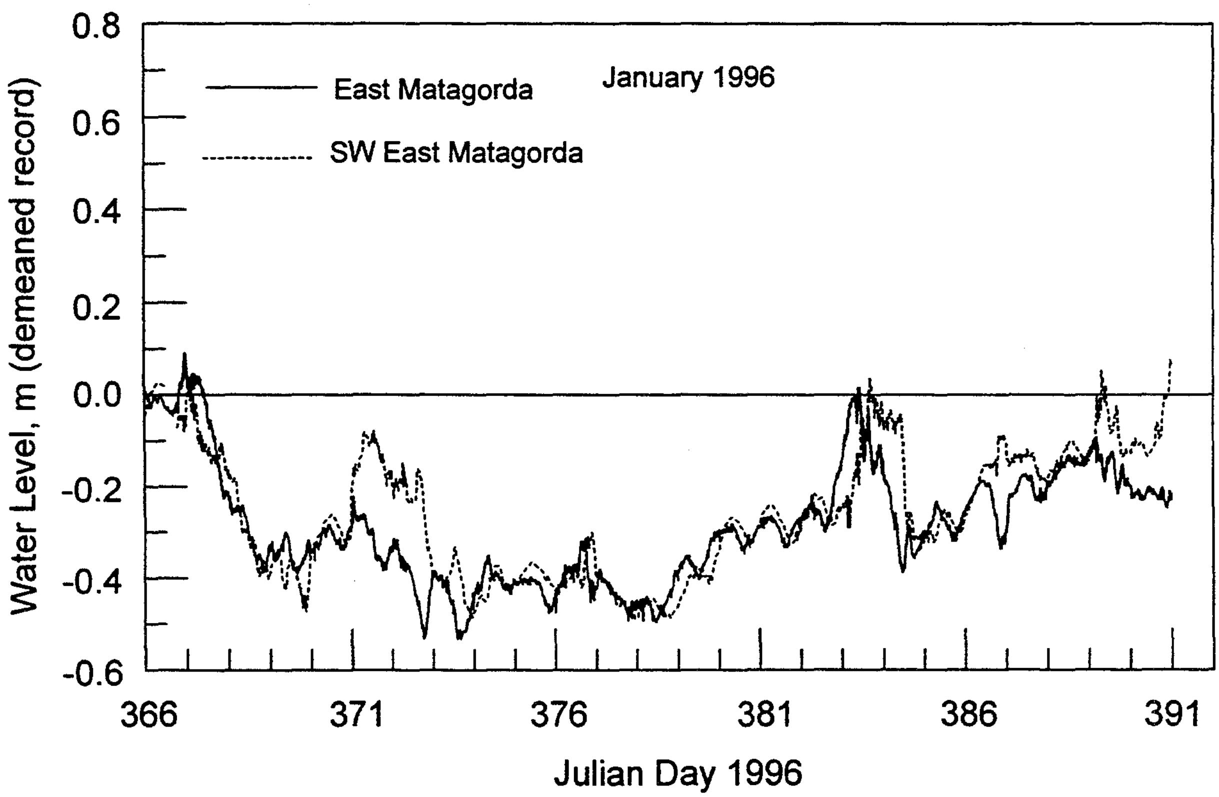


0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
Water Level, m (demeaned record)
East Matagorda
SW East Matagorda
280
300
320
340
360
380
Julian Day 1995 - 1996

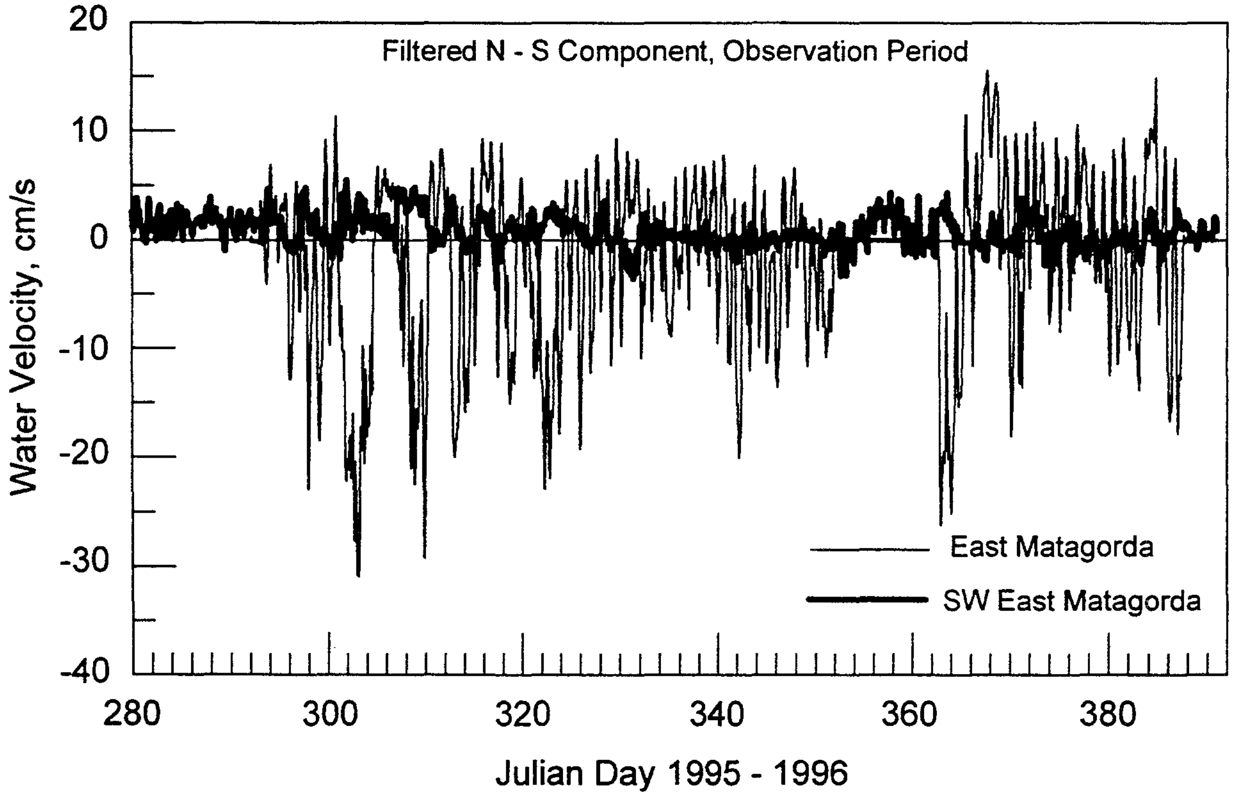

October 1995
Water Level, m (demeaned record)
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
274
279
284
289
294
299
304
Julian Day 1995
East Matagorda
SW East Matagorda

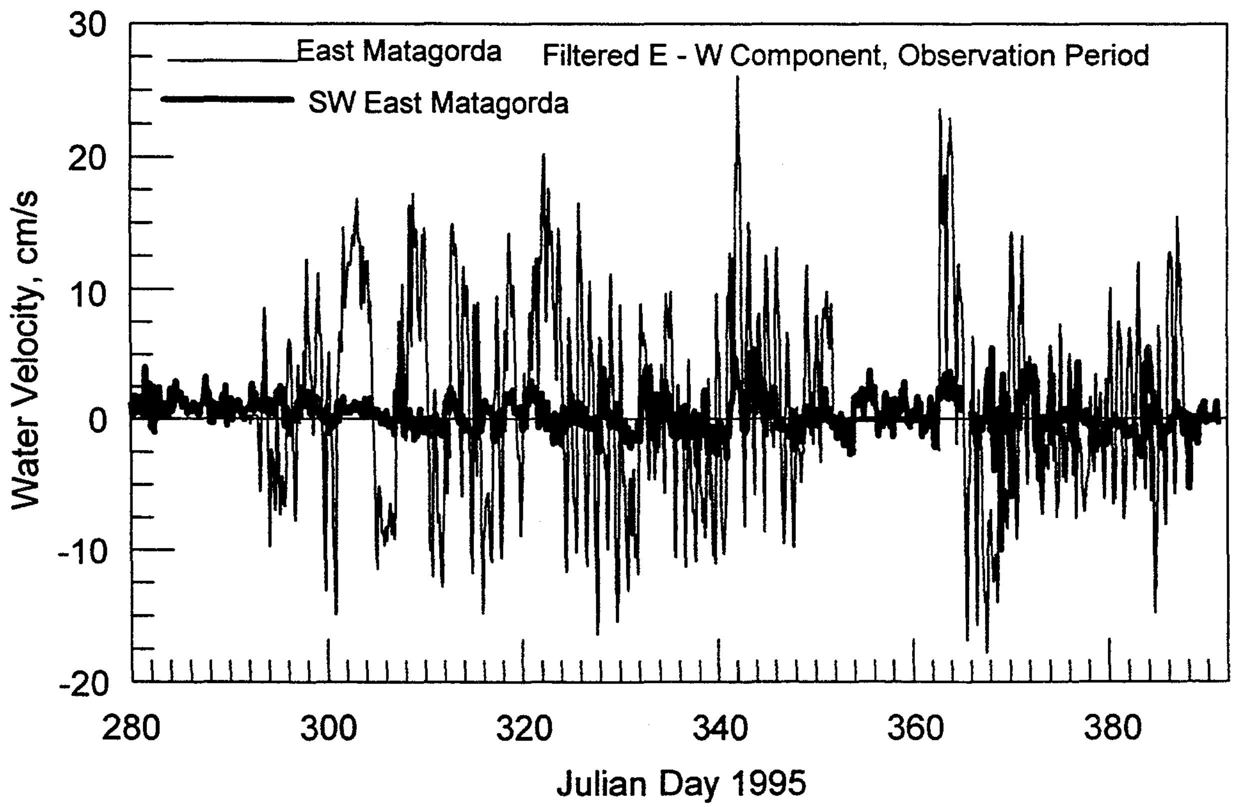

November 1995
Water Level, m (demeaned record)
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
305
310
315
320
325
330
Julian Day 1995
East Matagorda
SW East Matagorda

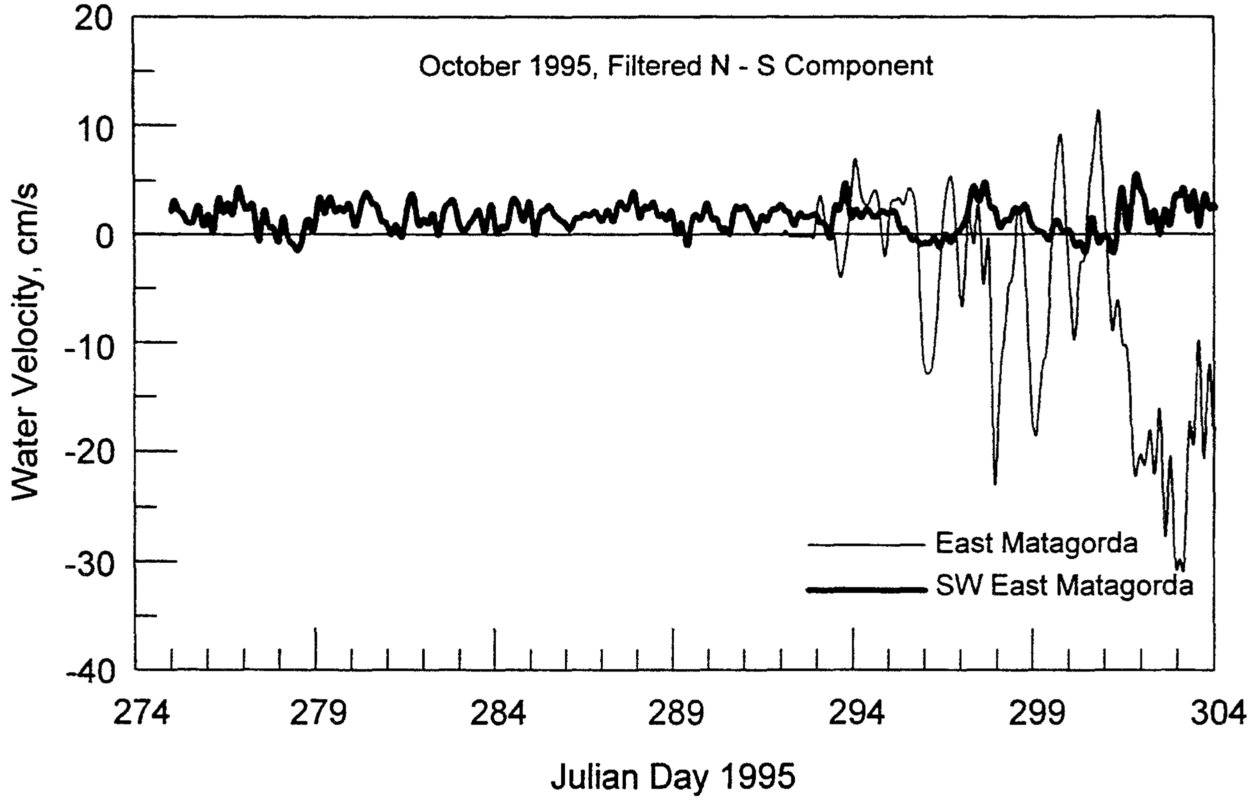

December 1995
East Matagorda
SW East Matagorda
Water Level, m (demeaned record)
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
335
340
345
350
355
360
365
Julian Day 1995

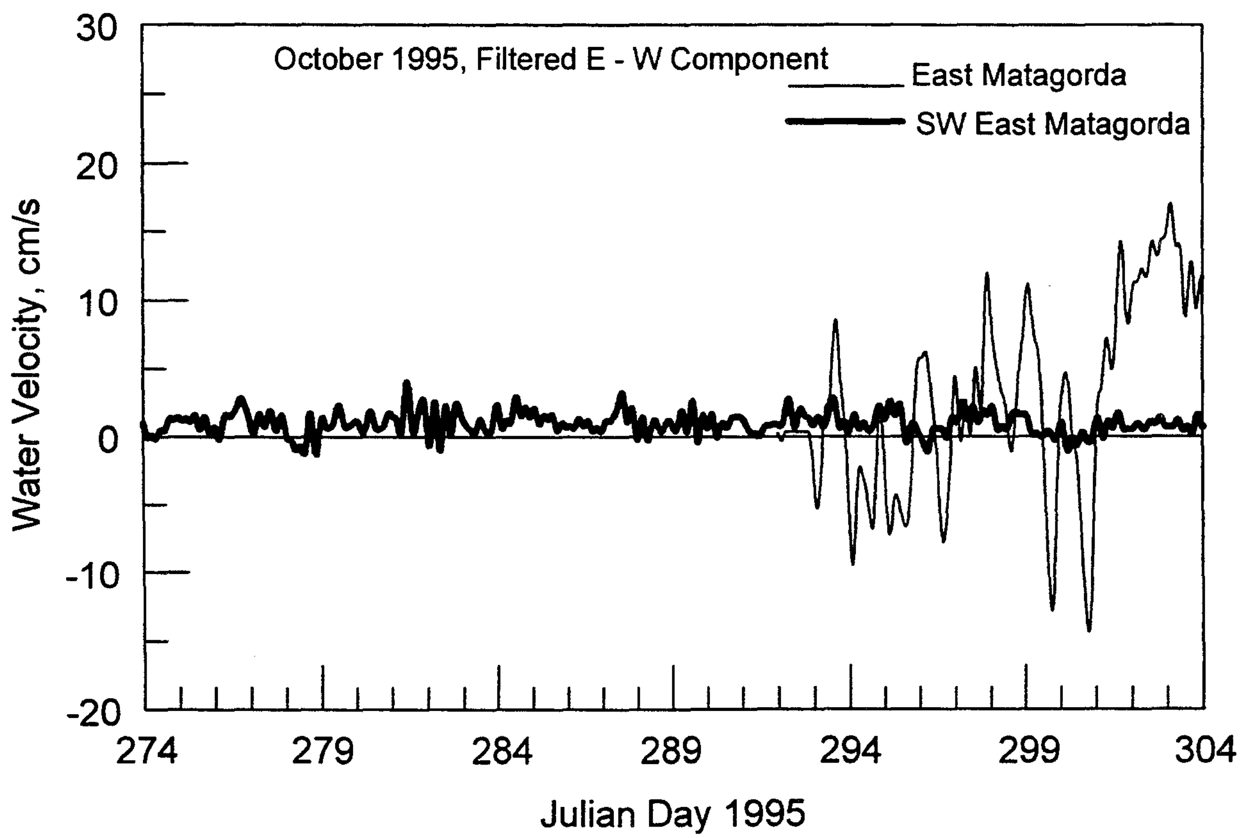

January 1996
East Matagorda
SW East Matagorda
Water Level, m (demeaned record)
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
366
371
376
381
386
391
Julian Day 1996

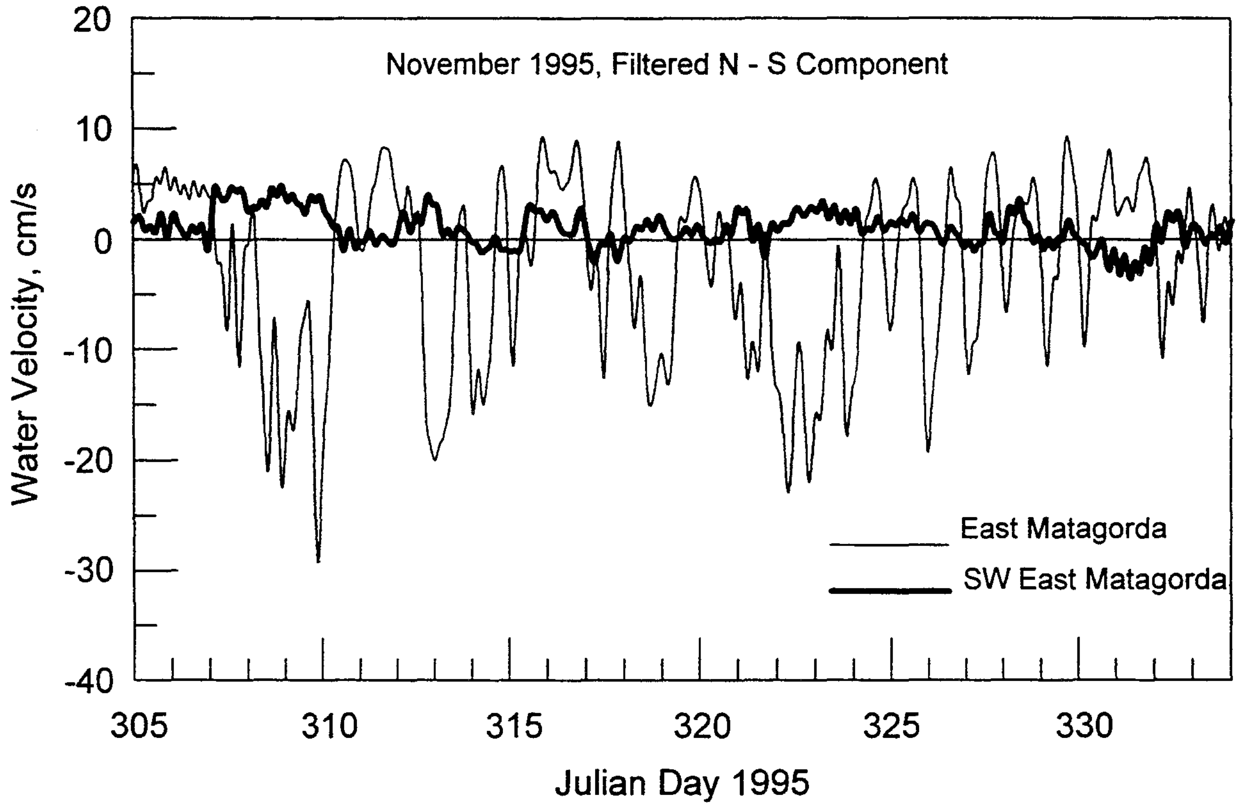
Current

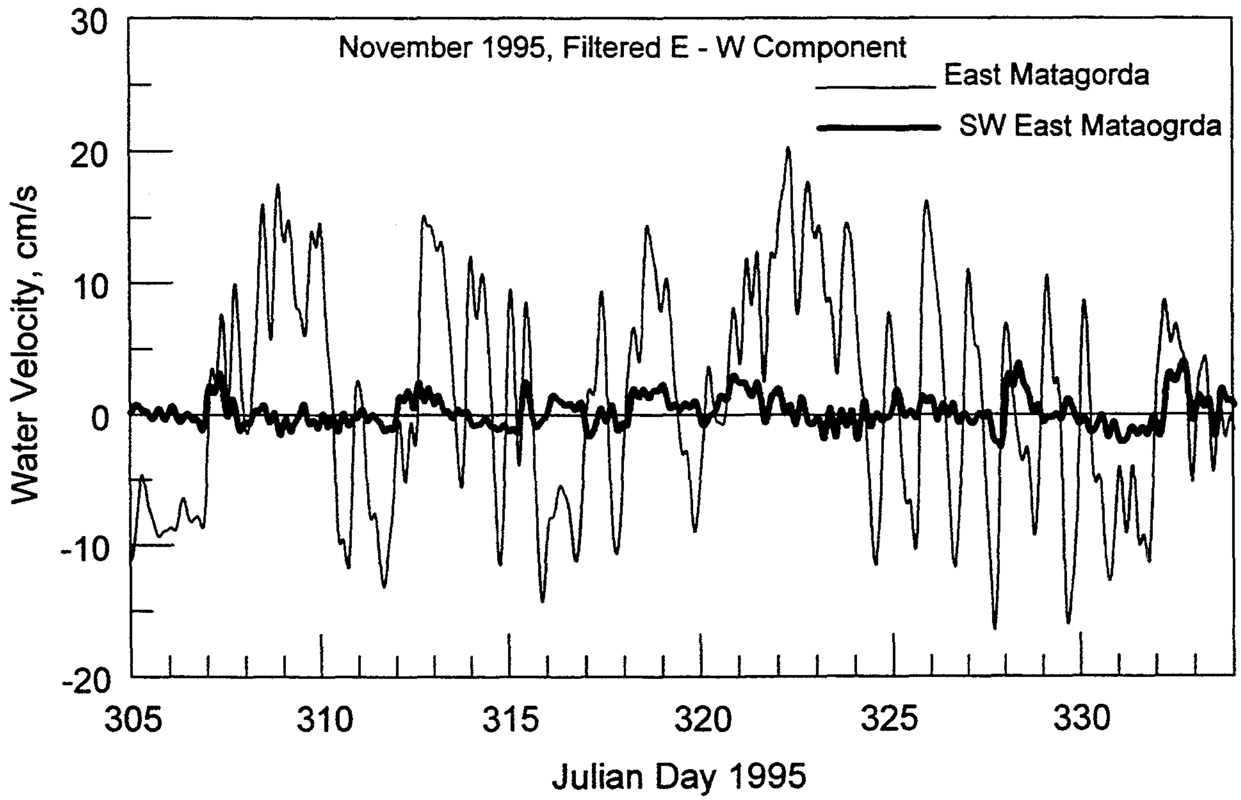

Filtered N - S Component, Observation Period
East Matagorda
SW East Matagorda
Water Velocity, cm/s
20
10
0
-10
-20
-30
-40
280
300
320
340
360
380
Julian Day 1995 - 1996

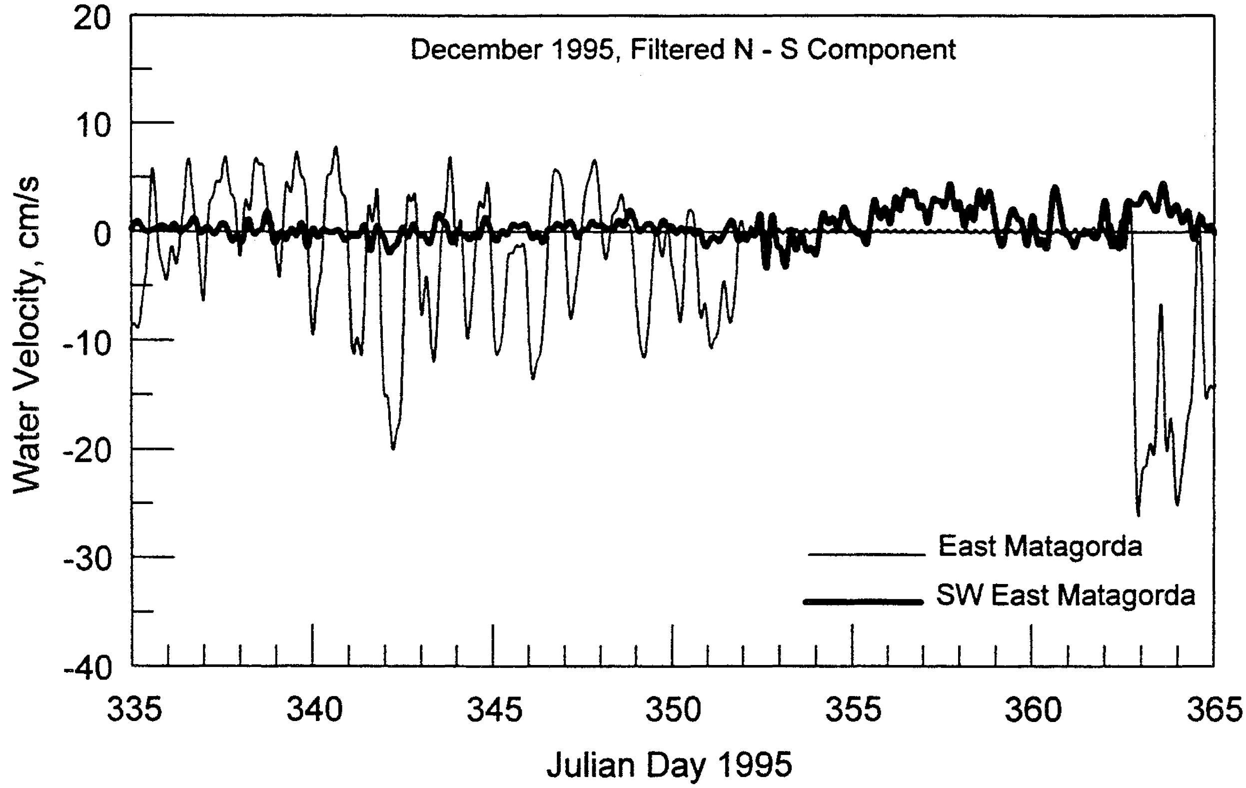

East Matagorda
Filtered E - W Component, Observation Period
SW East Matagorda
Water Velocity, cm/s
30
20
10
0
-10
-20
280
300
320
340
360
380
Julian Day 1995

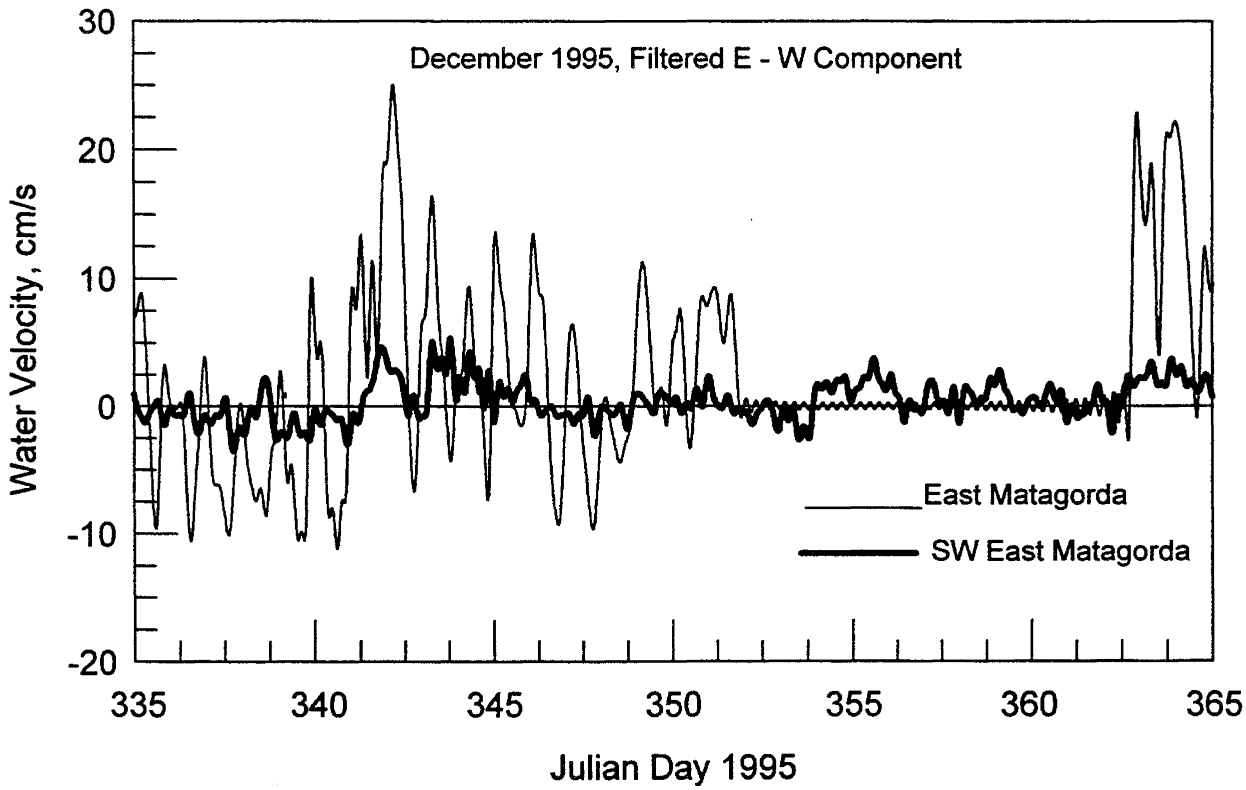

October 1995, Filtered N - S Component
Water Velocity, cm/s
Julian Day 1995
East Matagorda
SW East Matagorda
20
10
0
-10
-20
-30
-40
274
279
284
289
294
299
304

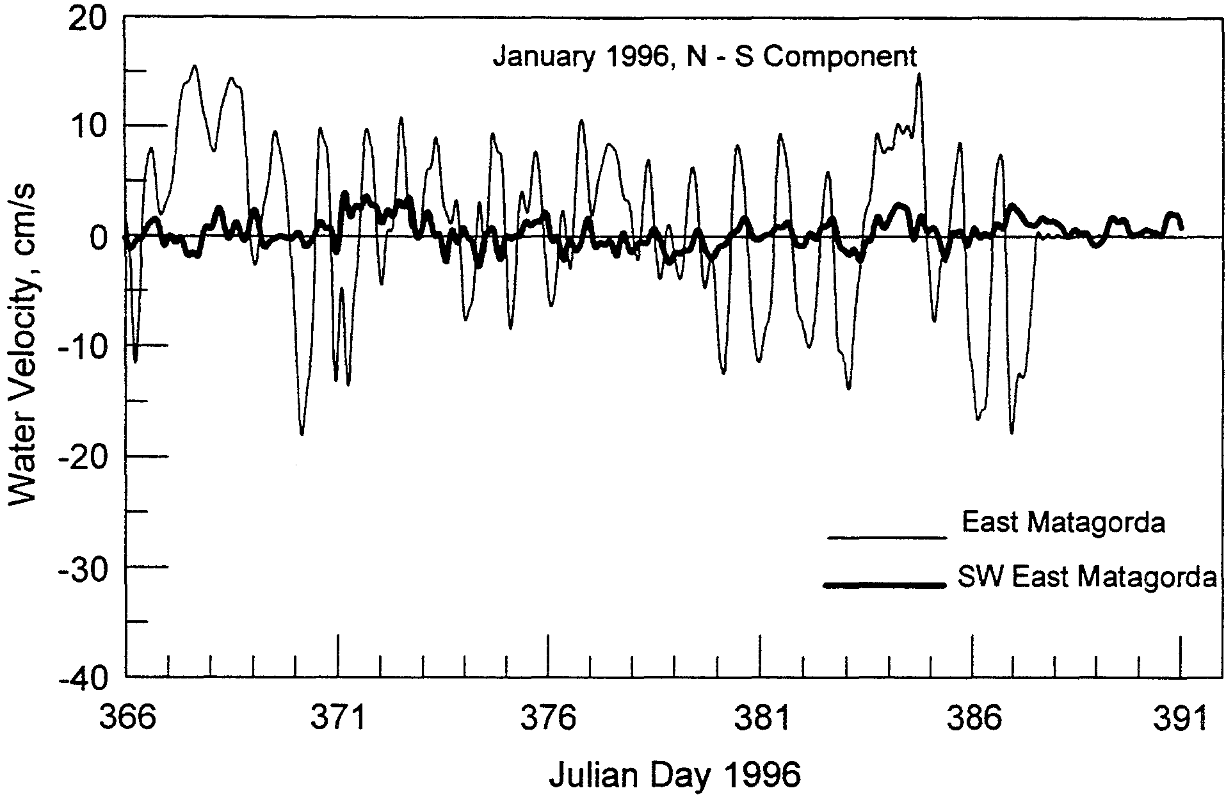

October 1995, Filtered E - W Component
Water Velocity, cm/s
Julian Day 1995
East Matagorda
SW East Matagorda
30
20
10
0
-10
-20
274
279
284
289
294
299
304

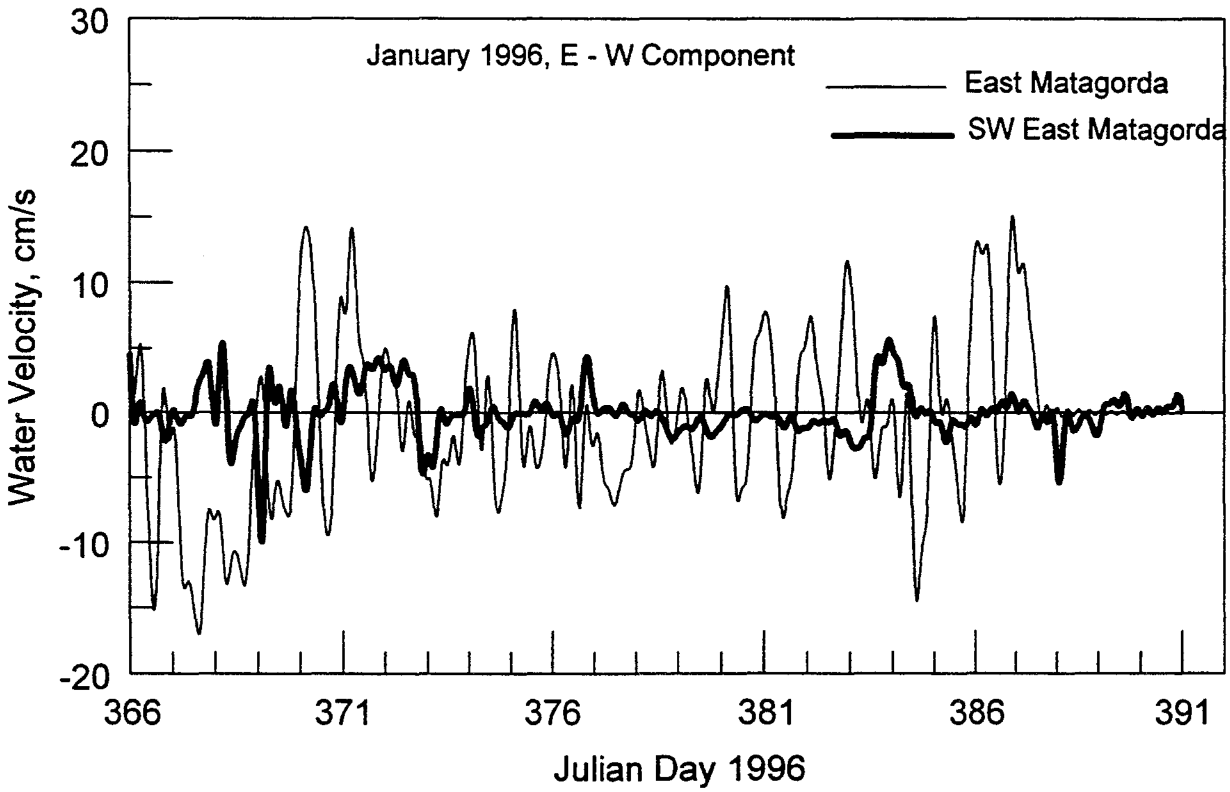

November 1995, Filtered N - S Component
Water Velocity, cm/s
20
10
0
-10
-20
-30
-40
305
310
315
320
325
330
Julian Day 1995
East Matagorda
SW East Matagorda


November 1995, Filtered E - W Component
East Matagorda
SW East Mataogrda
Water Velocity, cm/s
30
20
10
0
-10
-20
305
310
315
320
325
330
Julian Day 1995

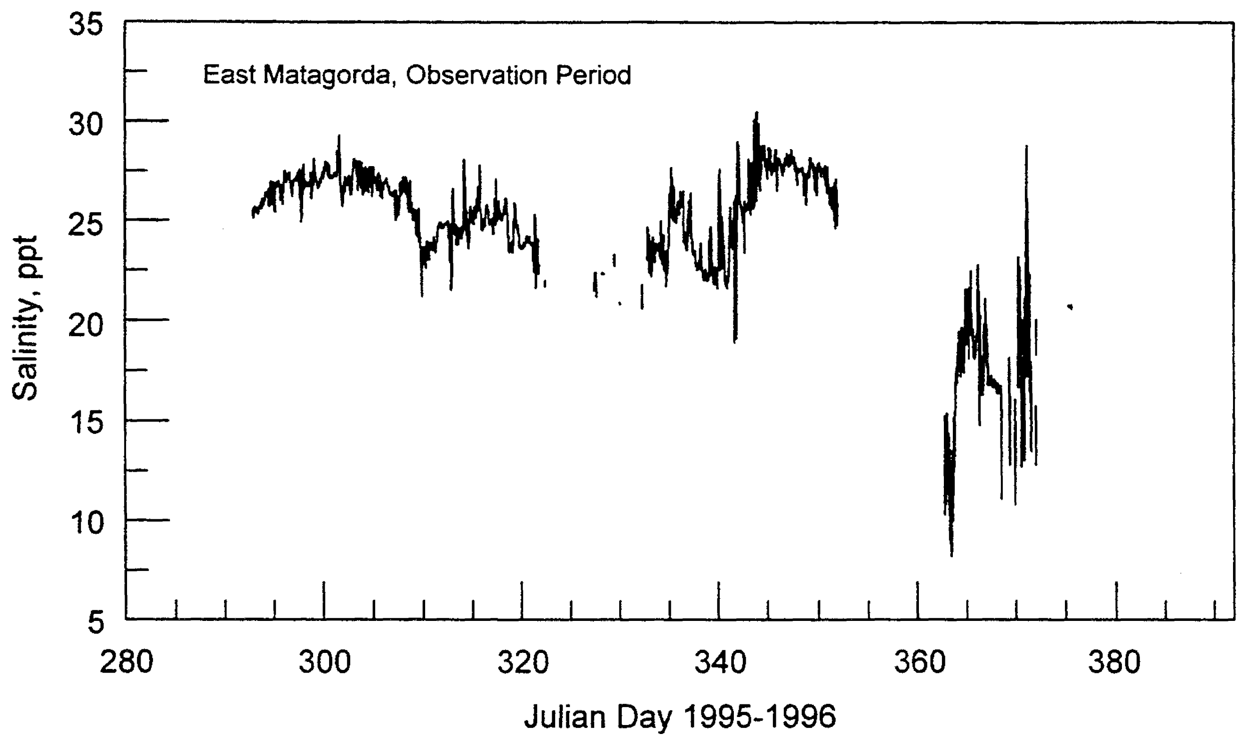

December 1995, Filtered N - S Component
Water Velocity, cm/s
20
10
0
-10
-20
-30
-40
335
340
345
350
355
360
365
Julian Day 1995
East Matagorda
SW East Matagorda

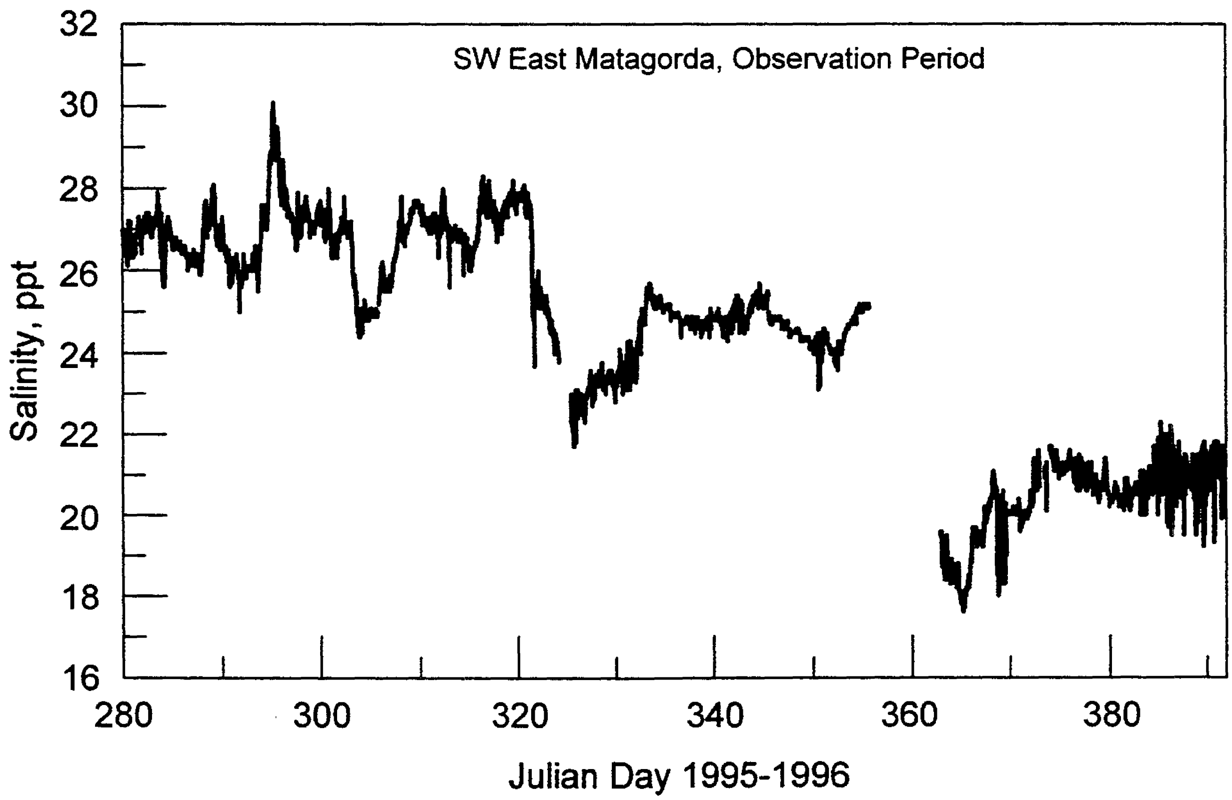

December 1995, Filtered E - W Component
Water Velocity, cm/s
30
20
10
0
-10
-20
335
340
345
350
355
360
365
Julian Day 1995
East Matagorda
SW East Matagorda

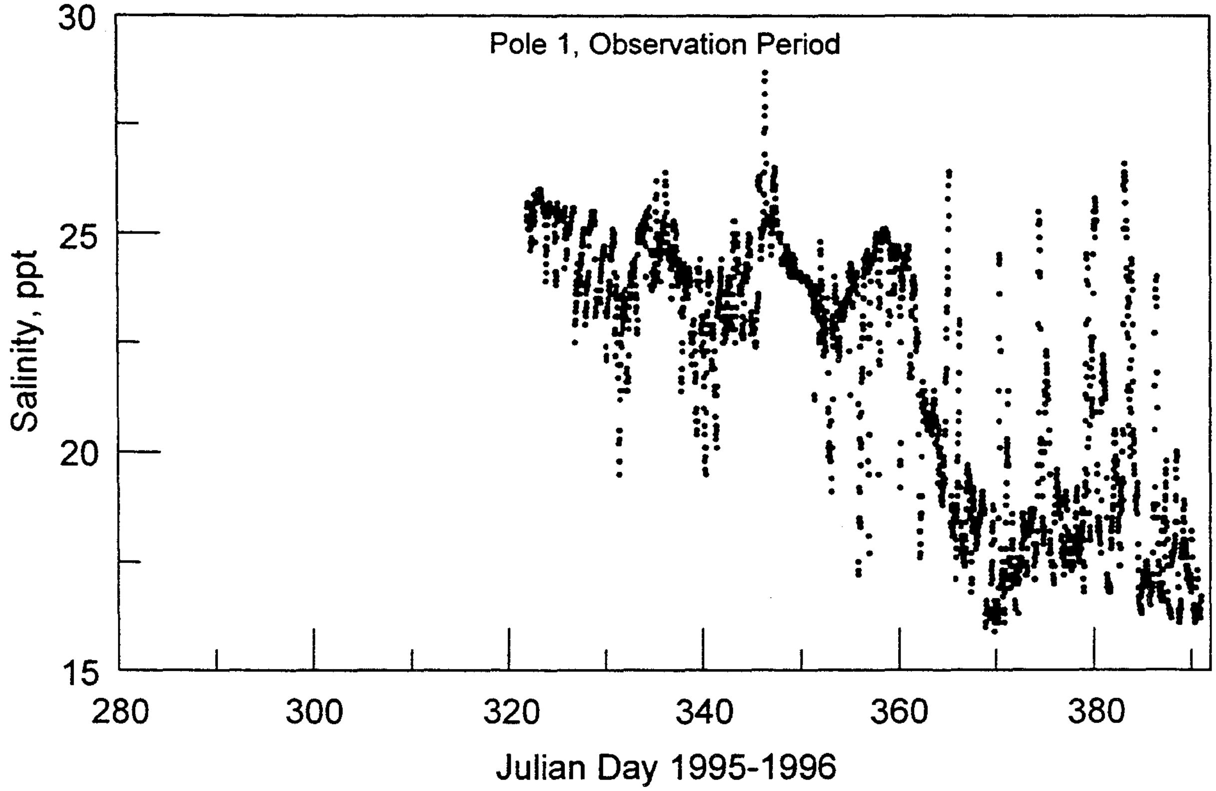

January 1996, N - S Component
East Matagorda
SW East Matagorda
Water Velocity, cm/s
20
10
0
-10
-20
-30
-40
366
371
376
381
386
391
Julian Day 1996

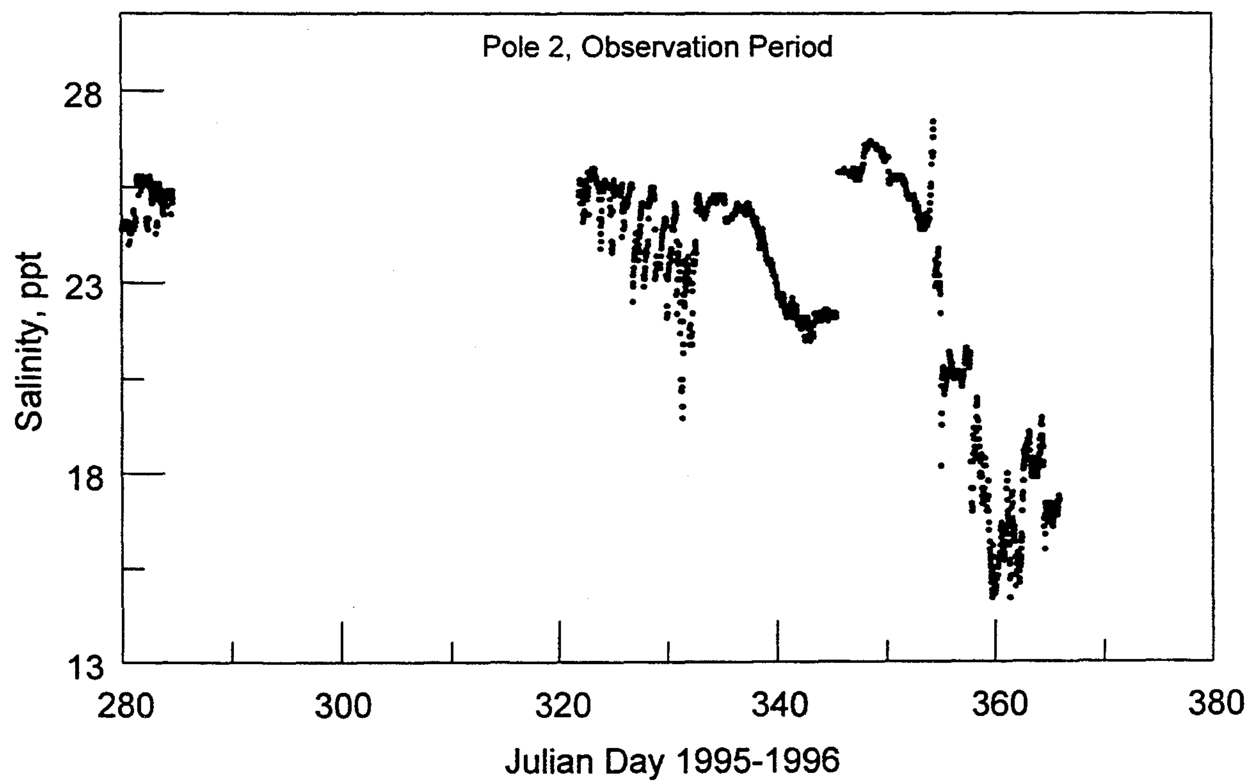

January 1996, E - W Component
East Matagorda
SW East Matagorda
Water Velocity, cm/s
30
20
10
0
-10
-20
366
371
376
381
386
391
Julian Day 1996

Salinity

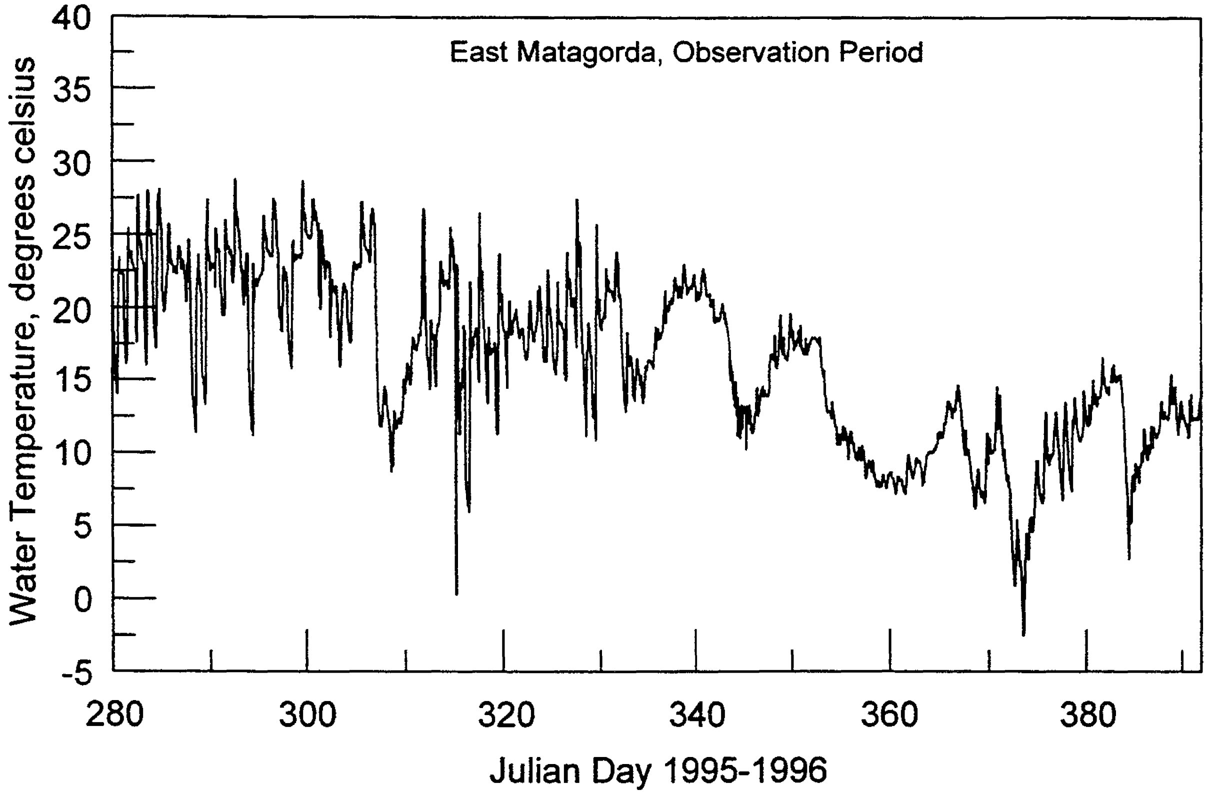

East Matagorda, Observation Period
35
30
25
20
15
10
5
Salinity, ppt
280
300
320
340
360
380
Julian Day 1995-1996

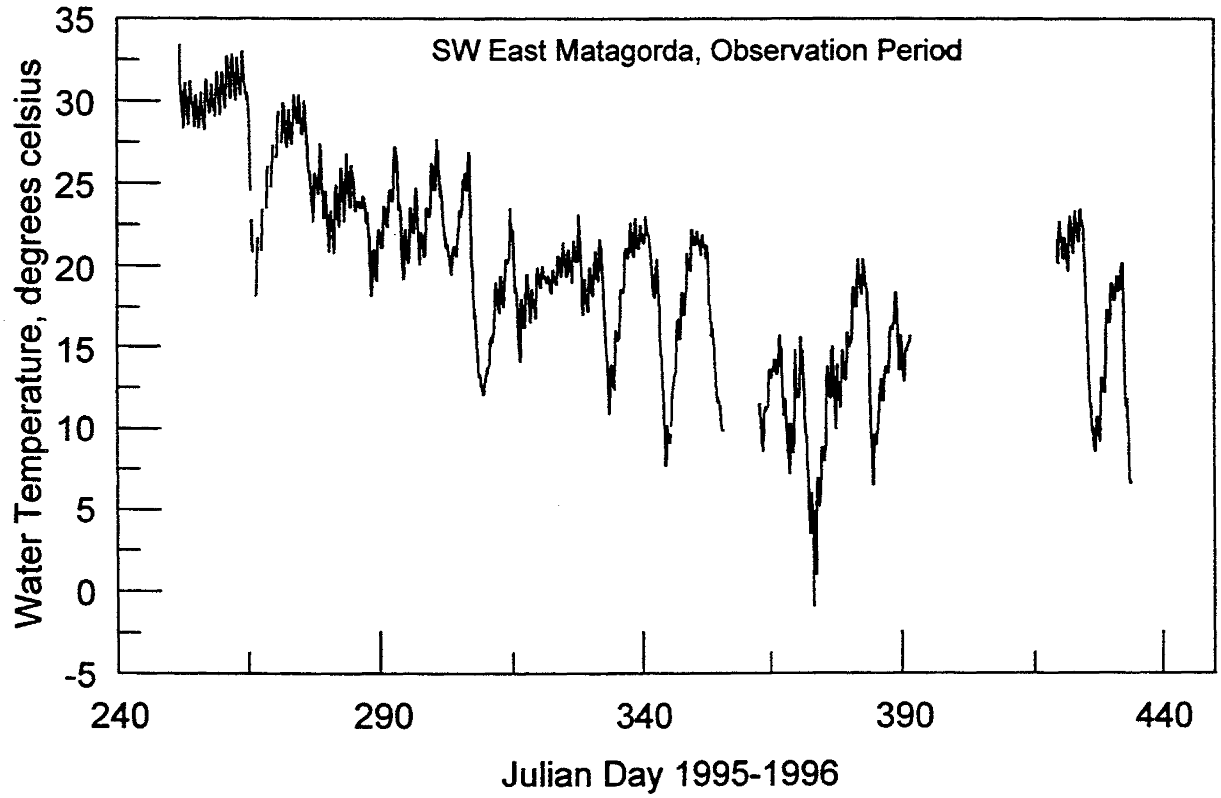

SW East Matagorda, Observation Period
32
30
28
26
24
22
20
18
16
Salinity, ppt
280
300
320
340
360
380
Julian Day 1995-1996

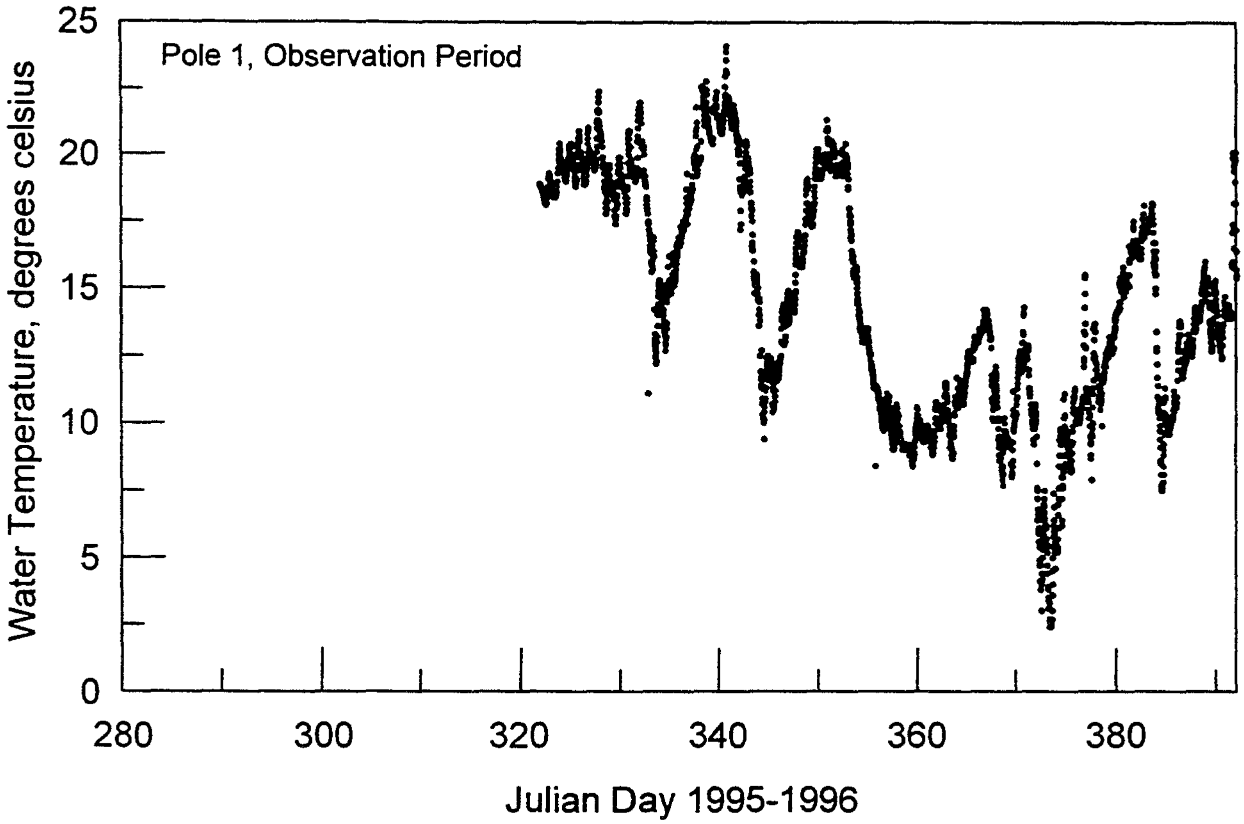

Pole 1, Observation Period
30
25
20
15
280
300
320
340
360
380
Salinity, ppt
Julian Day 1995-1996


Pole 2, Observation Period
28
23
18
13
280
300
320
340
360
380
Salinity, ppt
Julian Day 1995-1996

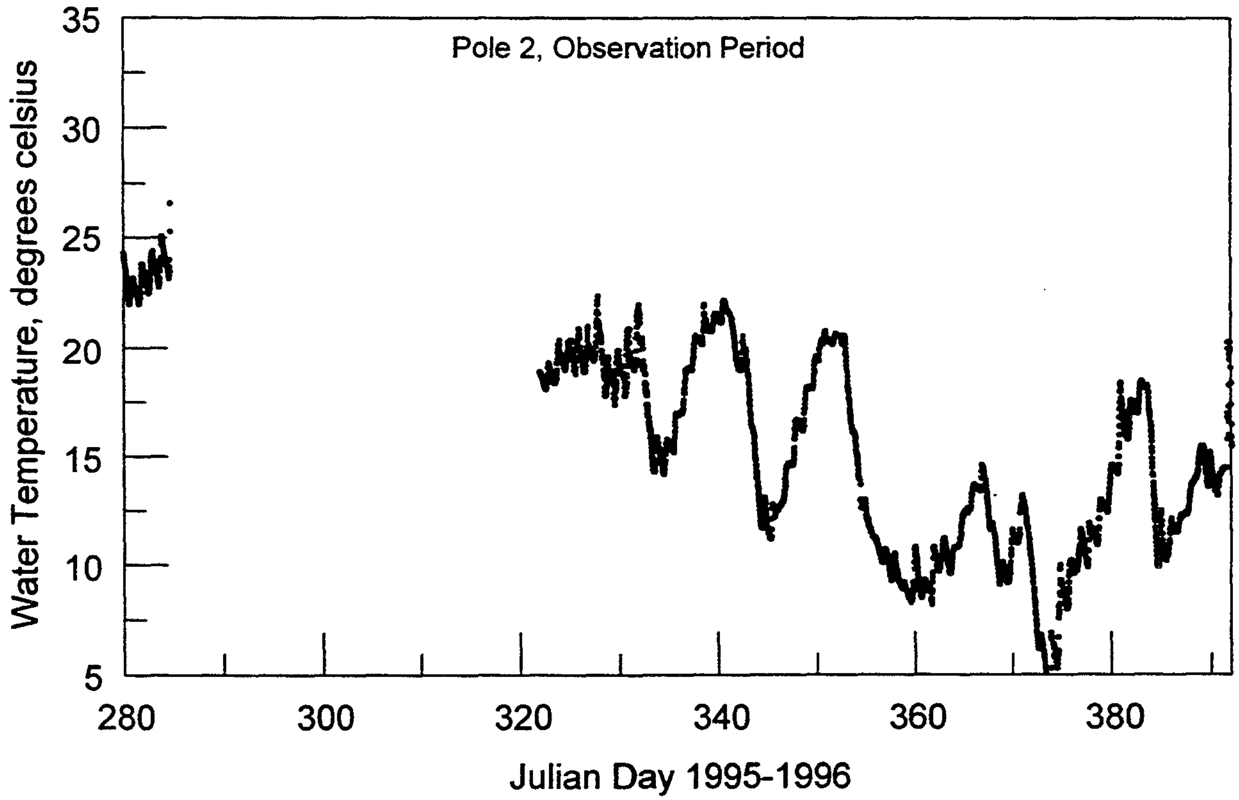
Water Temperature





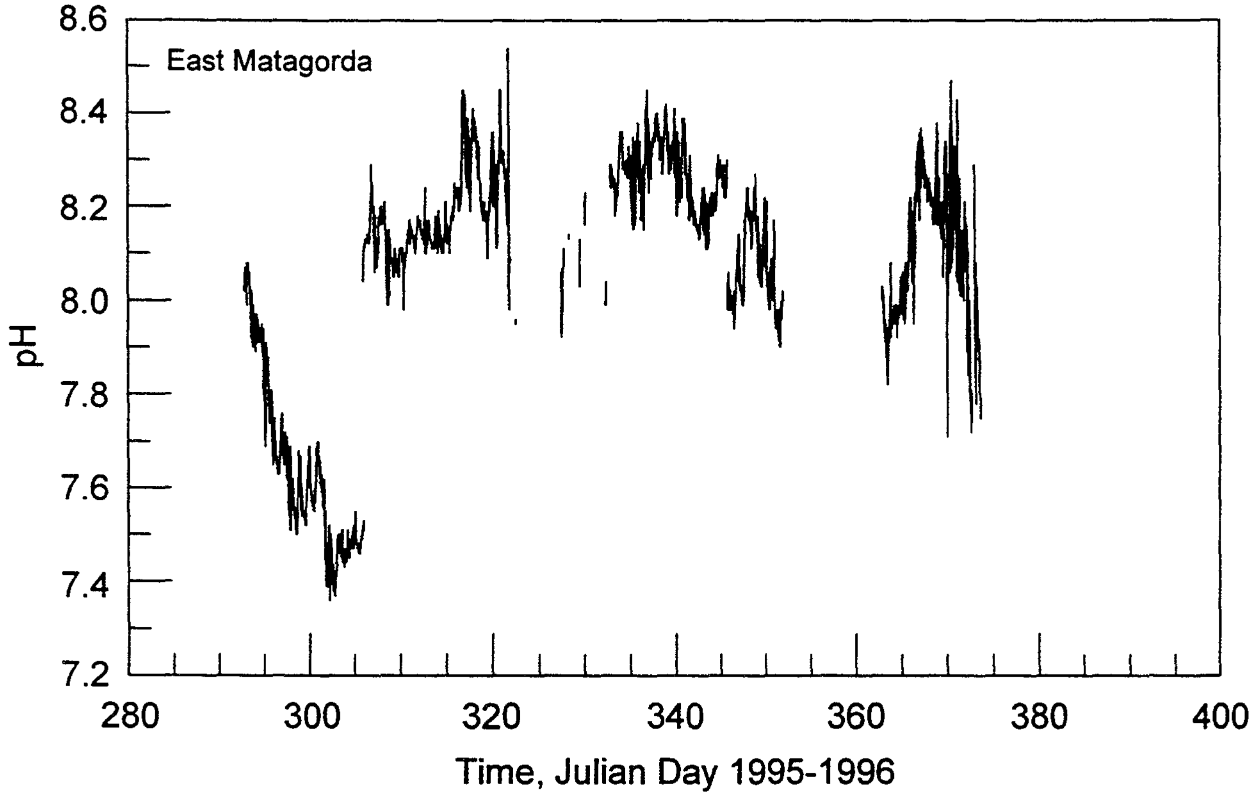


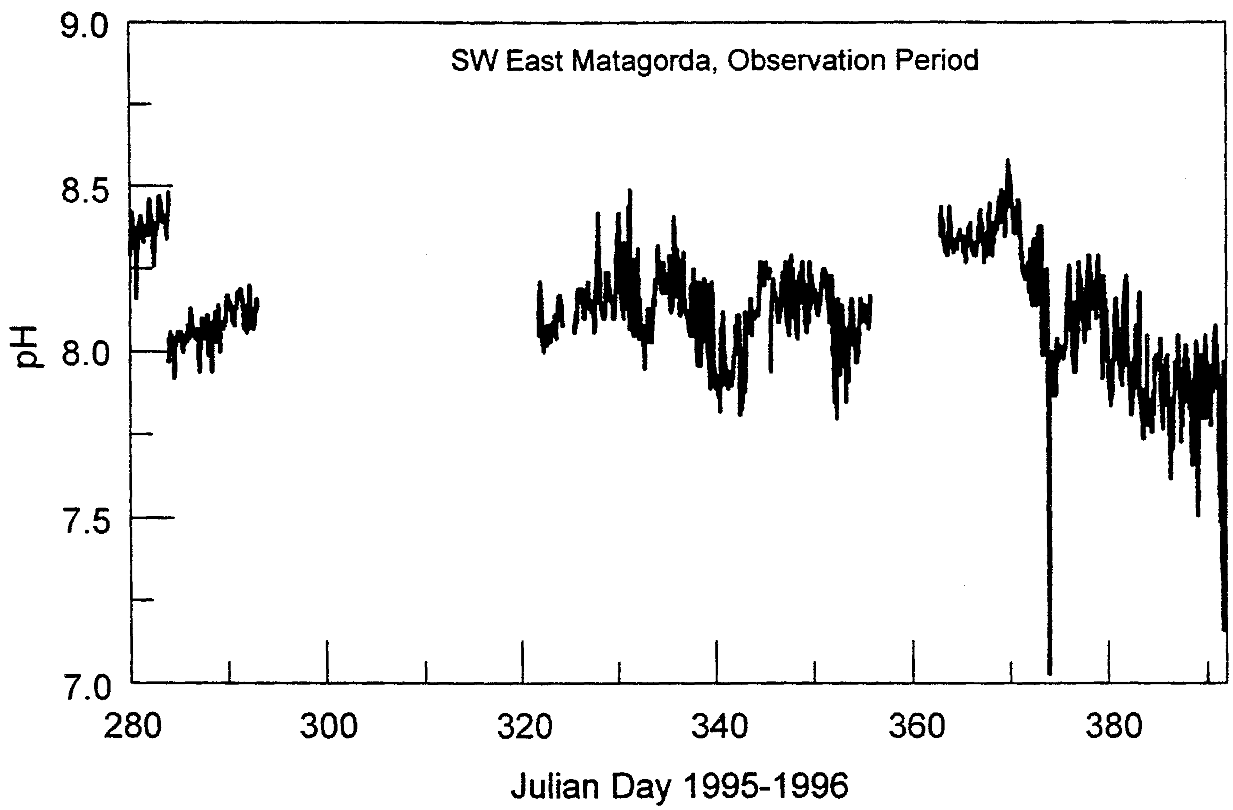
Pole 1, Observation Period
Water Temperature, degrees celsius
25
20
15
10
5
0
280
300
320
340
360
380
Julian Day 1995-1996



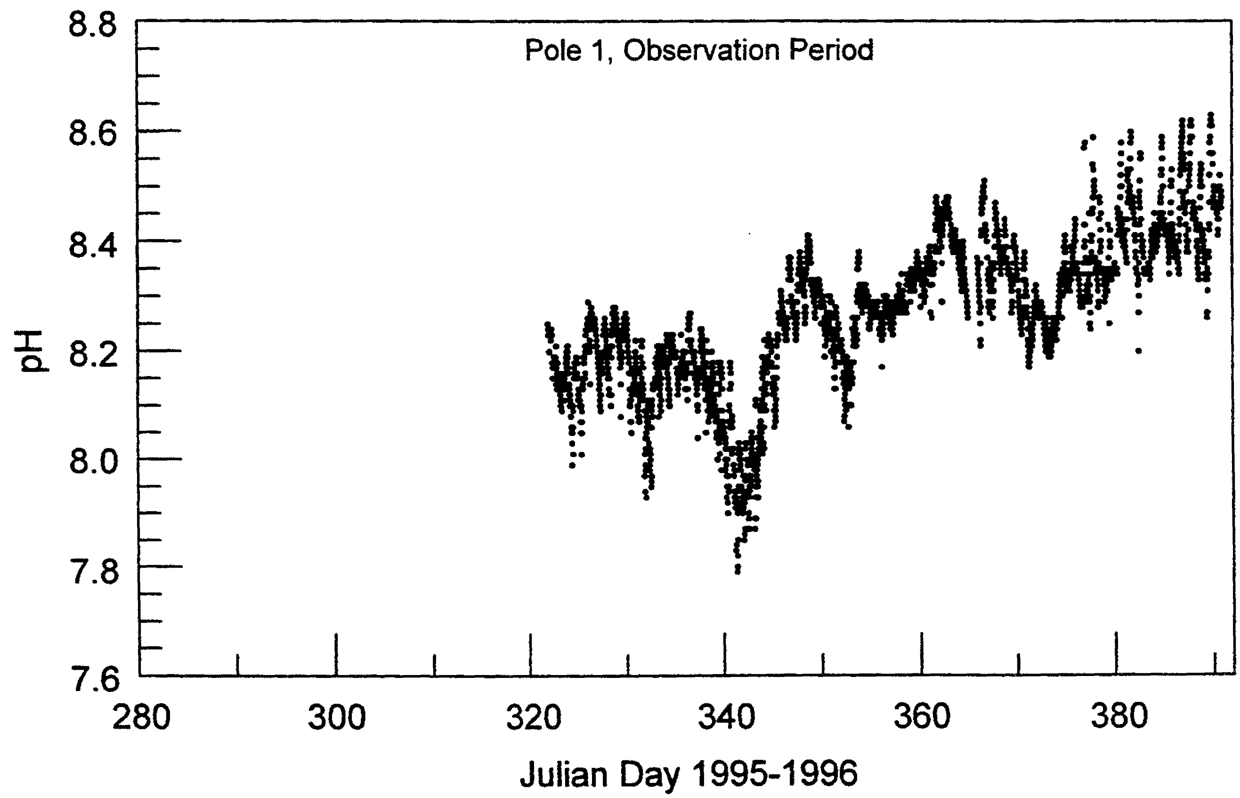
Pole 2, Observation Period
Water Temperature, degrees celsius
35
30
25
20
15
10
5
280
300
320
340
360
380
Julian Day 1995-1996

pH

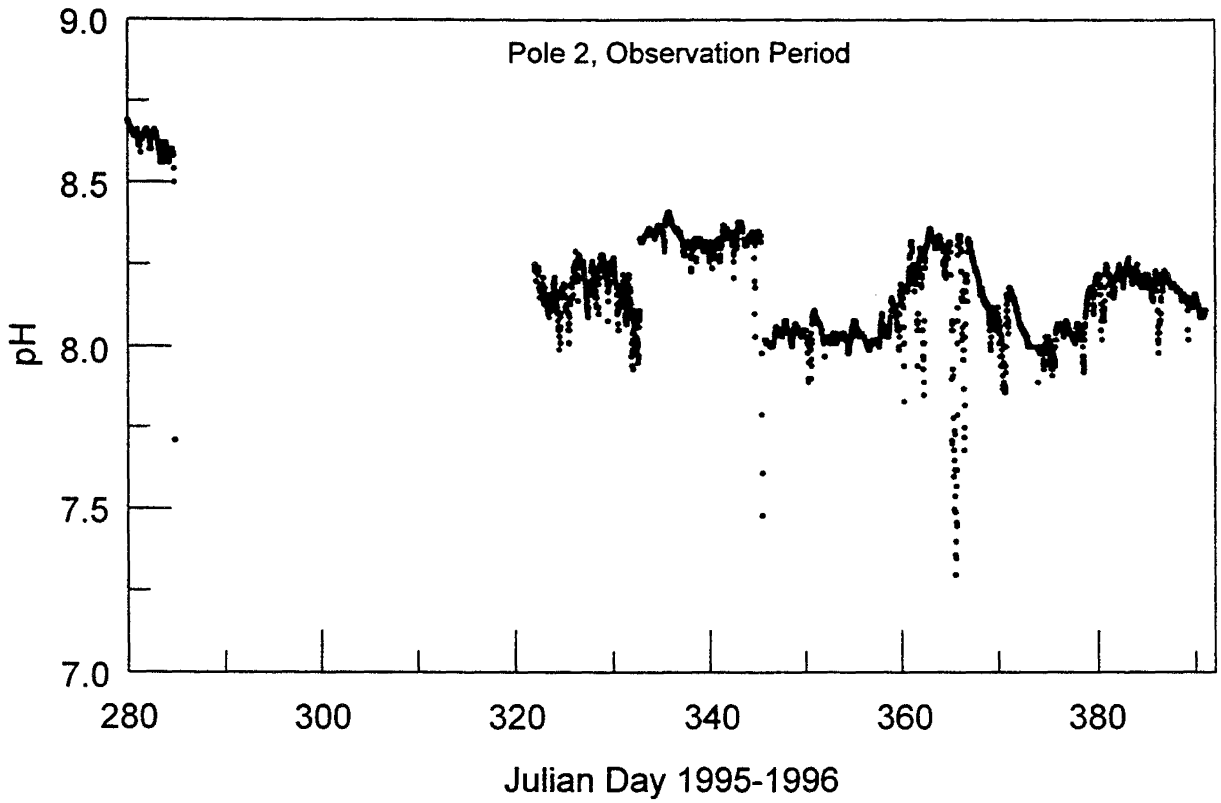

East Matagorda
8.6
8.4
8.2
8.0
7.8
7.6
7.4
7.2
pH
280
300
320
340
360
380
400
Time, Julian Day 1995-1996



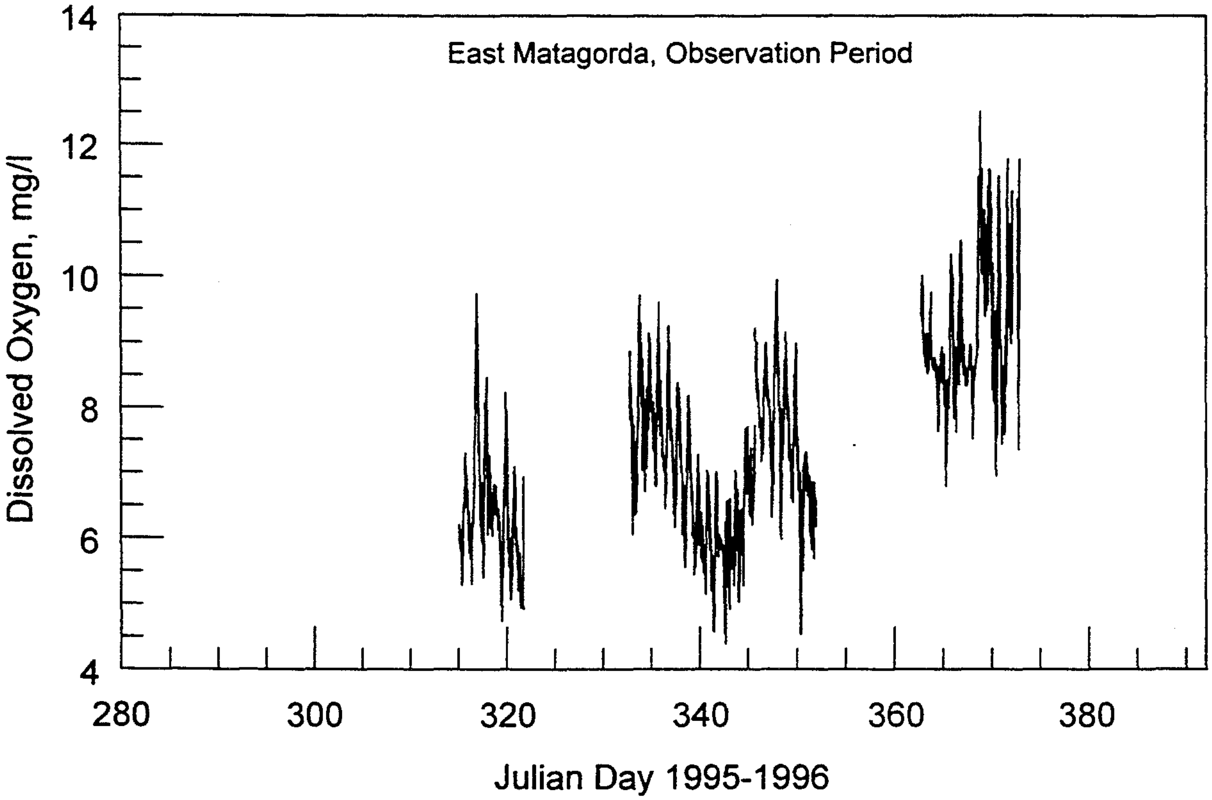
SW East Matagorda, Observation Period
pH
9.0
8.5
8.0
7.5
7.0
280
300
320
340
360
380
Julian Day 1995-1996

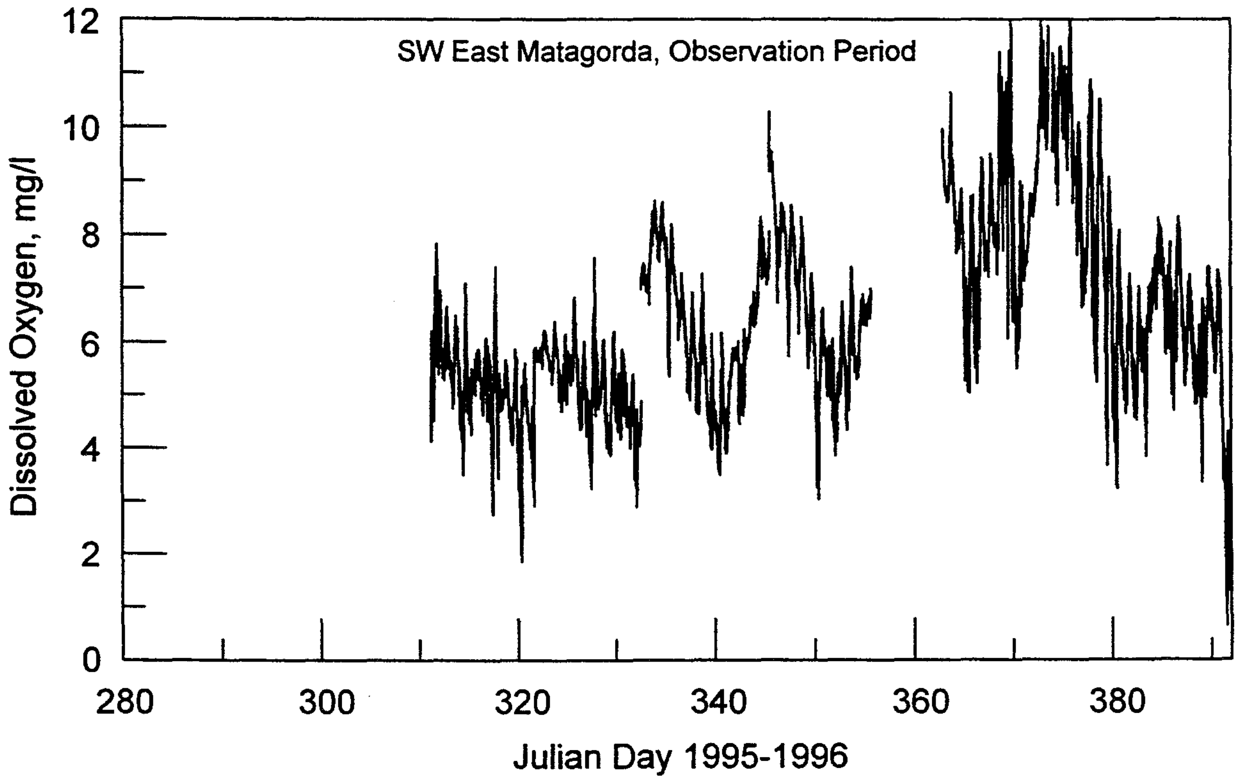


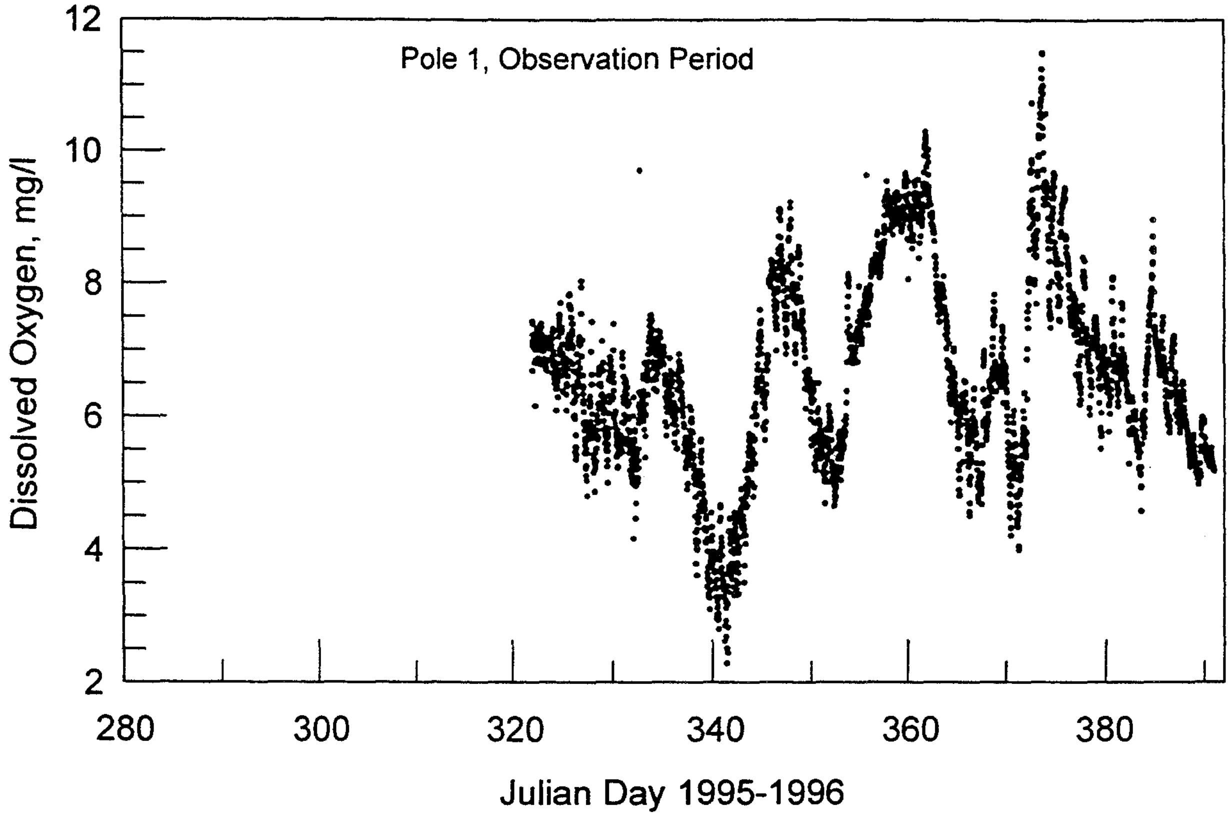
Pole 1, Observation Period
pH
8.8
8.6
8.4
8.2
8.0
7.8
7.6
280
300
320
340
360
380
Julian Day 1995-1996

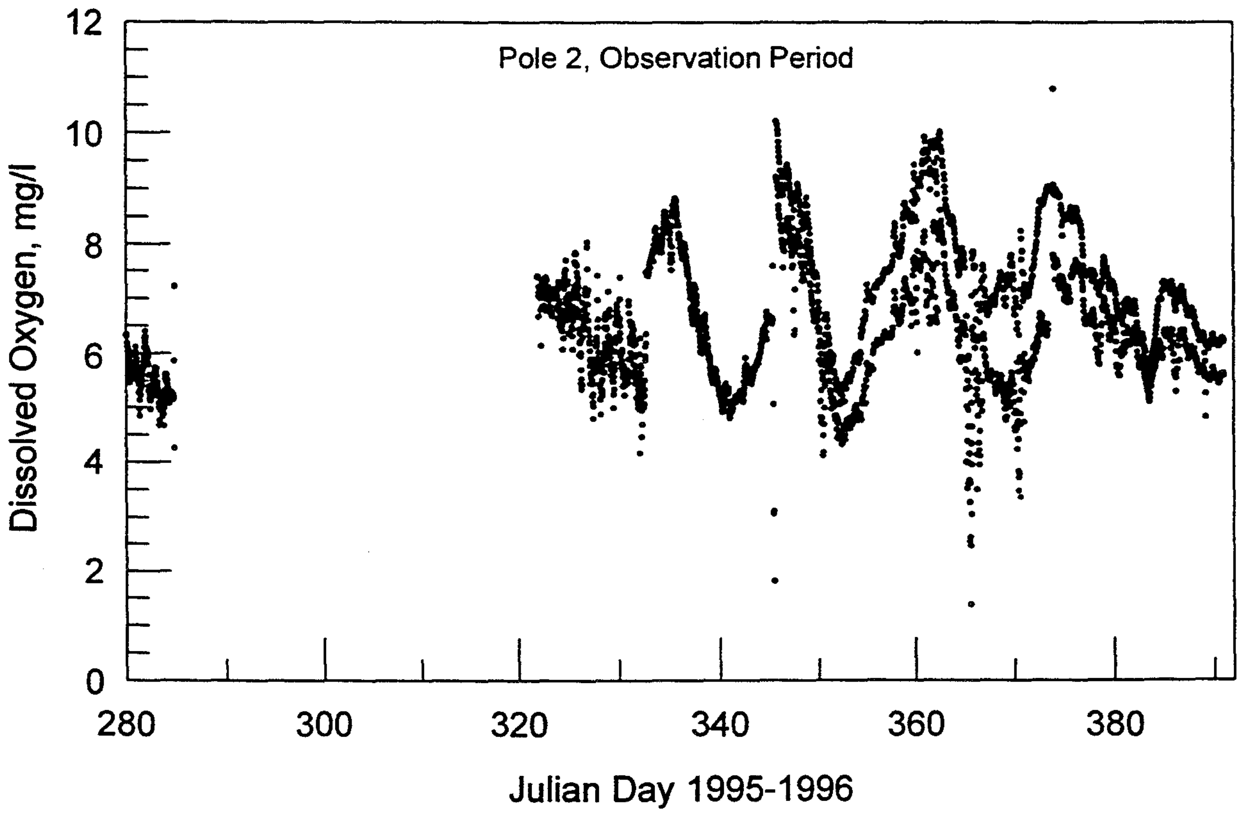


Dissolved Oxygen


East Matagorda, Observation Period
Dissolved Oxygen, mg/l
Julian Day 1995-1996
14
12
10
8
6
4
280
300
320
340
360
380


SW East Matagorda, Observation Period
Dissolved Oxygen, mg/l
Julian Day 1995-1996
12
10
8
6
4
2
0
280
300
320
340
360
380


Pole 1, Observation Period
Dissolved Oxygen, mg/l
Julian Day 1995-1996
12
10
8
6
4
2
280
300
320
340
360
380


Pole 2, Observation Period
Dissolved Oxygen, mg/l
Julian Day 1995-1996
12
10
8
6
4
2
0
280
300
320
340
360
380

Appendix E : A Pictorial Overview of East Matagorda Bay, Texas[1]

This appendix consists of two sections that contain, respectively, aerial and ground photographs of major morphological features and instrument platforms established or referenced in this study. The first section, aerial photographs, primarily covers the eastern and western vicinities of East Matagorda Bay. The approximate locations of the aerial photographs are given in Figure E-1. The second section, ground photographs, contains photographs of the instrument platforms and major morphological features discussed in the main text of this report.

[1] Prepared by Julie Celum, Conrad Blucher Institute, Texas A&M University-Corpus Christi.

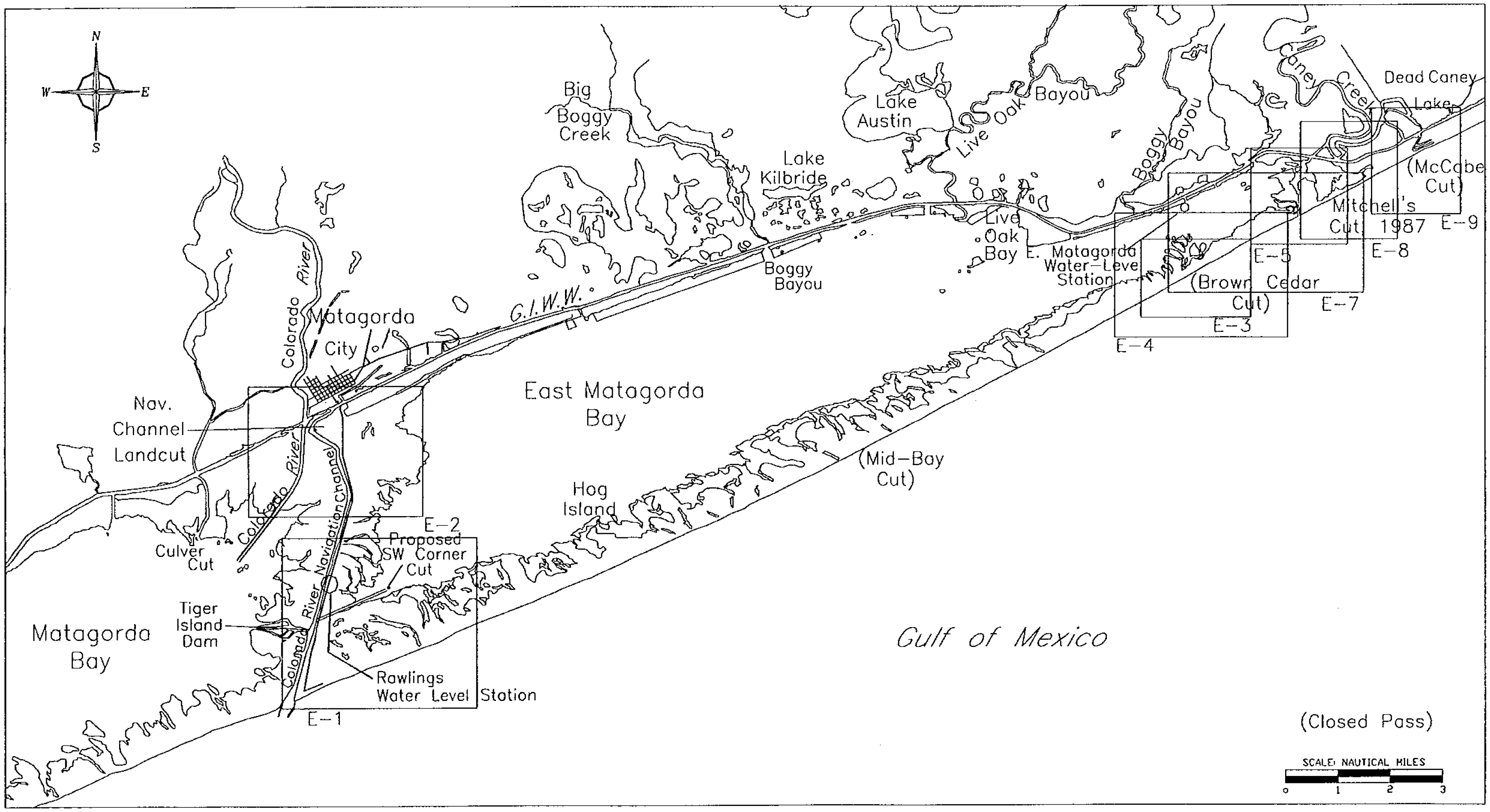


Figure E-1. Approximate location of aerial photograph coverage.

Aerial Photographs

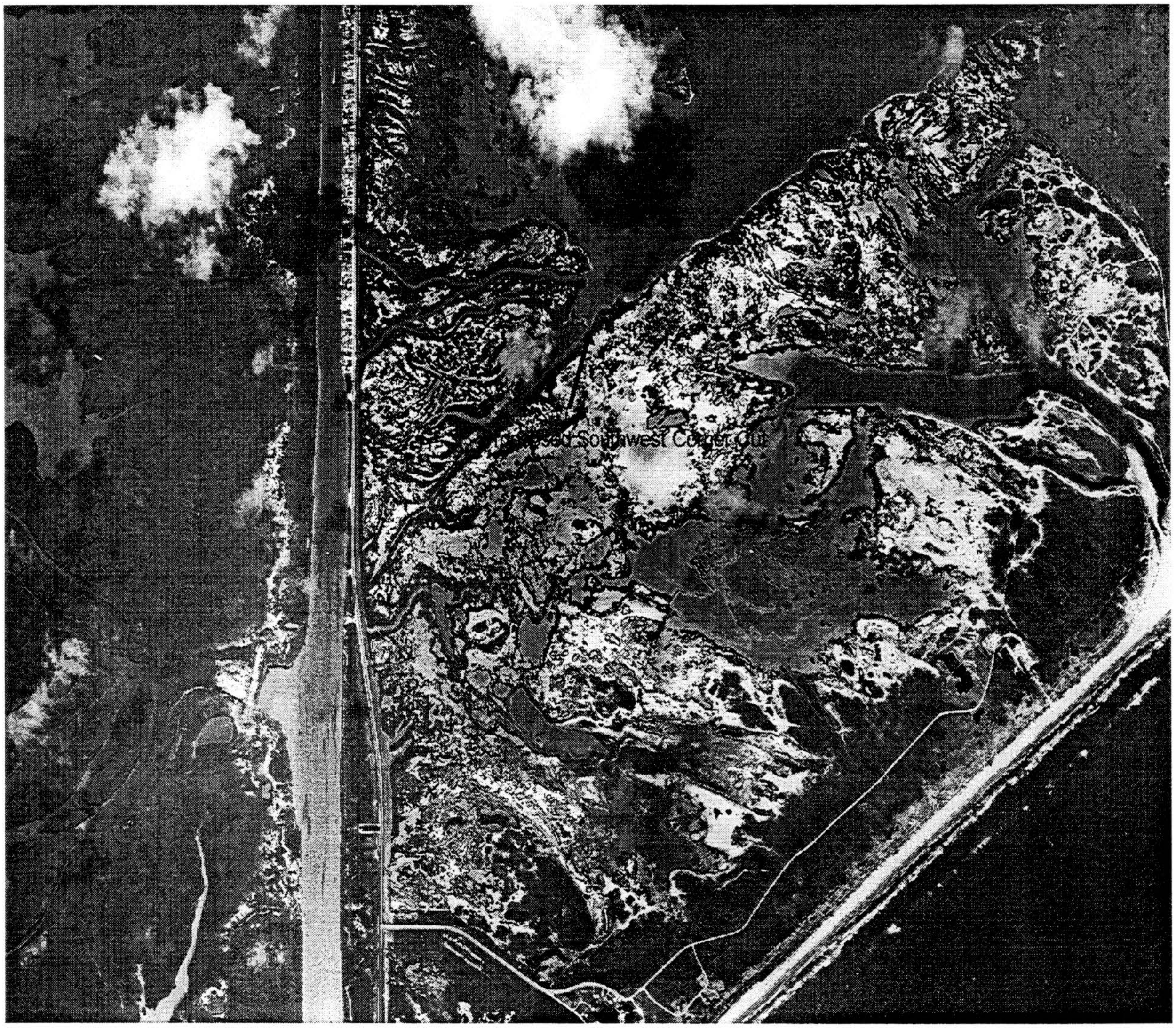


Figure E-2. Colorado River Navigation Channel and location of proposed SW Corner Cut, July 26, 1995.

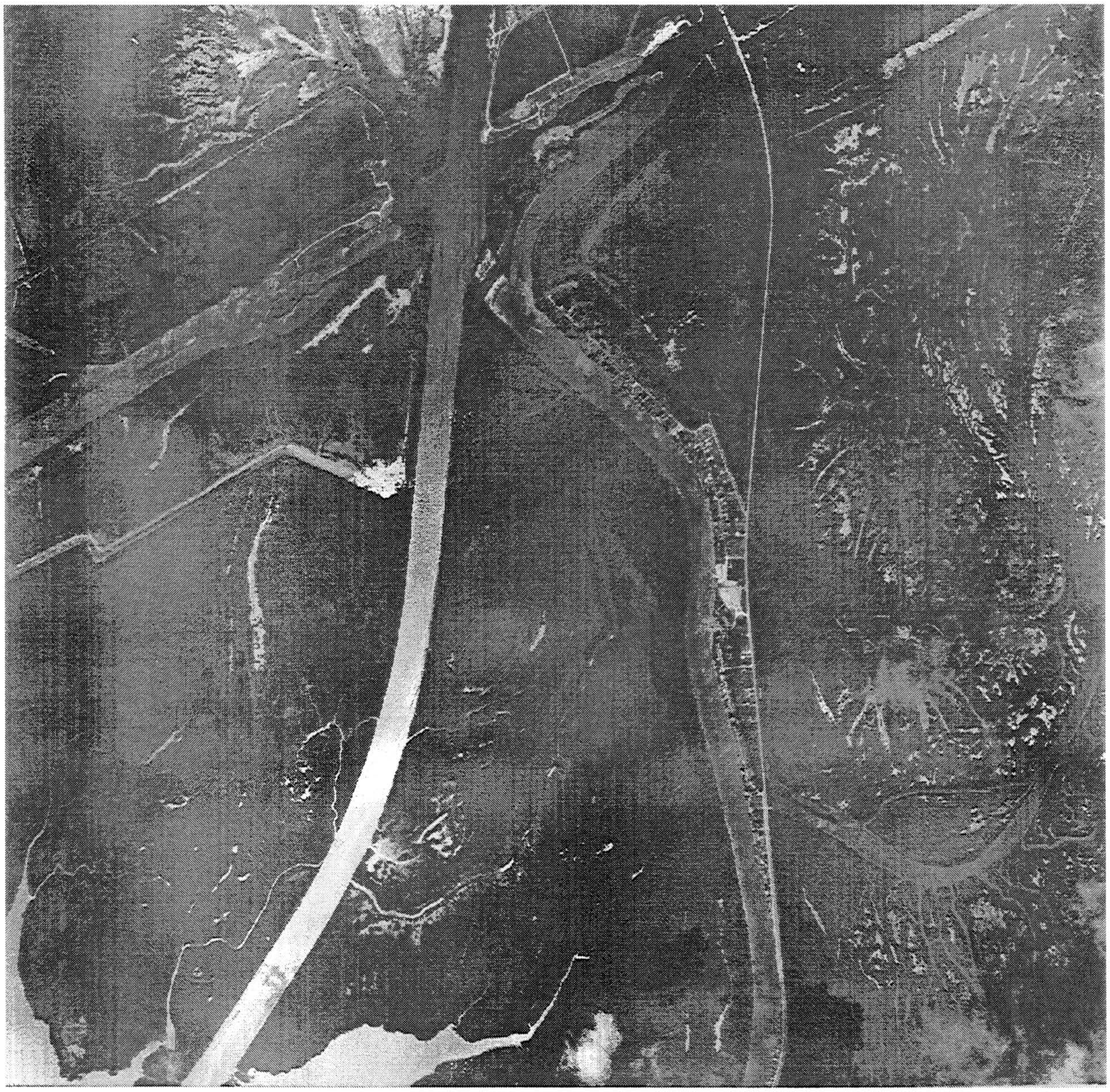


Figure E-3. Colorado River, East and West Locks on the GIWW, and the Colorado River Navigation Channel Landcut, July 26, 1995.

Figure E-4. Brown Cedar Cut, overwash delta, June 11, 1985.

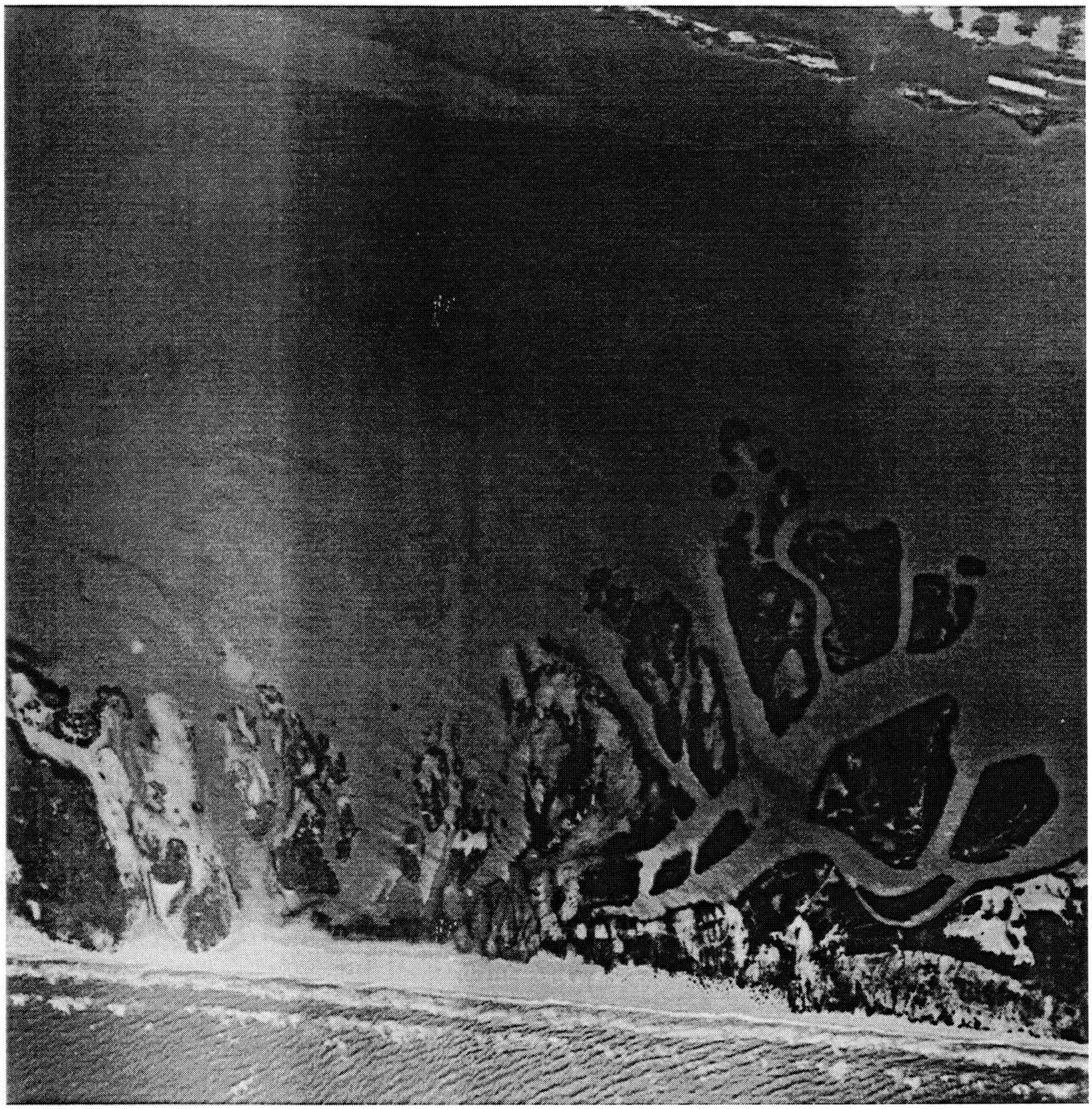


Figure E-5. Brown Cedar Cut, overwash delta, and barge traversing the GIWW (upper right hand corner of photograph), September 23, 1985.

Figure E-6. Redhouse Reef, on west side of Mitchell's Cut, September 23, 1985.

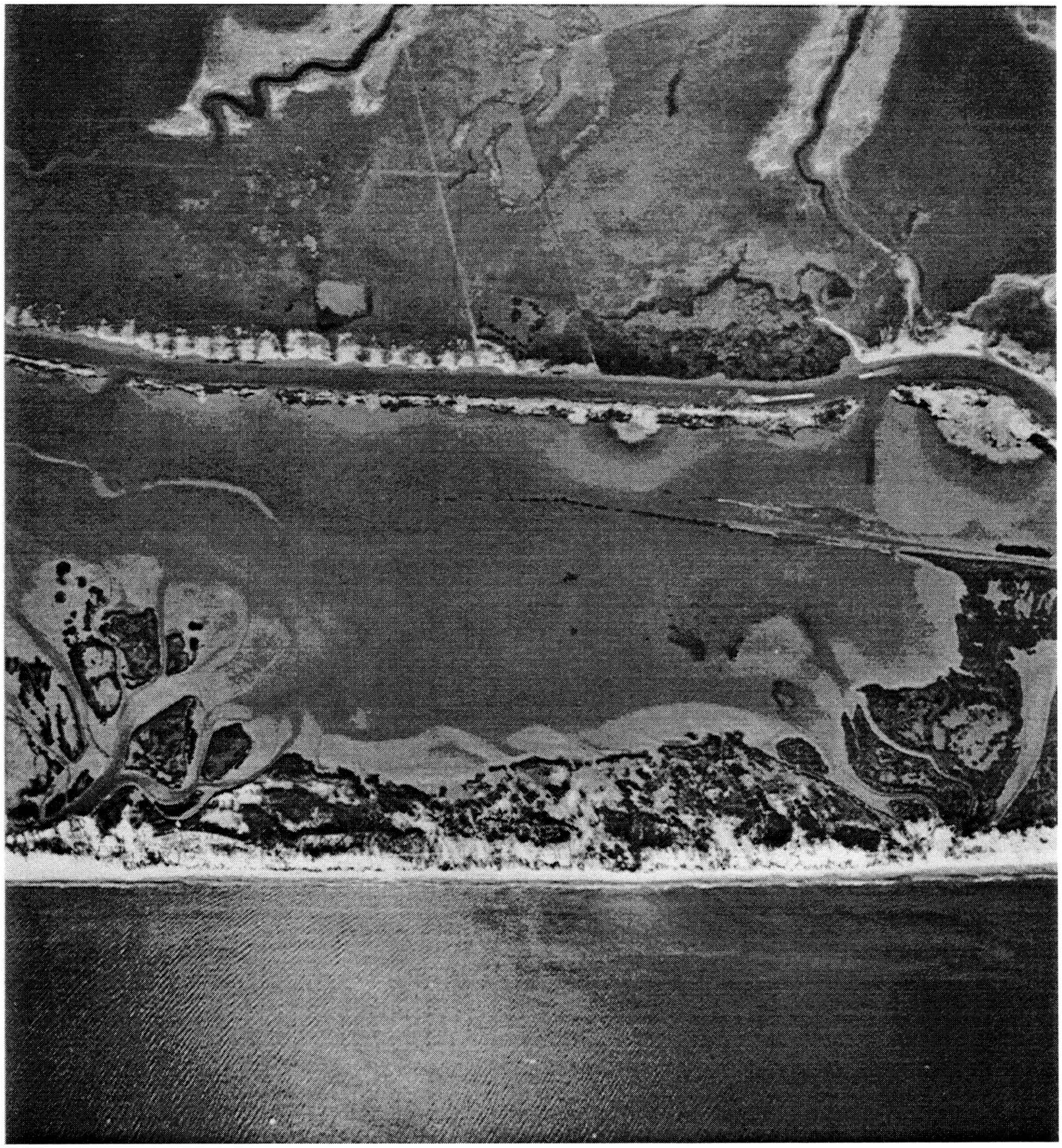


Figure E-7. Brown Cedar Cut delta to left, Redhouse Reef, and channel approaching site of Old Mitchell's Cut. Note relic GIWW and barge traffic in present GIWW, February 29, 1984.

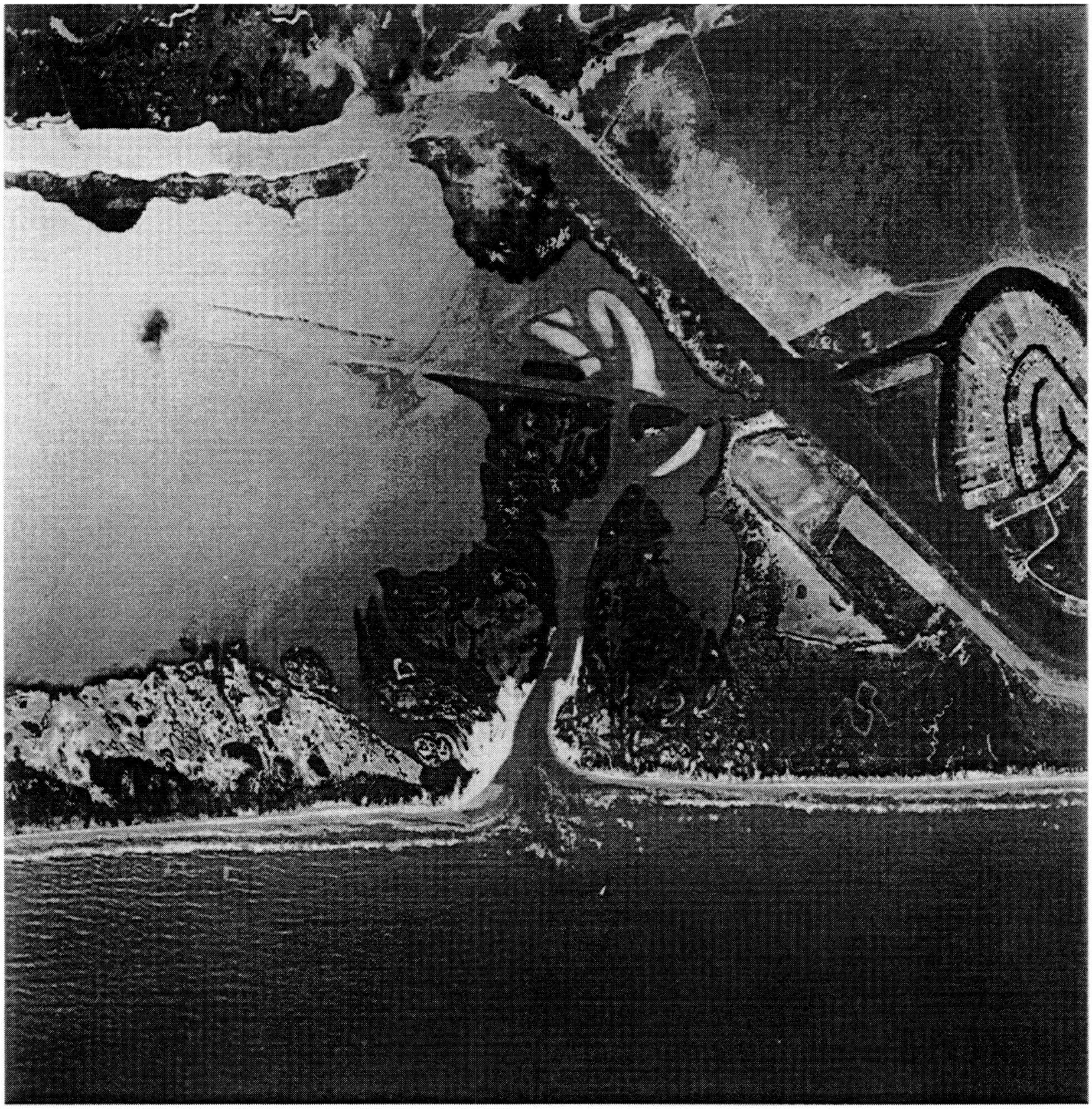


Figure E-8. Mitchell's Cut showing two channels into the Gulf, July 26, 1985.

Figure E-9. Mitchell's Cut, September 24,1990.

Figure E-10. McCabe's Cut, September 23, 1985; note channel orientation to Southwest.

Ground Photographs

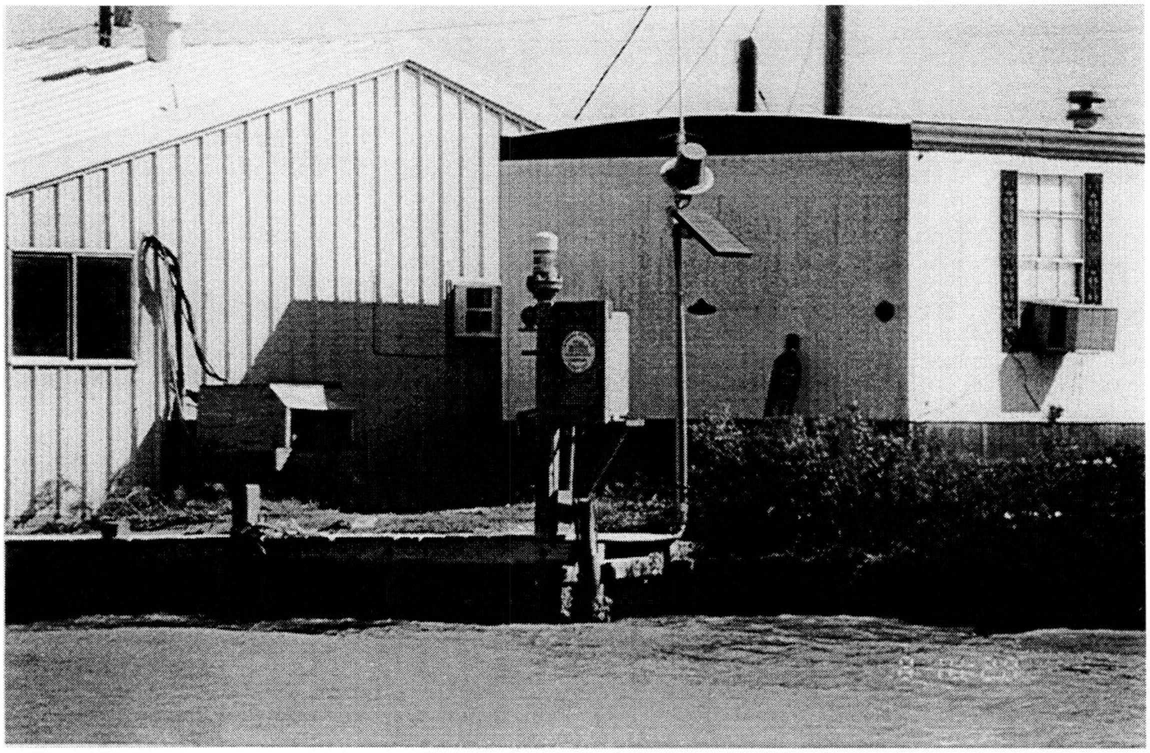


Figure E-11. Rawling's Bait Camp water-level station.

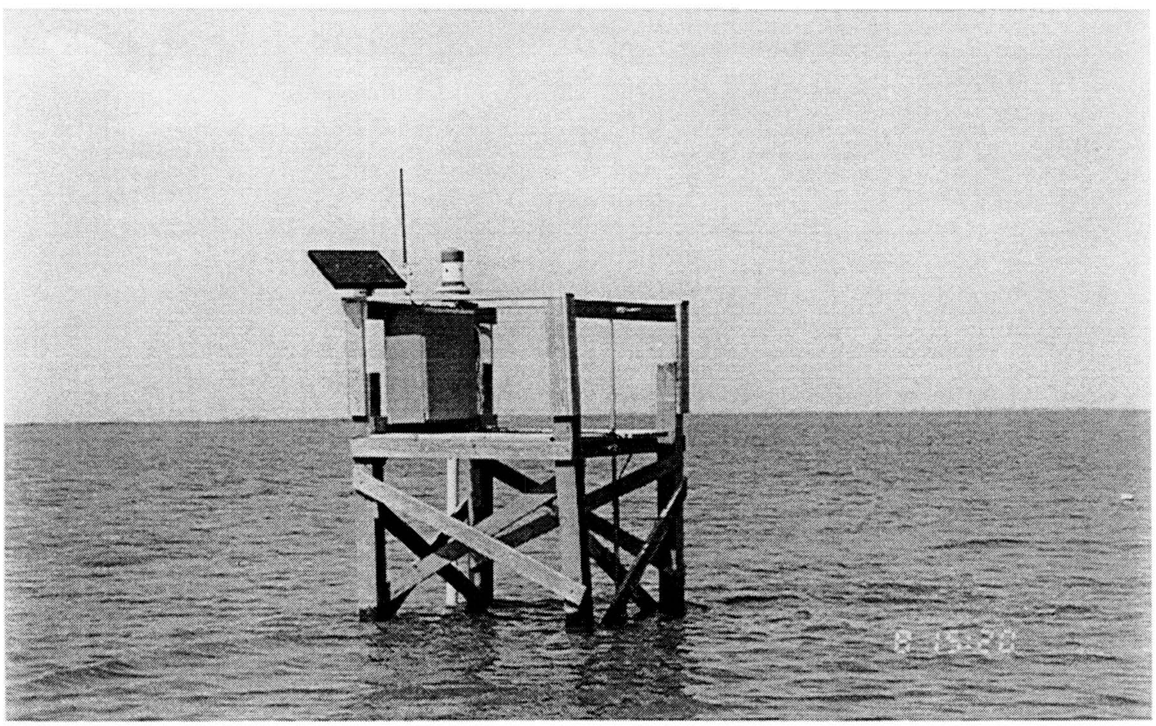


Figure E-12. SWEMAT platform.

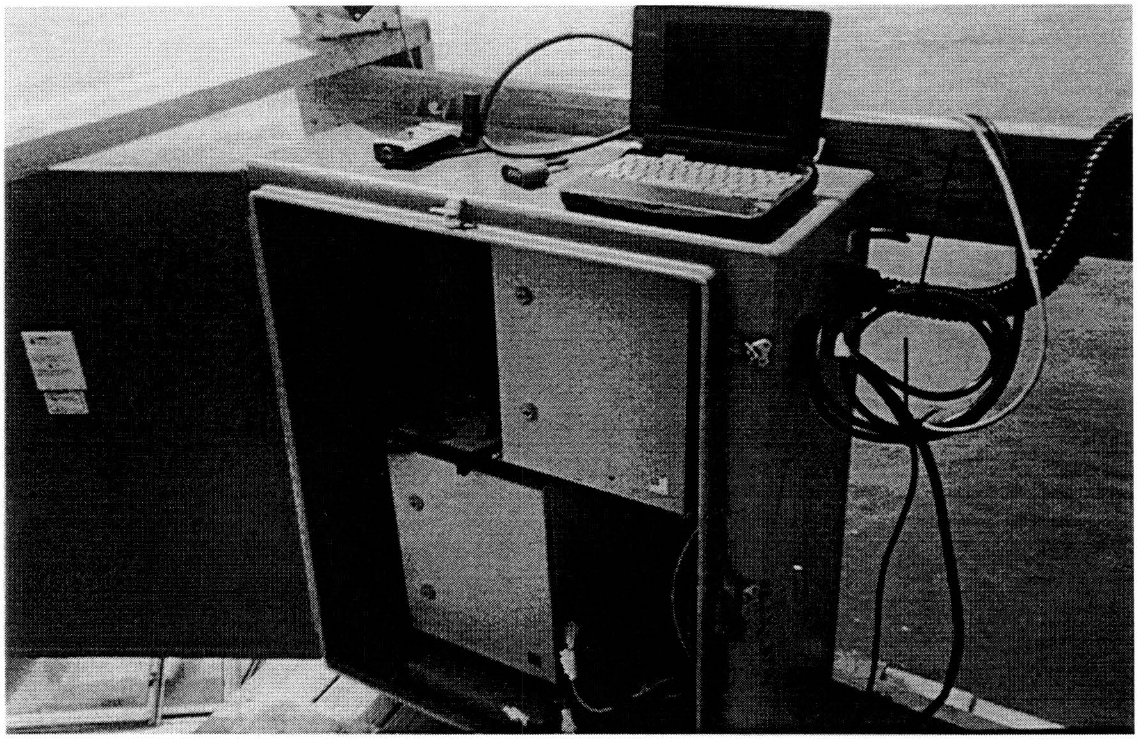


Figure E-13. SWEMAT electronics during data download.

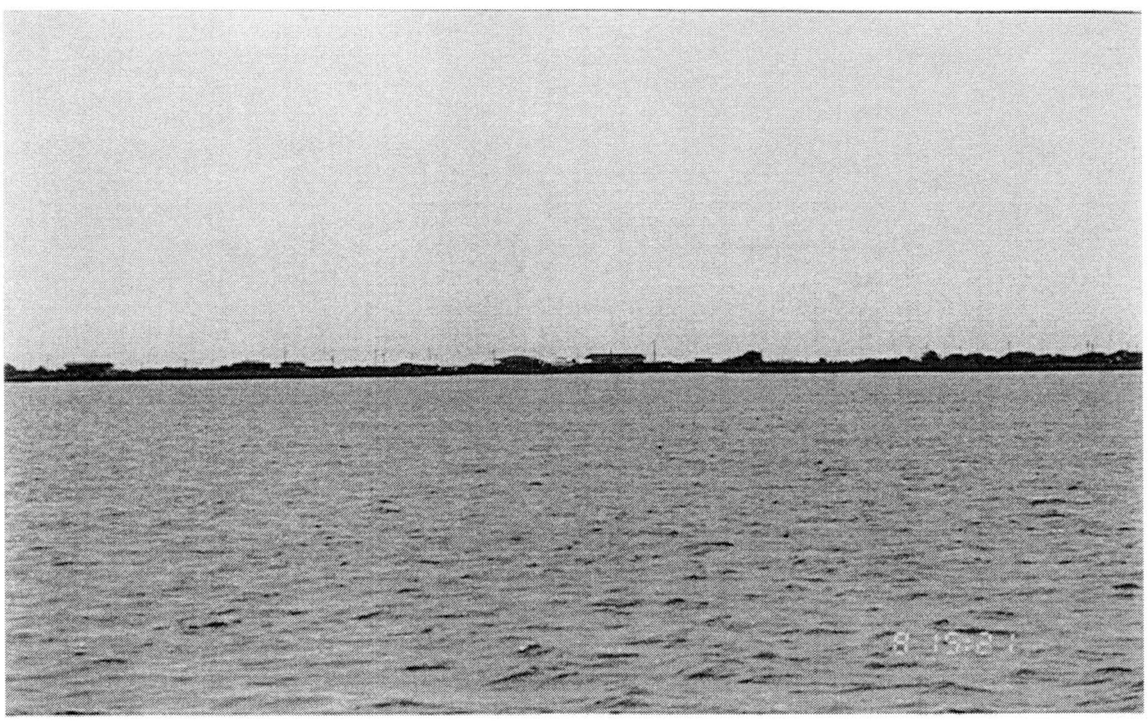


Figure E-14. Rawling's Bait Camp viewed from SWEMAT platform.

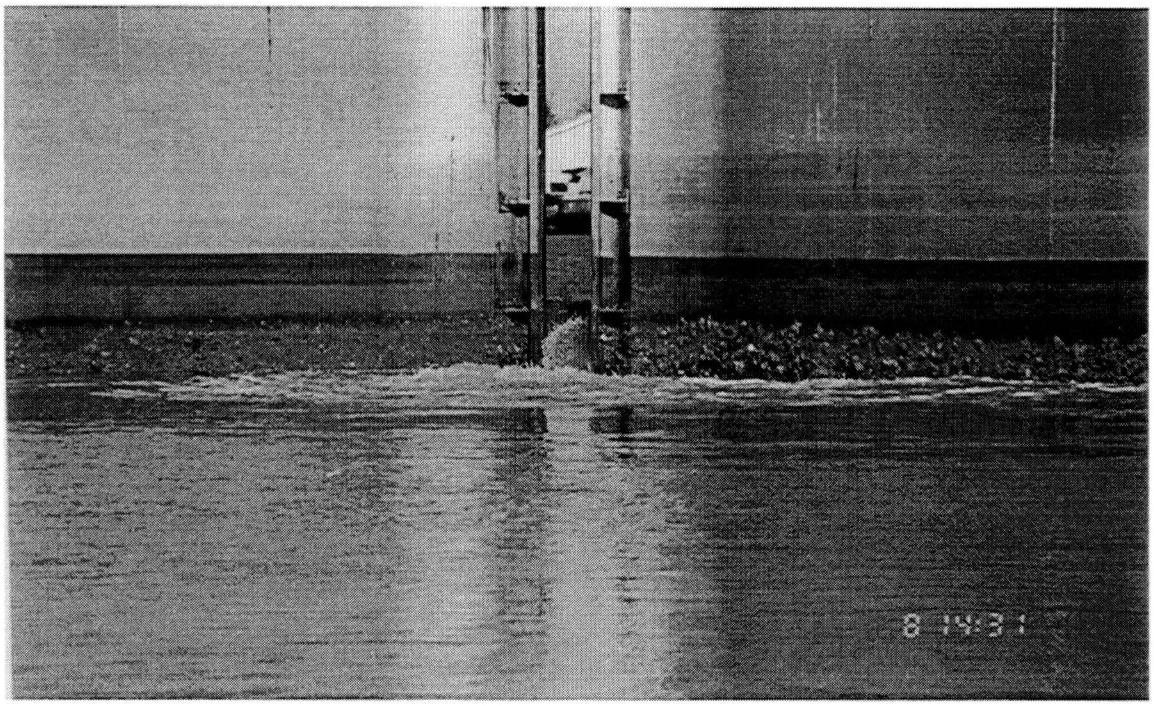


Figure E-15. Opening of gates at the East Lock (note approx. 1 ft difference in water level).

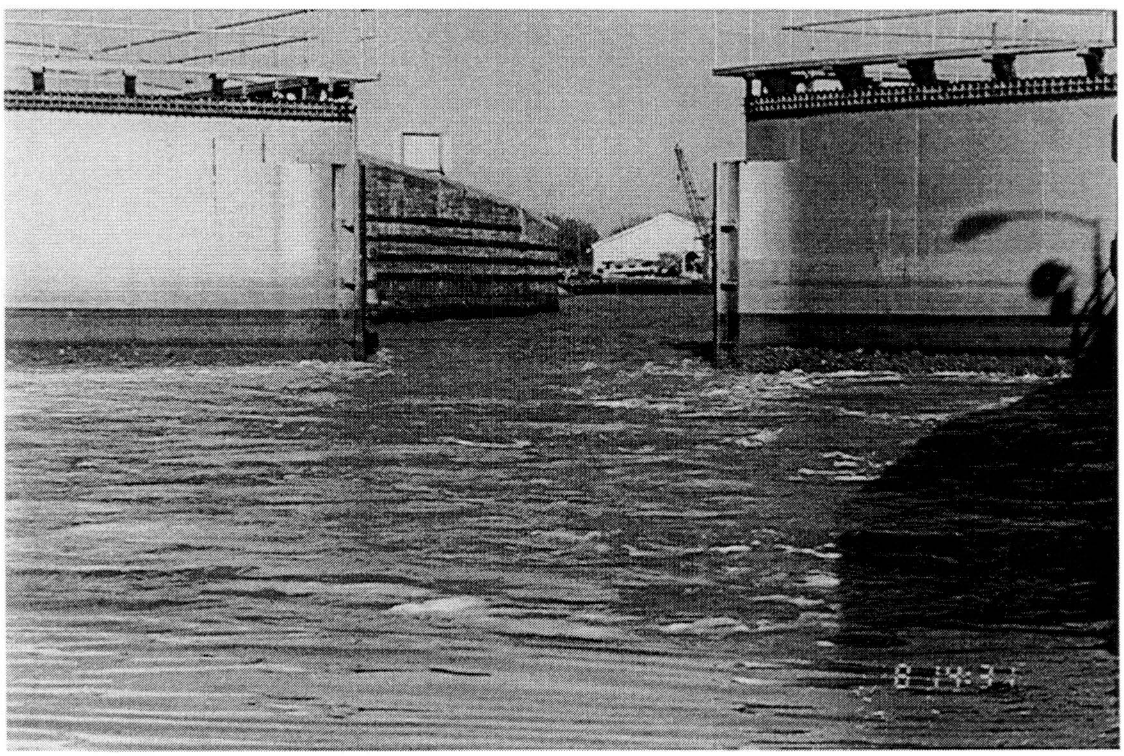


Figure E-16. Swirling current at the East Lock (east gate) while half open.

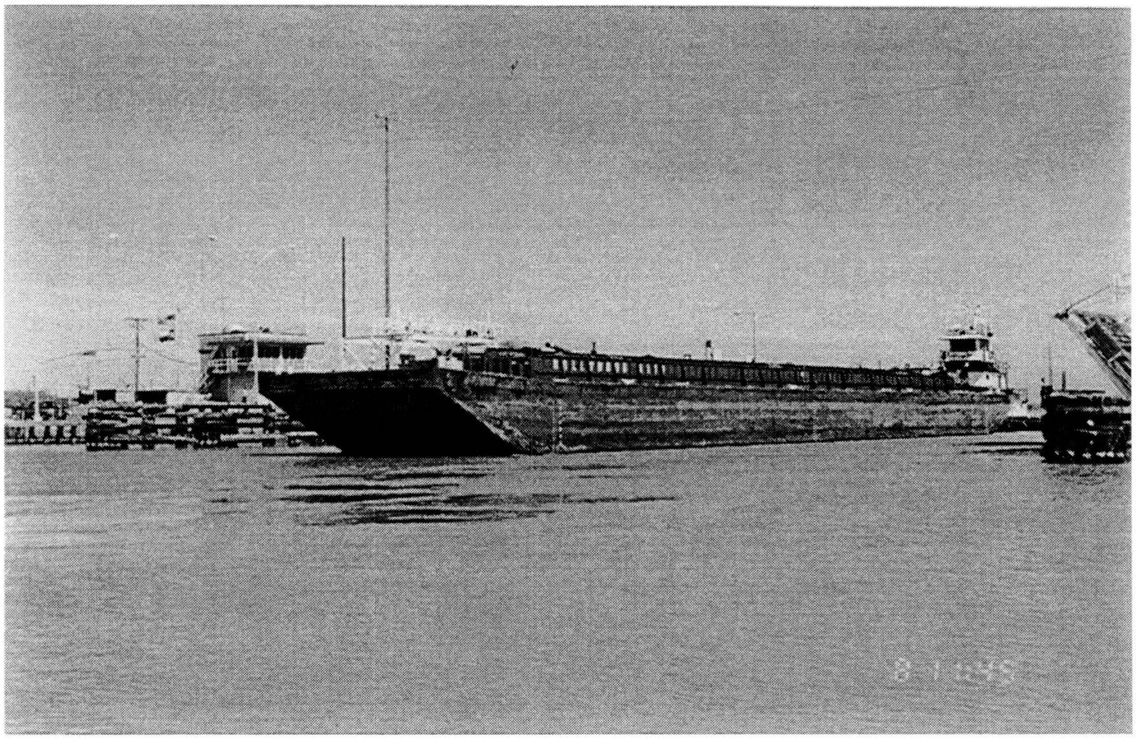


Figure E-17. Barge passing pontoon bridge on Farm Rd. 2031.

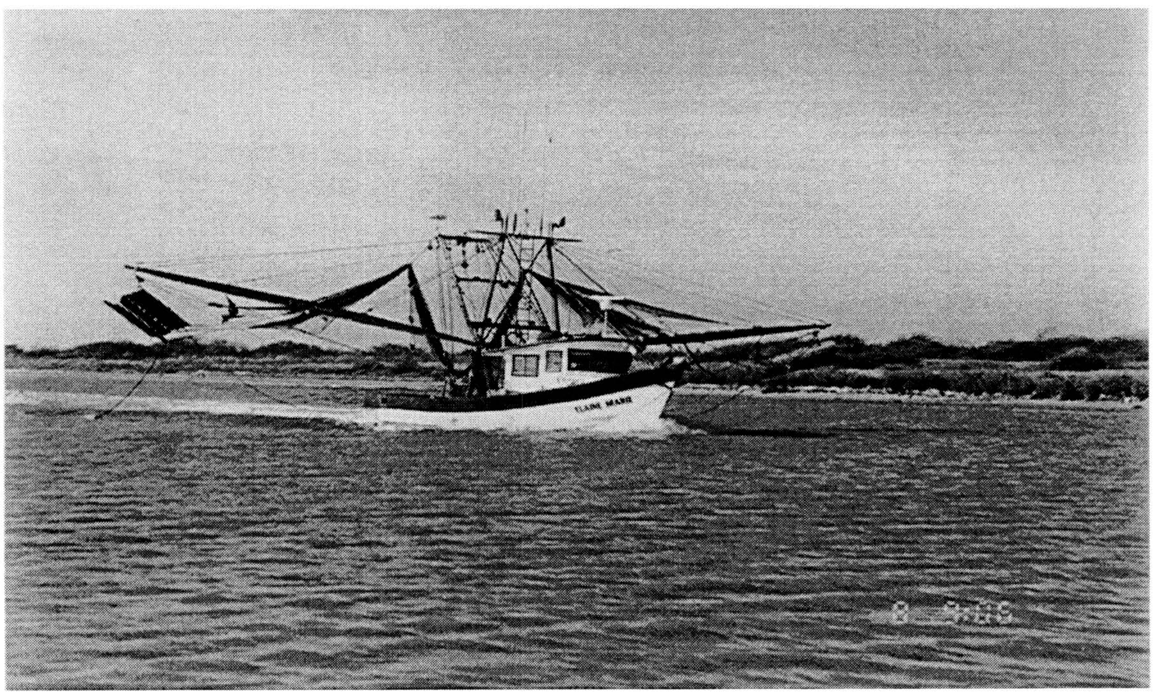


Figure E-18. Shrimp boat in Colorado River Navigation Channel.

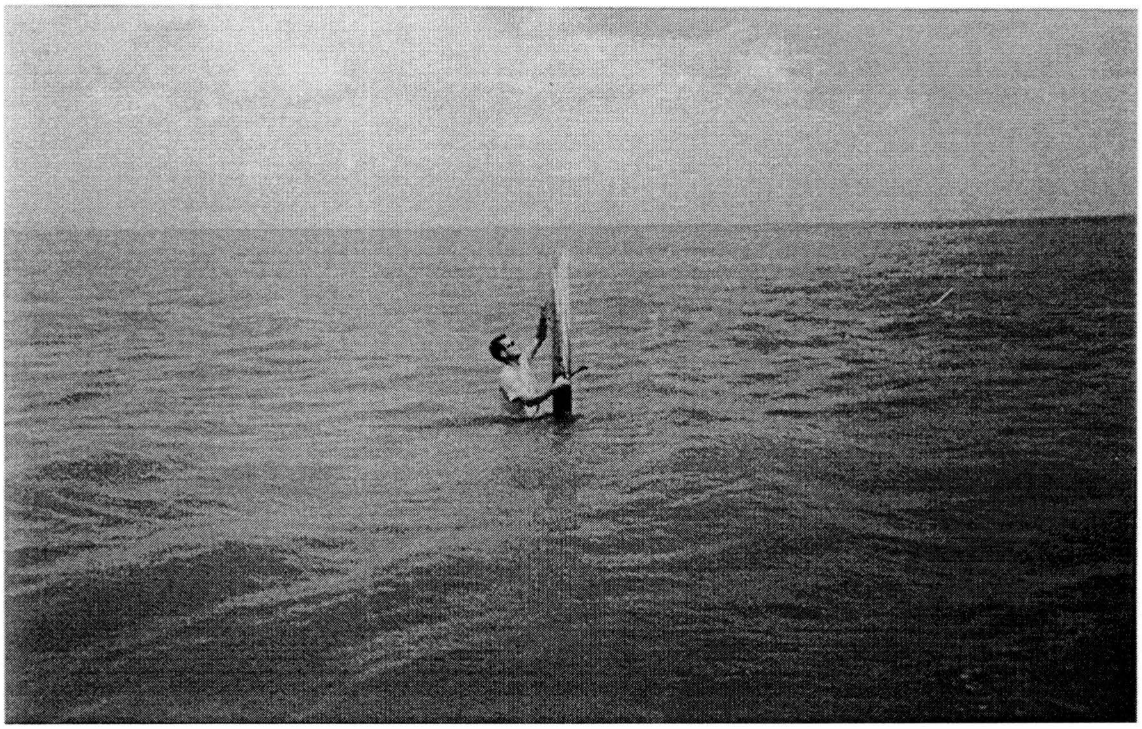


Figure E-19. Servicing Pole 2.

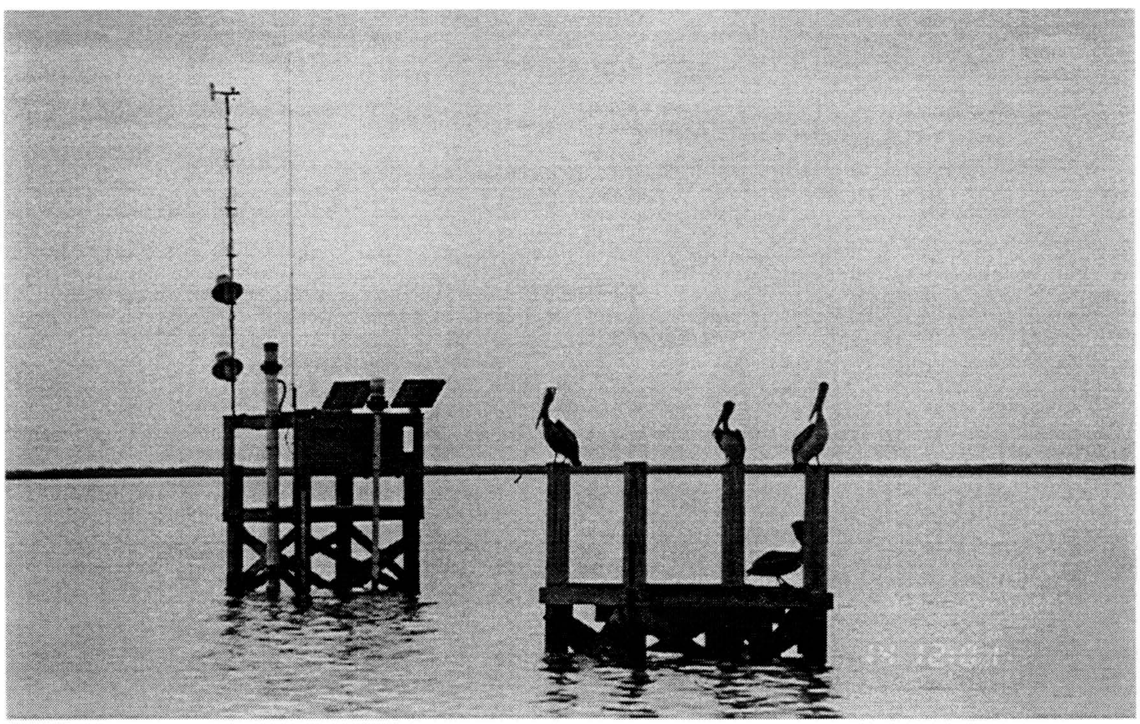


Figure E-20. East Matagorda main station (TCOON Station).

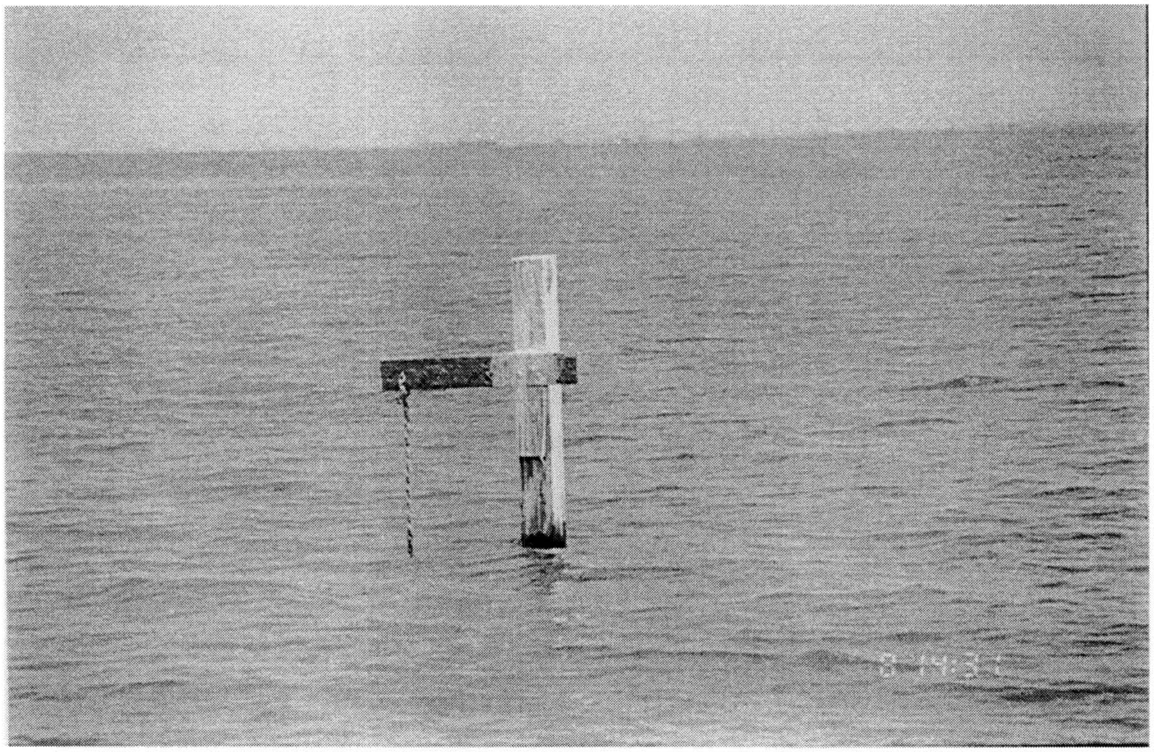


Figure E-21. Pole 1.

Figure E-22. Mitchell's Cut looking toward EMAT Bay.

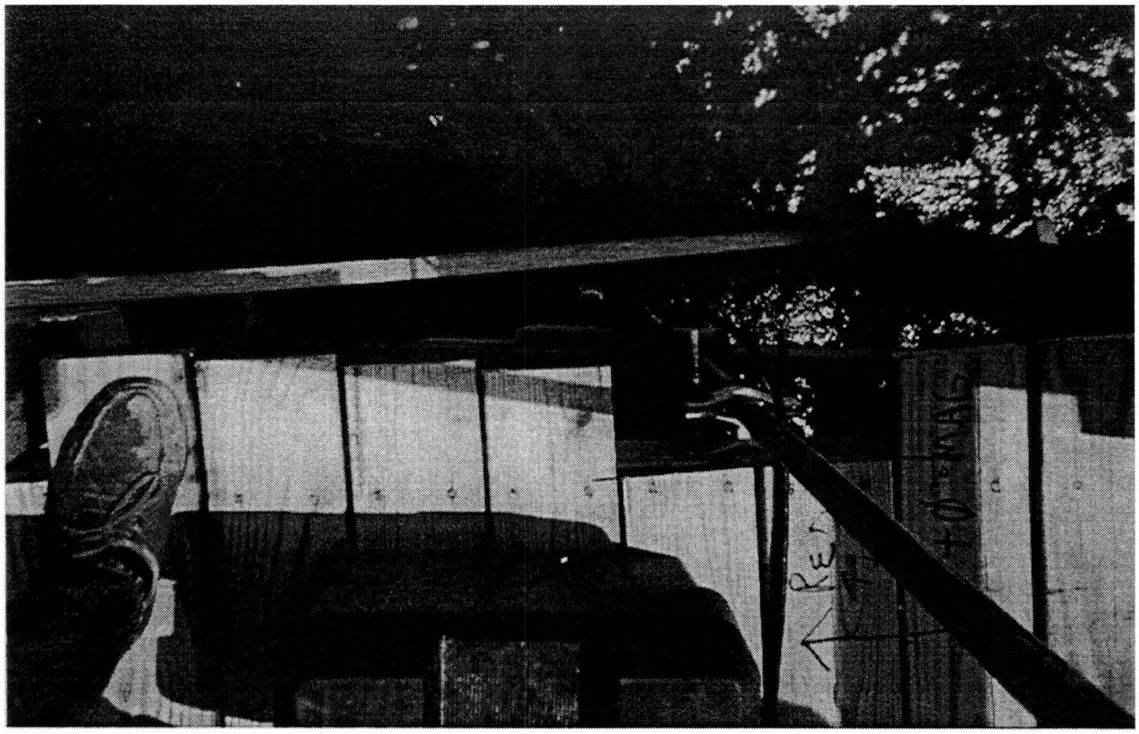


Figure E-23. Pole holding current meter at EMAT.

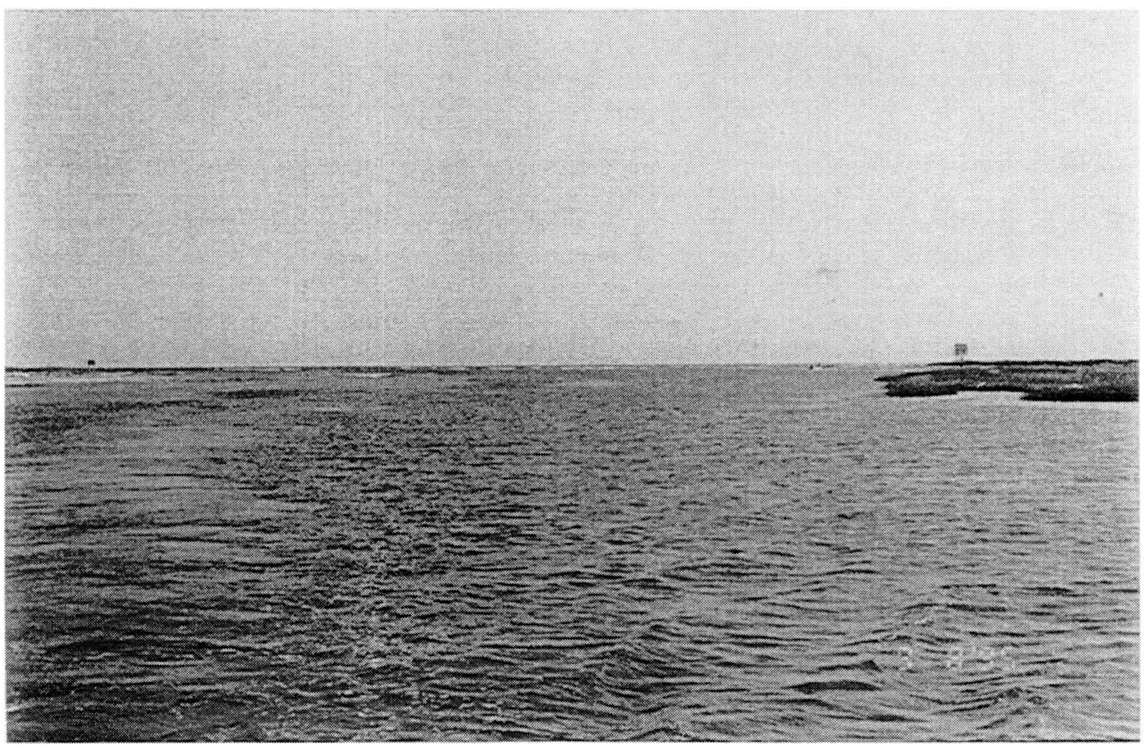


Figure E-24. Mitchell's Cut, looking toward the Gulf.

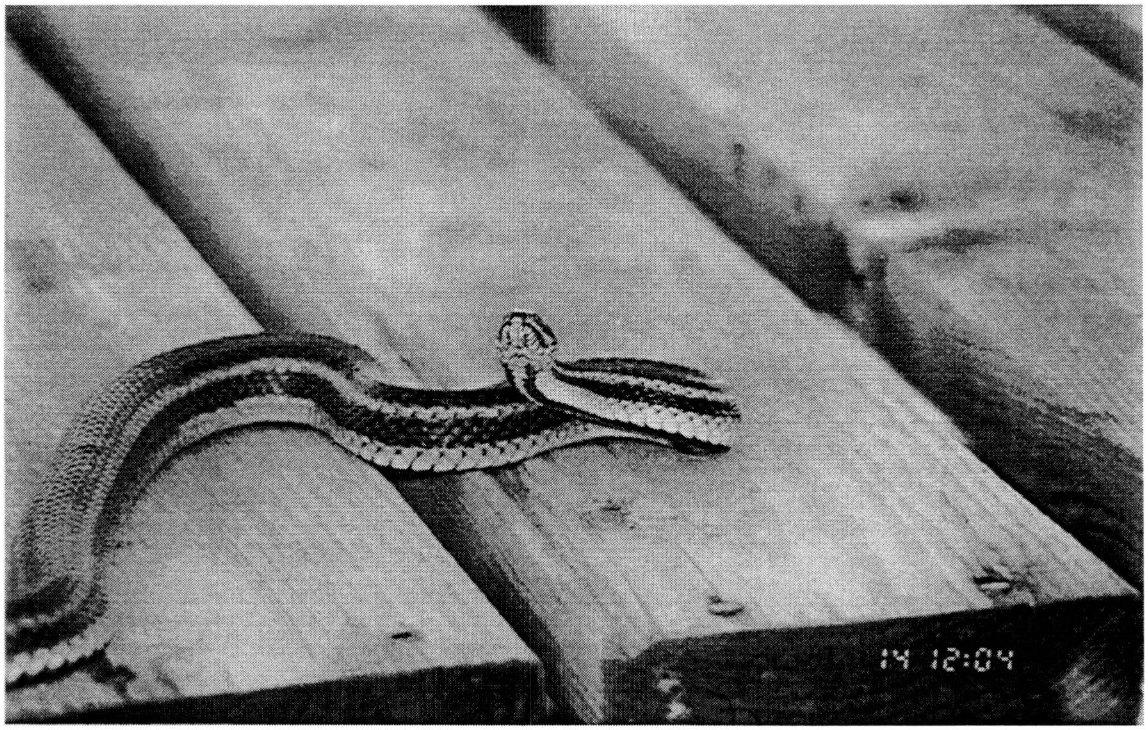


Figure E-25. Snake on platform at EMAT.

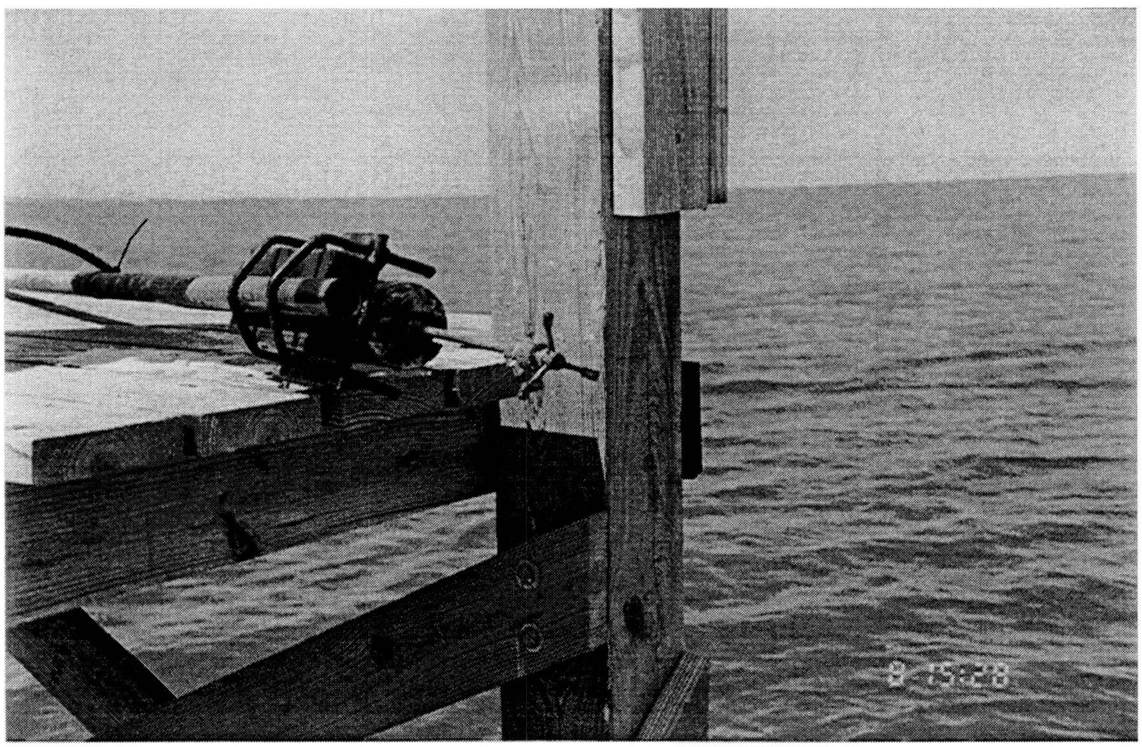


Figure E-26. Current meter being cleaned at SWEMAT.

Figure E-27. Caney Creek viewed from GIWW.

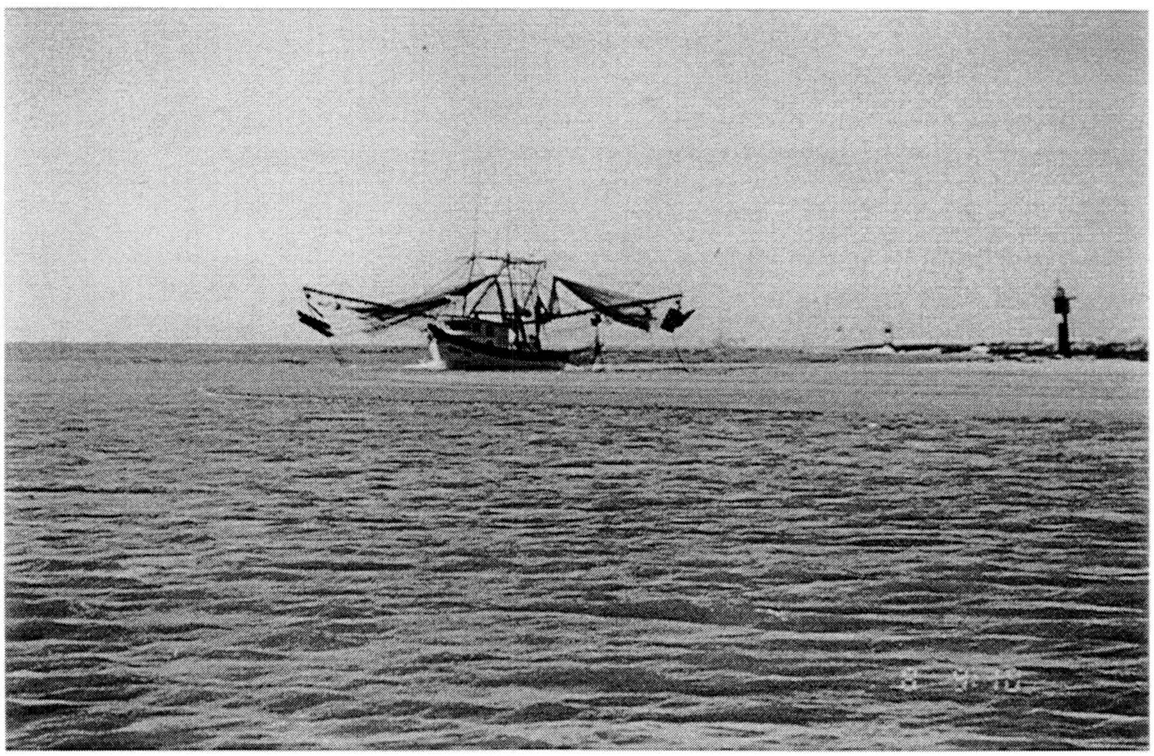


Figure E-28. Shrimp boat entering mouth of the Colorado River Navigation Channel.

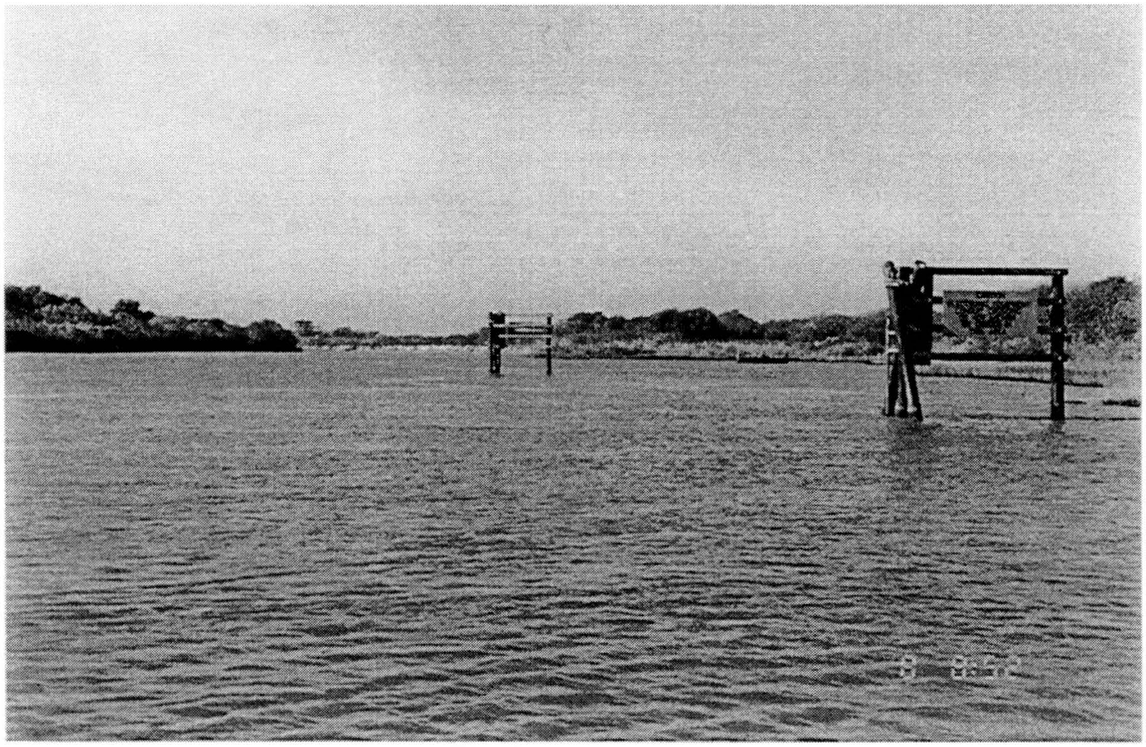


Figure E-29. Colorado River Navigation Channel Landcut, approached from the GIWW.

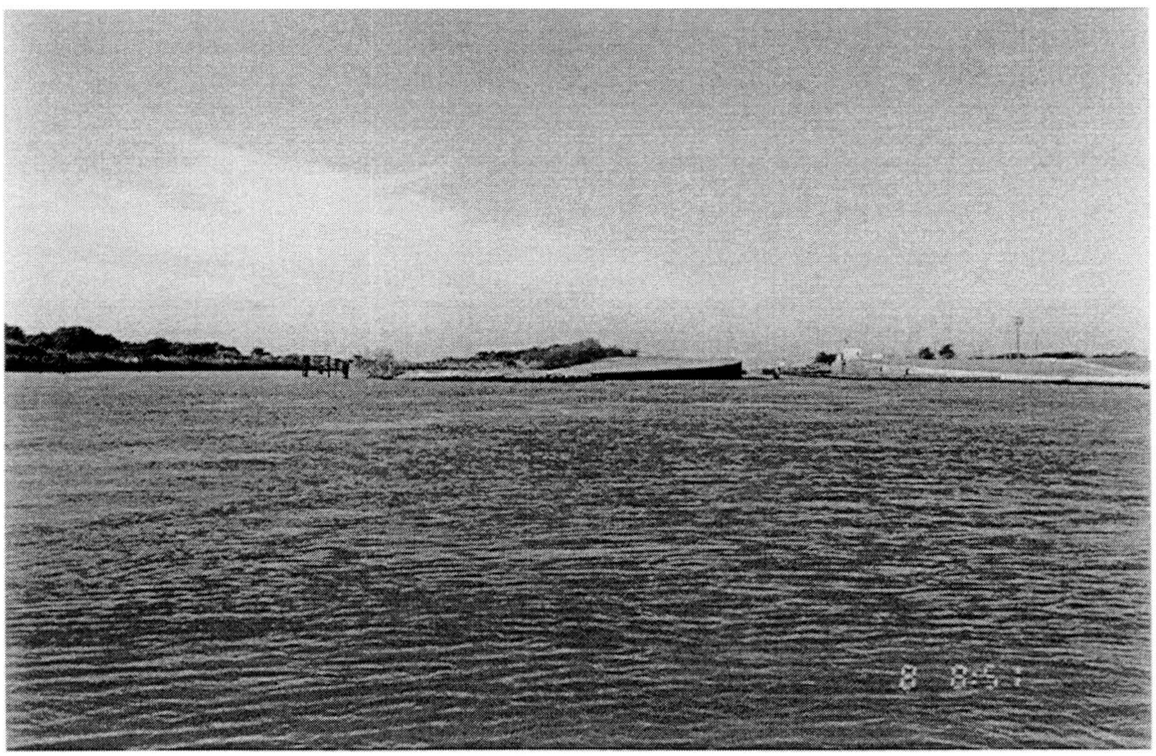


Figure E-30. East Lock Navigation Channel Landcut viewed from the east side.