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Bathymetric Data for Coastal Resource Management in Southwest Florida Waterways: Enhancement and Standardization of Field Collection Methods Used by the West Coast Inland Navigation District[1]

Robert Swett, David Fann[2]

Introduction

Pressures from a coastal population explosion and unprecedented waterway boating intensities are stressing many of our nations water bodies (Nordheimer 1993). Fifty-four percent of the U.S. population (135.1 million in 1991) lives in the coastal zone (U.S. Bureau of Census 1994). While population growth along our coasts has increased slightly above the overall U.S. growth rate since 1960, regions such as the Gulf Coast have experienced double the national rate of change. Florida's coastal population has increased 242 percent, from 4.9 to 16.4 million, four times the national rate. As a result, many inland bay waters in Florida have been transformed into "urban seas."

Recreational boaters and eco-tourists now use thousands of miles of channels and basins that were originally dredged as by-products of coastal development. These waterways were never designed as a transportation system and since many postdate the latest NOS hydrographic surveys, they do not even appear on NOAA small-craft charts (Antonini, Fann, and Roat 1999). State and local governments in Florida recognize the need to retrofit the thousands-of-miles of dredged channels into an integrated waterway transportation system consisting of arterial, secondary, and feeder canals, and basins. This approach is necessary to address boat traffic management issues and to reduce stress on surrounding natural habitats and waterfront communities (Fann, Antonini, Doubeck-Racine, Grella, and Listowski 1999).

The West Coast Inland Navigation District (WCIND) commissioned Florida Sea Grant (FSG), in May 1995, to design a management system for southwest Florida waterways consistent with municipal, county, Florida Department of Environmental Protection (FDEP), and Federal goals of facilitating safe boating and reducing boating impacts on natural resources. The design criteria were: (a) fit channel maintenance to boat draft needs;

(b) minimize impacts on bay habitats; (c) prioritize and evaluate management alternatives on a regional scale; and (d) identify information products for boaters and shore residents to encourage environmental awareness by users of the neighborhood waterways and boat access channels.

The WCIND and FSG have completed fieldwork for seven applications of this system, covering over 1000 miles of channels (Antonini and Box 1996; Antonini, Swett, Schulte, and Fann 1998; Swett, Antonini, and Schulte 1999; Swett, Fann, Antonini, and Alexander 2000, 2001). These studies include large-scale (1:4,800, 1:2,400) mapping of water depth, boat and facility characteristics, signage, and habitat. Detailed analyses delineate and quantify (a) levels of boat accessibility to the open bay, and (b) location and extent of channel depth restrictions within boat access channels. Results of these applications are providing the WCIND and the coastal counties with a rationale and method to implement waterway improvements and restoration using a Waterway Management System with the following elements: (a) dredging to maintain channel depth at user draft specifications; (b) locating signs by boat density and traffic patterns; (c) managing traffic, using boat distributions and travel routes; (d) siting habitat restoration to protect waterways; (e) permitting on a regional scale to accommodate water-dependent uses and to minimize environmental impacts; and (f) educating the public, using waterway maps and guide materials, to instill stewardship and best boating practices.

Current users of the Waterway Management System include Lee, Sarasota, and Manatee counties, the City of Sarasota, and the Town of Longboat Key. User organizations include natural resources, planning, public works, parks and recreation, and county extension service departments; neighborhood associations; and local boat owners. Waterway improvements are being undertaken at Shakett, Phillippi, and Gottfried Creeks (Sarasota County), based on the management criteria and project databases. A General Permit rule will be adopted by the FDEP on 4 August 2002 to provide for maintenance dredging of restricted access channels in a two county region, with significantly reduced administrative costs.

A number of events have occurred at the state and national level that highlight the success and the acceptance of the Waterway Management System. The FDEP agreed to utilize this methodology to implement a standardized regional approach to waterway planning and as a basis to review permit applications for maintenance dredging (MOA 1997). The 1998 Florida State Legislature enacted General Law CS/HB 3369, which broadened the mandate of the WCIND to engage in inland waterway management. Recognizing the value of the waterway management approach, the NOAA Coastal Services Center provided FSG with seed money to develop and implement this waterway management strategy.

WCIND and Florida Sea Grant also are committed to collect soundings in 47 popular anchorages within a five-county area in southwest Florida. This work stems from a 1995 Memorandum of Agreement among the FDEP, FSG College Program, the Southwest Florida Regional Planning Council, and the Boaters Action and Information League. The Memorandum established a pilot 5-year self-regulatory anchorage management program. The bathymetry collected at anchorages, in conjunction with other data sources, is being used to produce large-scale, detailed photomaps for anchorage users and for resource managers (Boaters Action and Information League 1999).

View all of the Introduction here: Introduction

Goals and Objectives

The primary objective of the Waterway Management System, as developed by the WCIND and FSG, is to provide a comprehensive, regional, GIS-based planning tool for resource management and channel maintenance. The four-county region that comprises the WCIND provides an ideal setting to test and revise the Project methodology and to gauge the success of its objectives, results, and recommendations. As outlined above, the value and necessity of the Project has been recognized, as reflected by the political will that has been exercised, at the local, regional, state, and national level, to implement and expand upon project recommendations and goals. The initial implementation of the Waterway Management Project for three WCIND counties will be completed this year. Upon completion, FSG and the WCIND expect to work with local, regional, and state entities to expand Project efforts throughout the state of Florida.

The principal goals of this NOAA-sponsored project are: 1) to enhance and standardize the bathymetric data collection procedures that have been used by the WCIND and FSG during prior implementations of the Waterway Management Project, 2) to provide a reliable and recurring source of bathymetric data, for areas not covered by NOAA surveys, that meets NOAA standards and that can be included on NOAA nautical charts, and 3) to evaluate survey equipment and procedures that could be used by third-party organizations, such as the Coast Guard Auxiliary or United States Power Squadrons, to collect bathymetric data under supervision provided by the WCIND or FSG. Improving past bathymetric survey and quality control procedures and acquiring additional hydrographic survey equipment and software have accomplished these goals. The project integrated DGPS and echo soundings with hydrographic survey software, which resulted in an increase in the efficiency of field operations and an improvement in the quality of the data collected.

Soundings were collected for approximately 313 miles of canals and waterways in Lee County (Figure 1), within the Caloosahatchee River system, from its mouth (west), to the county line. The soundings were thinned to a 5-foot spacing, and the final dataset includes over 700,000 depth points. The survey area includes numerous shore-parallel channels and approaches to open water from boating facilities, canals, and tributaries. The procedures implemented during this study will be used by the WCIND, on a recurring basis, to maintain bathymetric data for Manatee, Sarasota, Charlotte, and Lee counties. WCIND will make available to other entities, such as the Coast Guard Auxiliary or Power Squadrons, the survey procedures and equipment purchased from project funds so that they may collect bathymetric data in other areas. All bathymetric data collected utilizing the project procedures and equipment are on a CD that accompanies this report.

View all of Goals and Objectives here: Goals and Objectives

Project Equipment

Computer--the bathymetric survey was accomplished using a Rocky II+ ruggedized notebook from AMREL Systems, Inc. The notebook is designed for field and in-vehicle applications. The laptop is certified to the MIL-STD 810C and E and is resistant to rain (4 in./hr/ 0.5-4.5 mm/drop 30 min. period), temperature (operating--0° C to 50° C; storage--20° C to 60° C), shock, vibration, salt fog (35° C 5% 48 hour period), and humidity (85-95% RH). The computer used for office related tasks was a Dell Dimension XPS T750r 750 MHz Pentium III with an 18GB SCSI hard drive. Appendix A contains complete specifications for project equipment.

Software--The software programs listed below were used during various project phases.

1. ESRI ArcInfo 8.x for Workstation

2. ESRI ArcView 3.x

3. SURVCORR and BASELINE2--tide correction programs (supplied on accompanying CDROM)

4. Microsoft Excel

5. Microsoft Access

6. Microsoft Word

7. Adaptec Easy CD Creator

8. Trimble Pathfinder Office 2.51

9. Trimble Asset Survey Software

10. Trimble TSIP TALKER (version 2.0)

Differential Global Positioning System--the Regional Waterway Management System, as originally designed, is intended as a planning tool. However, the bathymetric survey procedures and methods meet Class 1 standards as described in the U.S. Army Corps of Engineers (USACE) Hydrographic Survey Manual (U.S. Army Corps of Engineers 2001) and hydrographic survey specifications of the National Ocean Service (National Ocean Service 1999).

A Trimble code phase DSM212H GPS receiver with an integrated MSK dual-channel receiver with Everest™ technology (which improves results in high multipath environments and locations where other radio frequencies could jam the GPS signals) was used to record horizontal positions for the bathymetric survey. Under optimum conditions, the horizontal accuracy (RMS) for the DMS212H, using the RTCM radiobeacon transmissions, is 50 cm + 1 ppm on a second-by-second basis, which, for the 4-county area of the WCIND, is better than 1 meter (Trimble Navigation Ltd. 1998b). Under normal operating conditions the horizontal accuracy for 95 percent of feature positions is 2 meters or less, which conforms with USACE and National Ocean Service (NOS) accuracy standards.

Survey Vessel--a Key West model 1720 open fisherman with a shallow V fiberglass hull and a center console served as the survey vessel. The Key West has a 70hp, 4-stroke, Evinrude outboard; fuel capacity of 31 gallons; 8-inch draft; 17-foot, 2-inch length; 6-foot, 10-inch beam; and weighs 1050 lbs.

Depth Sounding Equipment--sounding equipment consisted of a Bathy-500MF multi-frequency, single-beam echo sounder (Ocean Data Equipment Corporation); a Standard Horizon DS150 singlebeam echo sounder (Standard Communications); and a fiberglass sounding pole, calibrated and marked at 0.01-foot intervals.

Soundings from the Bathy-500MF and the DS150 were passed to HYPACK Max hydrographic survey software (Coastal Oceanographics, Inc.) loaded on the AMREL Rocky II+ notebook computer. Soundings were recorded to the nearest 0.1-foot with the Bathy-500 and to the nearest 0.1- foot with the DS100. The sounding pole was used to verify any suspect echo sounder readings and to check depths in shallow areas (below 3.8 feet). Calibration of the depth sounders was accomplished using a bar, which consisted of a 1.25 ft. X 2.9 ft. lead-weighted aluminum plate. The bar was lowered below the transducer with 25-foot long, 1/8-inch diameter twisted stainless steel wire cables marked at 5-foot intervals, from 5 feet to 20 feet.

Tide Level Recorders and Stilling Wells--tide observations were necessary to correct soundings to chart datum (MLLW). Tide level recorders consisted of Model 220 solid-state, ultrasonic fl uid level sensors manufactured by Infinities USA, Inc. Each Model 220 data logger stores 3,906 records, which allows for 16 days of tide data at a logging interval of 6 minutes. Data fi les were downloaded, in the field, to an HP-48GX calculator.

Each gauge was mounted on a stilling well, the dimensions of which are shown in Figure 2. All sections of the stilling well were cemented together except for the cap, which is secured to the closet flange using two padlocks to protect the tide level recorder. The stilling well was secured to a piling using wooden I-beam mounts and stainless steel worm gear clamps.

View all of Project Equipment here: Project Equipment

Project Planning and Preparation

Project Planning Map

Large-scale (1:7200) maps of the study area were prepared to delineate salt-water-accessible canals, channels, and other waterways where centerline depths were to be surveyed. Planned waterway centerlines were drawn by Lee County Marine Services Program personnel with knowledge of travel routes actually used by boaters. USGS 1-meter DOQQs served as the map base, and other map themes included the locations and characteristics of signs, vertical benchmarks, hydrologic areas, tide gauges, locks, and boat lifts. Hydrologic areas are defined by project personnel to guide the placement of tide gauges and the scheduling of depth survey work. Their inclusion on the planning map was important for complex areas, as exemplified by the City of Cape Coral (Figure 3). The maps served to plan the work schedule, monitor field progress, and annotate areas as they were completed.

View all of Project Planning and Preparation here: Project Planning and Preparation

Field Procedures

Tide Gauge Installation

Once appropriate tide gauge sites were established, secure facilities were found where gauges could be installed. Each proposed gauge site was visited to confirm the presence of vertical benchmarks and their suitability to determine tide gauge elevation. The majority of benchmarks were located within sight of the tide gauge installation, such as on a seawall or on an adjacent road or structure. A licensed surveyor was hired to establish vertical control for one gauge installation.

Tide gauge stilling wells were securely fastened to a protected piling or other suitable mounting location (Figure 5F) using stainless steel straps, similar to automotive hose clamps, but available in lengths of 4 feet or longer. An I-beam of 2 x 4 lumber, securely screwed together and placed between the stilling well and piling, provided a stable mount with a suitable standoff distance. The field crew carefully monitored the gauges elevation relative to the piling to check for vertical slippage or other problems.

Tide gauge vertical control, relative to NGVD29 or NAVD88, was determined by differential leveling (double running) conducted by project personnel. When the benchmark was located on a seawall, simultaneous measurements to the water surface from both the gauge and benchmark were used to establish gauge elevation. The average of three or more measurements, made under calm conditions, was used to establish the gauge elevation. From other benchmarks, not located on seawalls, the gauge elevation was established via differential leveling. The MLLW tidal datum was determined in reference to an historical NOS tidal benchmark located in the study area. The NOS tidal benchmark sheet provided elevations of tidal and geodetic datums referenced to MLLW (feet). Tidal benchmark sheets were obtained from the following NOAA web site: http://co-ops.nos.noaa.gov/bench.html .

During installation of the tide gauge, critical parameters were recorded, including benchmark characteristics and a record of the procedures and measurements obtained during tide gauge calibration and leveling procedures. This information was of vital importance when correcting depth measurements to the MLLW tidal datum.

Tide corrections were performed by means of a computer program, Survey Tide Correction (SURVCORR.exe), developed by the University of Florida (UF) Coastal and Oceanographic Engineering program. SURVCORR was developed to correct depths within a winding canal or river system. The program, with inputs of spatially referenced soundings and tide gauge readings, determines and applies depth corrections based on time and relative location. Tide data are interpolated to each centerline, or user-constructed baseline point, by assuming a linear variation of the tide through the system. Weighting the interpolation by the distance from a gauge provides correction for non-linear effects, such as viscous dissipation. A more detailed description of the program can be found in the Appendix B.

View all of Field Procedures here: Field Procedures

Post-processing of Survey Data

Tidal Datum Determination

The NOS control tide station chosen to compute NTDE equivalent tidal datums for the project area is located at Fort Myers (Station ID: 8725520) on the Caloosahatchee River, and is part of the National Water Level Observation Network (NWLON). The tidal datums computed for Fort Myers are for the 1960-1978 Tidal Epoch, and are based on a series length of 18 years (1966-1984). The primary control tide station that was used to compute the Fort Myers tidal datums is located at St. Petersburg (8726520). The Fort Myers station was selected as the control station because it better reflects the local tidal influences within the Caloosahatchee River than does the St. Petersburg gauge. The NOS accepted tidal datums (feet), referenced to station datum, for the Fort Myers gauge are as follows (http://co-ops.nos.noaa.gov/data_res.html):

View all of Post-processing of Survey Data here: Post-processing of Survey Data

Results and Conclusions

The bathymetric GIS data set contained on the accompanying CD has information on over 700,000 point depths recorded for all channel center-lines and approaches to boating facilities, in an area extending from the mouth to the Lee/Hendry County boundary, and the canals, rivers, and creeks that drain into this reach of the Caloosahatchee River. The mean depth of the study area is 6 feet. The data were collected by an on-the-water survey conducted between June 2001 and April 2002, using a Trimble DSM212H 12-channel receiver, with integrated dual-channel MSK differential beacon receiver and Bathy-500MF and Horizon DS150 sounders.

All depths in tidal waters are referenced to the navigation datum, mean lower low water (MLLW), and are rounded to the nearest 0.5-foot. In non-tidal areas (above locks), the datum is the National Geodetic Vertical Datum of 1929 (NGVD29). Tide gauges were installed at 28 locations (Figure 4) during the period of data collection, and depths were corrected to MLLW or NGVD29 using computer programs prepared by the University of Florida Department of Coastal Engineering.

Depths recorded with the Bathy-500MF were used to verify the soundings recorded simultaneously by the DS150. The DS150, a low cost sounder, was evaluated for potential use in future shallow-area surveys conducted by third party entities under the supervision of the WCIND and FSG. Survey results revealed that the DS150 provided depths that were more consistent and reliable than those provided by the Bathy-500MF. The Bathy-500MF was subject to regularly occurring, short series of depths that were several feet deeper or shallower than were actual depths. Scripts were developed to identify and clean the anomalous depths recorded by the Bathy-500MF, however the procedure was tedious and time consuming.

View all of Results and Conclusions here: Results and Conclusions

GIS Data Sets and Imagery

A CD-ROM accompanies this report and contains all geographic data sets as ARC/INFO® export files and ArcView® shapefiles (ESRI). The geographic data sets include: 1) soundings, reduced to Mean Lower Low Water (MLLW) or NGVD29 in areas behind locks, and recorded to the nearest 0.5-foot, 2) the location of the water level recorders used to correct soundings to MLLW, and 3) channels, created from soundings and represented as line features. Collection times are recorded in Coordinated Universal Time (UTC) for soundings. The projection parameters for all geographic data sets are as follows:

Projection: Albers

Datum: NAD83

Units: Meters

Spheroid: GRS1980

1st Standard Parallel: 24.0

2nd Standard Parallel: 31.5

Central Meridian: -84.0

Latitude of Projections Origin: 24.0

False Easting (meters): 400000.0

False Northing (meters): 0.0

The CD-ROM contains resampled USGS Digital Orthophoto Quarter Quadrangles at 1, 3, and 6-meter resolutions in JPEG format. Metadata, compliant with standards outlined by the Federal Geographic Data Committee, is provided on the CD-ROM for each geographic data set. The ArcView project (e.g., /ProjectDataCD/leephase3.apr) was created with a view containing all data sets and imagery. The included JPEG imagery requires that the JPEG (JFIF) extension be invoked from the available extensions.

The data sets and imagery that are included are described as follows:

View all of GIS Data Sets and Imagery here: GIS Data Sets and Imagery

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Appendix A

Equipment Specifications

View all of Appendix A here: Appendix A

Appendix B

Survey Tide Correction Program

Conceptual Description

View all of Appendix B here: Appendix B

Footnotes

1. This publication was supported by the National Sea Grant College Program of the U.S. Department of Commerces National Oceanic and Atmospheric Administration (NOAA) under NOAA Grant No. NA 16RG-2195. Additional funding was provided by NOAA grant No. NA 06OC-0400 and the West Coast Inland Navigation District. The views expressed are those of the authors and do not necessarily reflect the view of these organizations.

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2. Prepared for the:

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On behalf of the West Coast Inland Navigation District

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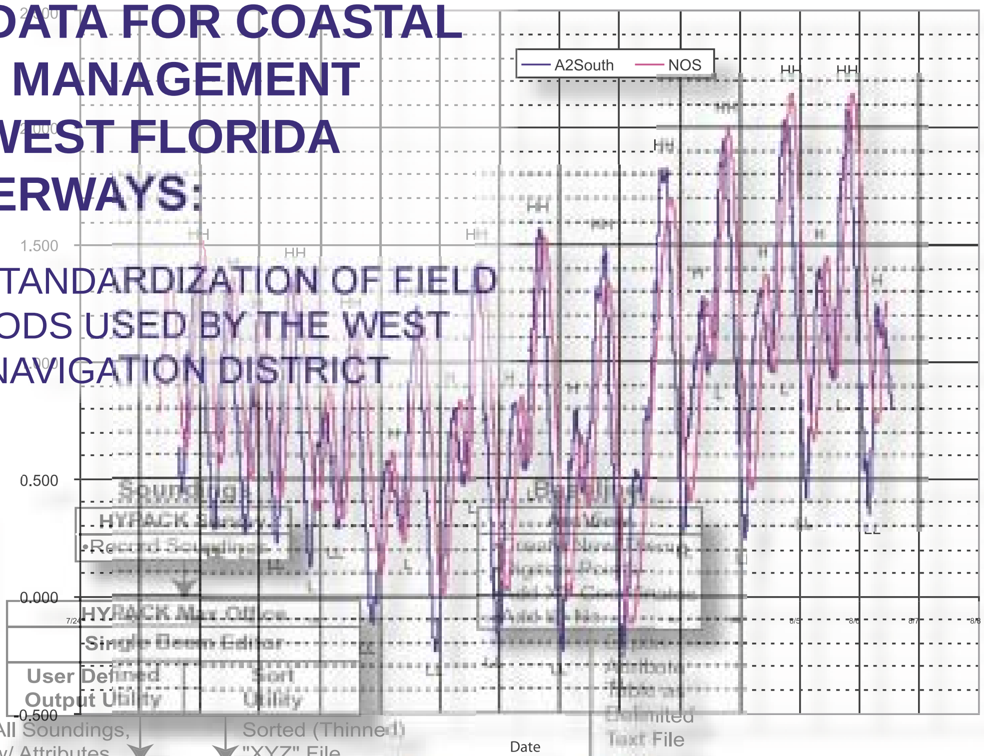

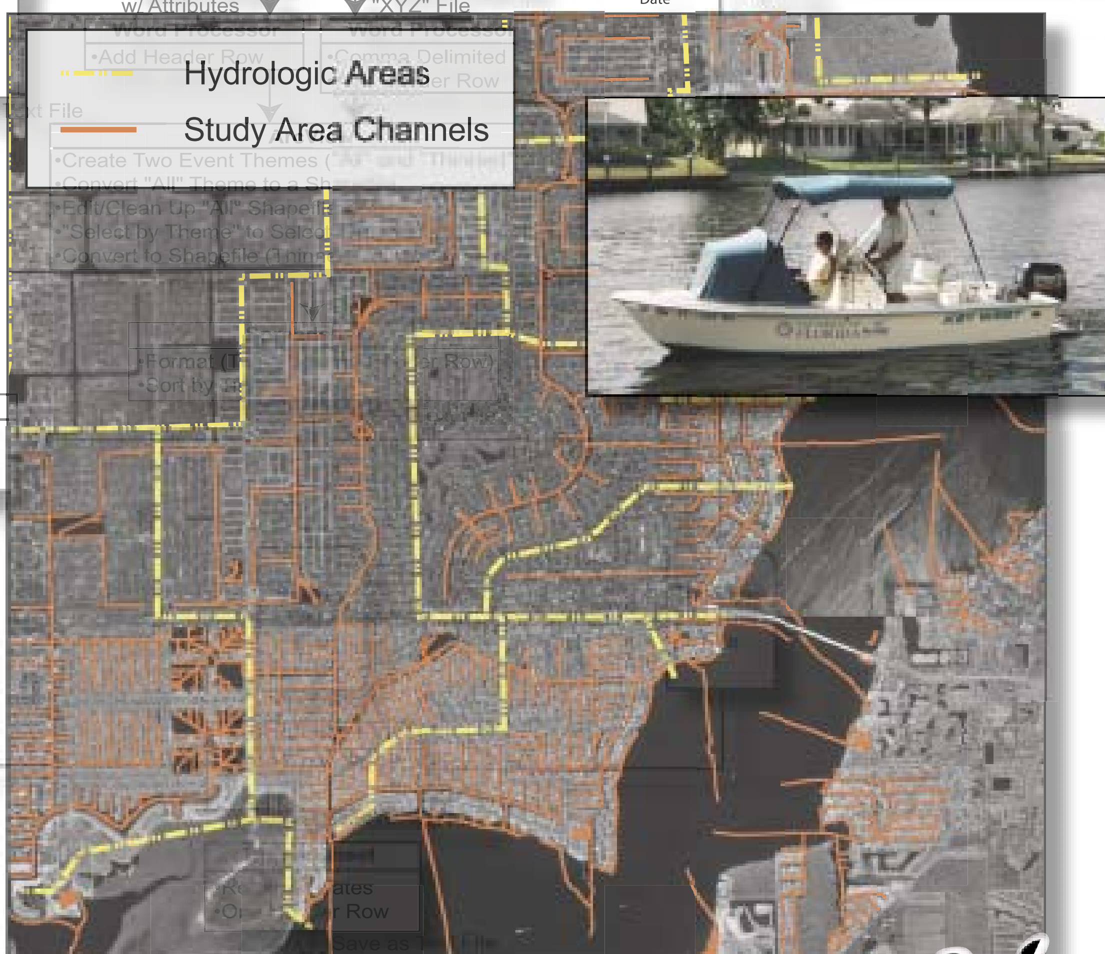

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Illustrations

Abbreviations and Acronyms

AML	Arc Macro Language
DGPS	Differential Global Positioning System
DOQQ	Digital Orthophoto Quarter Quadrangle
ESRI	Environmental Systems Research Institute
FDEP	Florida Department of Environmental Protection
FSG	Florida Sea Grant
GIS	Geographic Information System
GPS	Global Positioning System
JPEG	Joint Photographic Experts Group
MHHW	Mean Higher High Water
MHW	Mean High Water
MLW	Mean Low Water
MLLW	Mean Lower Low Water
MSK	Minimum Shift Keying
MTL	Mean Tide Level
NAVD88	North American Vertical Datum of 1988
NGVD29	National Geodetic Vertical Datum of 1929
NMEA	National Marine Electronics Association
NOS	National Ocean Service
PDOP	Positional Dilution of Precision
PRC	Pseudorange Corrector
RTCM	Radio Technical Commission for Maritime Services
SNR	Signal-to-Noise Ratio
TSIP	Trimble Standard Interface Protocol
WCIND	West Coast Inland Navigation District
UF	University of Florida
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
USGS	U.S. Geological Survey
UTC	Coordinated Universal Time

Introduction

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Goals and Objectives

The primary objective of the Waterway Management System, as developed by the WCIND and FSG, is to provide a comprehensive, regional, GIS-based planning tool for resource management and channel maintenance. The four-county region that comprises the WCIND provides an ideal setting to test and revise the Project methodology and to gauge the success of its objectives, results, and recommendations. As outlined above, the value and necessity of the Project has been recognized, as reflected by the political will that has been exercised, at the local, regional, state, and national level, to implement and expand upon project recommendations and goals. The initial implementation of the Waterway Management Project for three WCIND counties will be completed this year. Upon completion, FSG and the WCIND expect to work with local, regional, and state entities to expand Project efforts throughout the state of Florida.

The principal goals of this NOAA-sponsored project are: 1) to enhance and standardize the bathymetric data collection procedures that have been used by the WCIND and FSG during prior implementations of the Waterway Management Project, 2) to provide a reliable and recurring source of bathymetric data, for areas not covered by NOAA surveys, that meets NOAA standards and that can be included on NOAA nautical charts, and 3) to evaluate survey equipment and procedures that could be used by third-party organizations, such as the Coast Guard Auxiliary or United States Power Squadrons, to collect bathymetric data under supervision provided by the WCIND or FSG. Improving past bathymetric survey and quality control procedures and acquiring additional hydrographic survey equipment and software have accomplished these goals. The project integrated DGPS and echo soundings with hydrographic survey software, which resulted in an increase in the efficiency of field operations and an improvement in the quality of the data collected.

Soundings were collected for approximately 313 miles of canals and waterways in Lee County (Figure 1), within the Caloosahatchee River system, from its mouth (west), to the county line. The soundings were thinned to a 5-foot spacing, and the final dataset includes over 700,000 depth points. The survey area includes numerous shore-parallel channels and approaches to open water from boating facilities, canals, and tributaries. The procedures implemented during this study will be used by the WCIND, on a recurring basis, to maintain bathymetric data for Manatee, Sarasota, Charlotte, and Lee counties. WCIND will make available to other entities, such as the Coast Guard Auxiliary or Power Squadrons, the survey procedures and equipment purchased from project funds so that they may collect bathymetric data in other areas. All bathymetric data collected utilizing the project procedures and equipment are on a CD that accompanies this report.

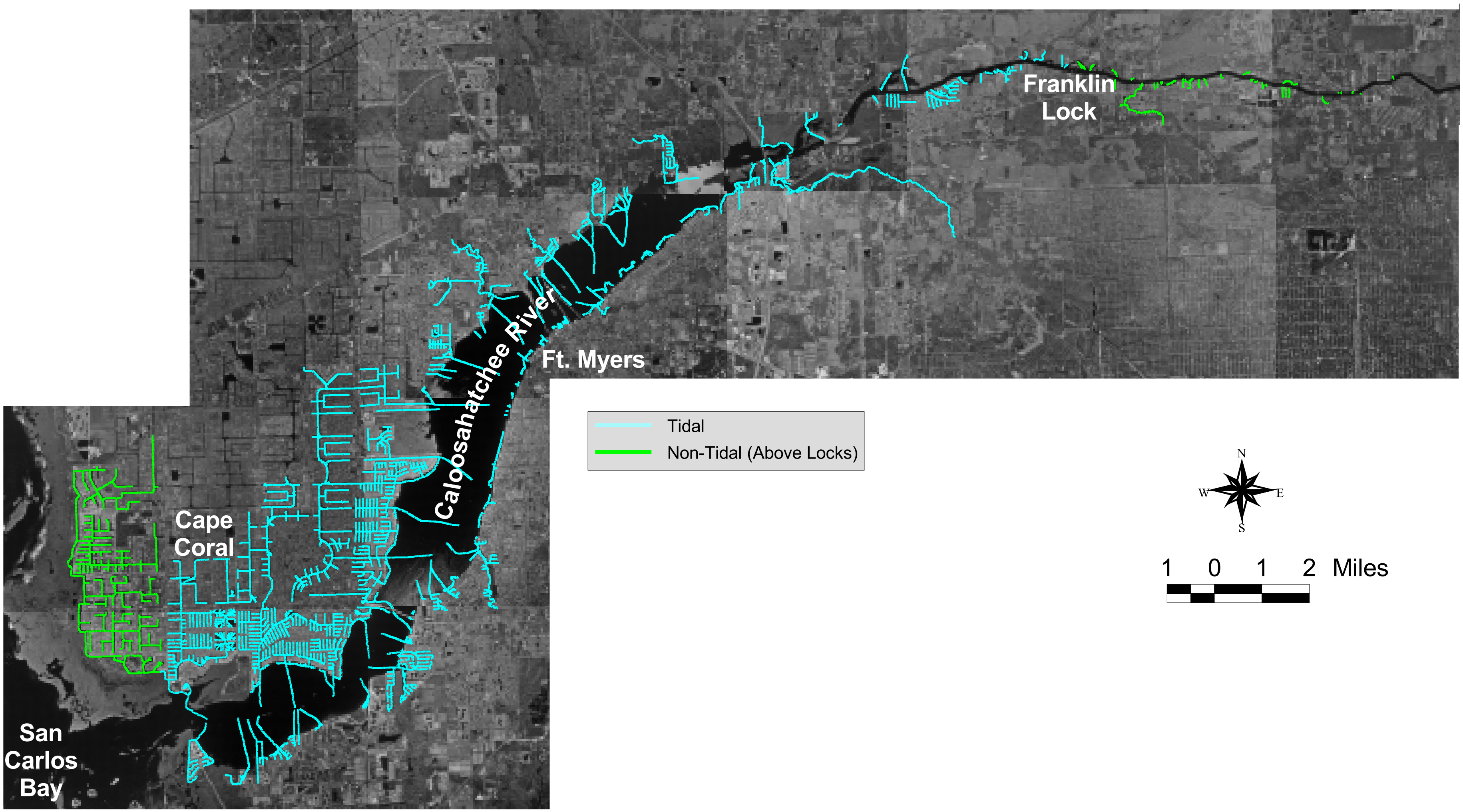


FIGURE 1. WATERWAYS IN THE STUDY AREA

Project Equipment

Computer—the bathymetric survey was accomplished using a Rocky II+ ruggedized notebook from AMREL Systems, Inc. The notebook is designed for field and in-vehicle applications. The laptop is certified to the MIL-STD 810C and E and is resistant to rain (4 in./hr/ 0.5-4.5 mm/drop 30 min. period), temperature (operating—0º C to 50º C; storage—20º C to 60º C), shock, vibration, salt fog (35º C 5% 48 hour period), and humidity (85-95% RH). The computer used for office related tasks was a Dell Dimension XPS T750r 750 MHz Pentium III with an 18GB SCSI hard drive. Appendix A contains complete specifications for project equipment.

Software--The software programs listed below were used during various project phases.

1. ESRI ArcInfo 8.x for Workstation
2. ESRI ArcView 3.x
3. SURVCORR and BASELINE2—tide correction programs (supplied on accompanying CD-ROM)
4. Microsoft Excel
5. Microsoft Access
6. Microsoft Word
7. Adaptec Easy CD Creator
8. Trimble Pathfinder Office 2.51
9. Trimble Asset Survey Software
10. Trimble TSIP TALKER (version 2.0)

Differential Global Positioning System—the Regional Waterway Management System, as originally designed, is intended as a planning tool. However, the bathymetric survey procedures and methods meet Class 1 standards as described in the U.S. Army Corps of Engineers (USACE) Hydrographic Survey Manual (U.S. Army Corps of Engineers 2001) and hydrographic survey specifications of the National Ocean Service (National Ocean Service 1999).

A Trimble code phase DSM212H GPS receiver with an integrated MSK dual-channel receiver with Everest™ technology (which improves results in high multipath environments and locations where other radio frequencies could jam the GPS signals) was used to record horizontal positions for the bathymetric survey. Under optimum conditions, the horizontal accuracy (RMS) for the DMS212H, using the RTCM radiobeacon transmissions, is 50 cm + 1 ppm on a second-by-second basis, which, for the 4-county area of the WCIND, is better than 1 meter (Trimble Navigation Ltd. 1998b). Under normal operating conditions the horizontal accuracy for 95 percent of feature positions is 2 meters or less, which conforms with USACE and National Ocean Service (NOS) accuracy standards.

Survey Vessel—a Key West model 1720 open fisherman with a shallow V fiberglass hull and a center console served as the survey vessel. The Key West has a 70hp, 4-stroke, Evinrude outboard; fuel capacity of 31 gallons; 8-inch draft; 17-foot, 2-inch length; 6-foot, 10-inch beam; and weighs 1050 lbs.

Depth Sounding Equipment—sounding equipment consisted of a Bathy-500MF multi-frequency, single-beam echo sounder (Ocean Data Equipment Corporation); a Standard Horizon DS150 single-beam echo sounder (Standard Communications); and a fiberglass sounding pole, calibrated and marked at 0.01-foot intervals.

Soundings from the Bathy-500MF and the DS150 were passed to HYPACK Max hydrographic survey software (Coastal Oceanographics, Inc.) loaded on the AMREL Rocky II+ notebook computer. Soundings were recorded to the nearest 0.1-foot with the Bathy-500 and to the nearest 0.1- foot with the DS100. The sounding pole was used to verify any suspect echo sounder readings and to check depths in shallow areas (below 3.8 feet). Calibration of the depth sounders was accomplished using a bar, which consisted of a 1.25 ft. X 2.9 ft. lead-weighted aluminum plate. The bar was lowered below the transducer with 25-foot long, 1/8-inch diameter twisted stainless steel wire cables marked at 5-foot intervals, from 5 feet to 20 feet.

Tide Level Recorders and Stilling Wells—tide observations were necessary to correct soundings to chart datum (MLLW). Tide level recorders consisted of Model 220 solid-state, ultrasonic fluid level sensors manufactured by Infinities USA, Inc. Each Model 220 data logger stores 3,906 records, which allows for 16 days of tide data at a logging interval of 6 minutes. Data files were downloaded, in the field, to an HP-48GX calculator.

Each gauge was mounted on a stilling well, the dimensions of which are shown in Figure 2. All sections of the stilling well were cemented together except for the cap, which is secured to the closet flange using two padlocks to protect the tide level recorder. The stilling well was secured to a piling using wooden I-beam mounts and stainless steel worm gear clamps.

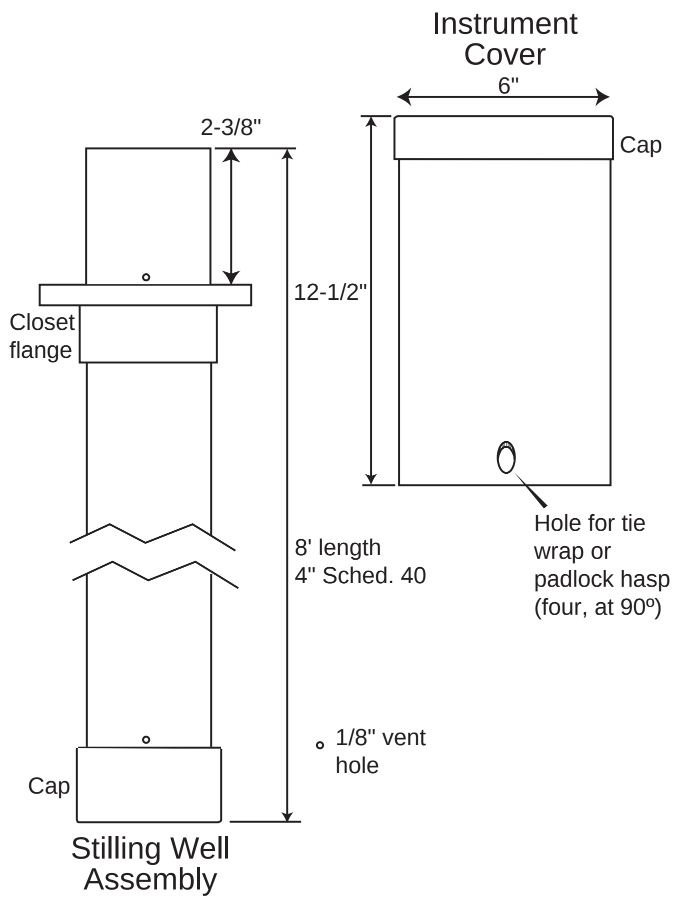


FIGURE 2. TIDE GAUGE STILLING WELL AND HOUSING

Project Planning and Preparation

Project Planning Map

Large-scale (1:7200) maps of the study area were prepared to delineate salt-water-accessible canals, channels, and other waterways where centerline depths were to be surveyed. Planned waterway centerlines were drawn by Lee County Marine Services Program personnel with knowledge of travel routes actually used by boaters. USGS 1-meter DOQQs served as the map base, and other map themes included the locations and characteristics of signs, vertical benchmarks, hydrologic areas, tide gauges, locks, and boat lifts. Hydrologic areas are defined by project personnel to guide the placement of tide gauges and the scheduling of depth survey work. Their inclusion on the planning map was important for complex areas, as exemplified by the City of Cape Coral (Figure 3). The maps served to plan the work schedule, monitor field progress, and annotate areas as they were completed.

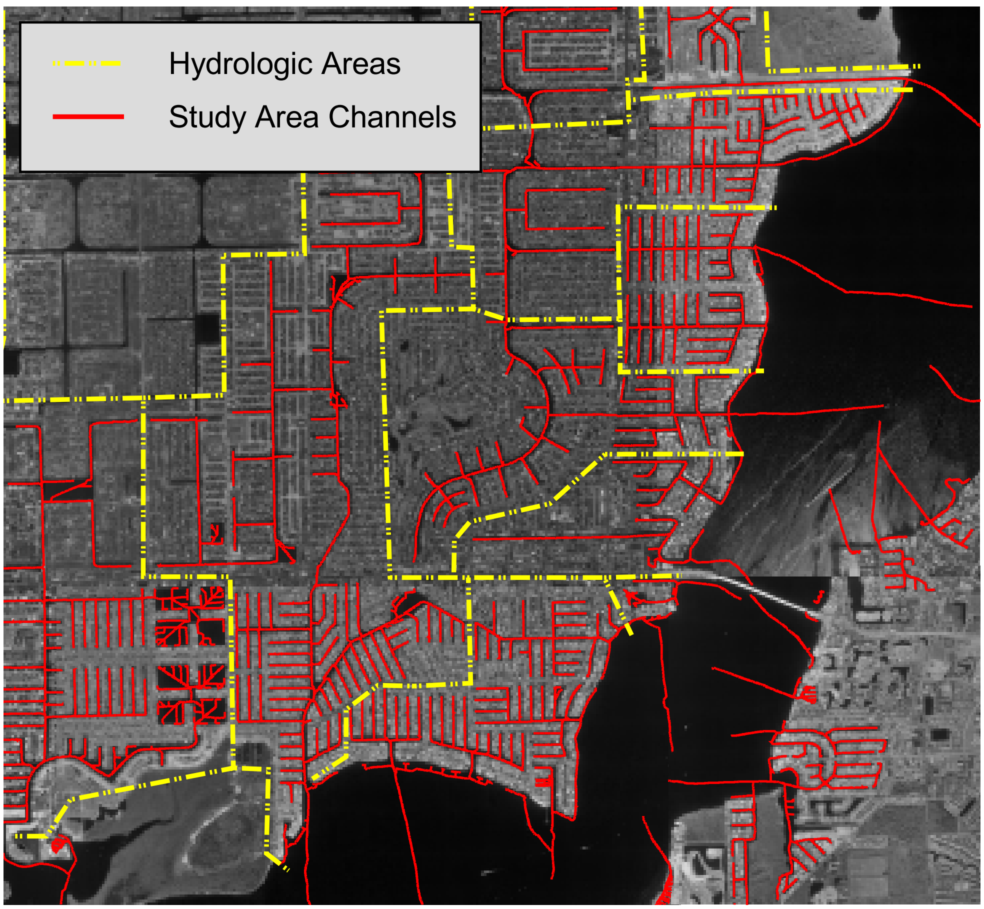


FIGURE 3. HYDROLOGIC AREAS

Tide Gauge Siting

During collection of bathymetric data, the water surface elevation relative to mean lower low water (MLLW) varied with local tides, freshwater flows, and environmental effects (e.g., wind). To correct for these effects, all bathymetric data was collected near a gauge or between pairs of gauges. Gauge sites were selected in accordance with NOS and USACE standards required for tidal correction of bathymetric data (National Ocean Service 1999; U.S. Army Corps of Engineers 2001). Definition of hydrologic areas and the spatial distribution of project tide gauges were determined in consultation with Dr. D. Max Sheppard, a Professor in the University of Florida Coastal and Oceanic Engineering

Program (Figure 4). Other factors considered for gauge locations included the availability of safe, secure sites and nearby monuments of known elevation, to which gauges could be referenced.

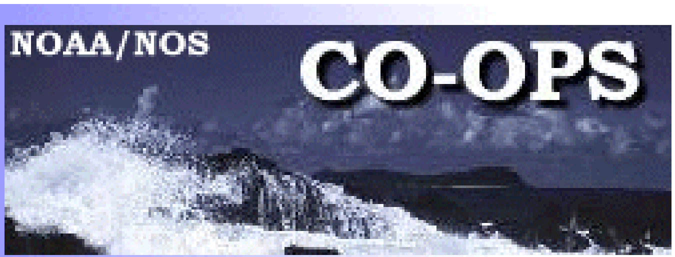
Survey Vessel Outfitting

Survey equipment was securely mounted on the vessel before initiating fieldwork (Figure 5). A 17-foot Key West was used for the bathymetric survey (Figure 5G). A special side mount for the Bathy-500MF transducer fits in a rod holder on either the port or starboard side (Figure 5A). The DGPS antenna was attached directly above the transducer mount and, thus, directly over the Bathy-500MF transducer (Figure 5A and C). A custom-fabricated mount held the Bathy-500MF instrument on the inside, forward, port side (Figure 5D); a custom fabric cover protected the Bathy-500MF from spray. The DSM212H DGPS was mounted on the inside back cover of the Bathy-500MF. The Horizon DS150 transducer was transom mounted and the DS150 display unit placed on the console, visible to the boat operator. A swivel chair for the equipment operator, forward of the console, replaced the original passenger seat cushion (Figure 5E). A swivel mount, adapted from a commercial monitor stand, held the AMREL laptop forward of the chair (Figure 5B). This mount was bolted to the aft bulkhead of the foredeck. A custom canvas dodger, with a roll-up clear plastic forward window, protected the entire work area from spray and rain and provided shade to improve the laptop computer display visibility (Figure 5G). Two custom 12V outlets, in addition to the cigar lighter on the console, provided power for the survey equipment. A dual-battery system, with a second battery added in parallel with the original boat battery, proved a reliable source of clean instrument power.

Figure 4. Tide Station Loctions

A. Bathy 500-MF Sounder, Transducer, and DGPS Antenna
B. Data Collector's Work Station
C. Bar Check
D. Data Collector During Soundings
E. Data Collector's Chair and Bathy Sounder Mount
F. Infinities Portable Tide Gauge and Stilling Well
G. Key West 17-foot Boat

Figure 5. Survey Equipment Installations



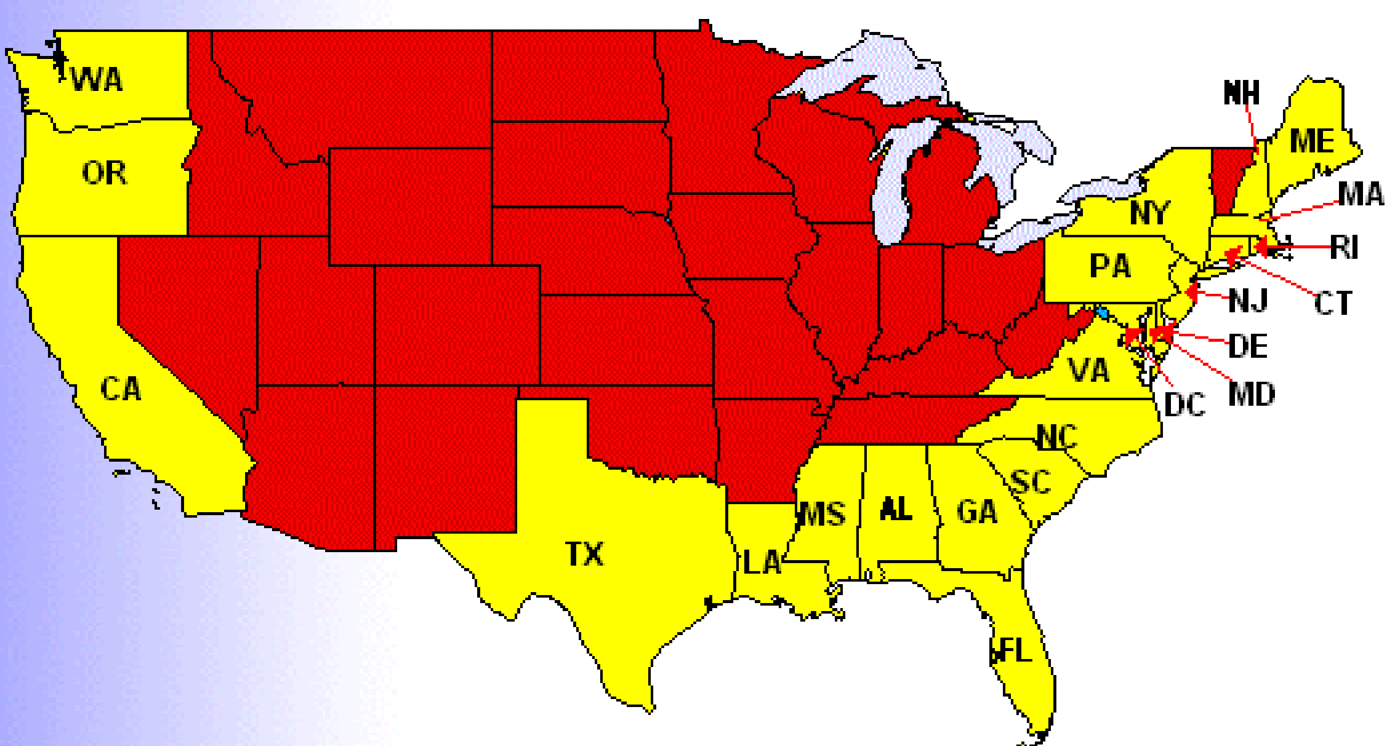
Important Notice:

CO-OPS has updated to a new National Tidal Datum Epoch (1983-2001). For more information click HERE. Data products will be added as they are updated to the new tidal epoch.

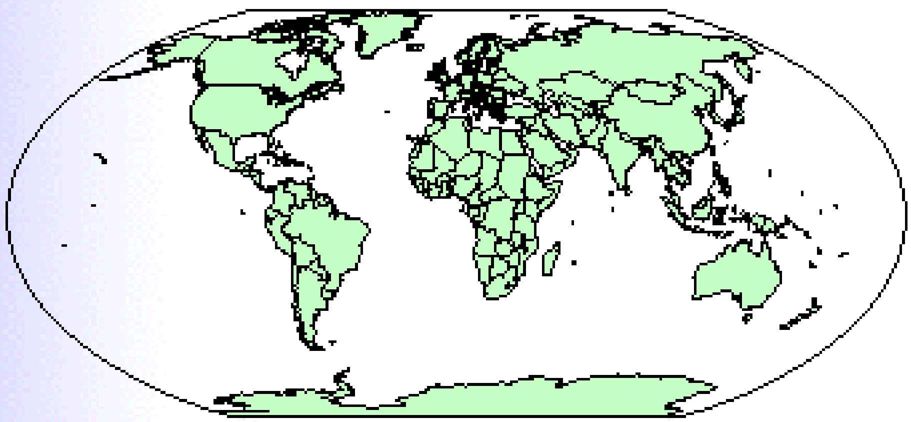
- **List of Stations that are Scheduled for EPOCH Update**
- **List of Stations that are Not Scheduled for EPOCH Update**

PUBLISHED BENCHMARK SHEETS

Below is a map of states and geographical areas where CO-OPS maintains Published Benchmark Sheets. Specific stations are listed within each area.



Non U.S. Bench Marks



Select region of interest

- National Geodetic Survey Web Site

Home | PORTS | Predictions | Observations | Bench Marks
FAQ | Station Locator | Publications | About CO-OPS | Product Info.

Field Procedures

Tide Gauge Installation

Once appropriate tide gauge sites were established, secure facilities were found where gauges could be installed. Each proposed gauge site was visited to confirm the presence of vertical benchmarks and their suitability to determine tide gauge elevation. The majority of benchmarks were located within sight of the tide gauge installation, such as on a seawall or on an adjacent road or structure. A licensed surveyor was hired to establish vertical control for one gauge installation.

Tide gauge stilling wells were securely fastened to a protected piling or other suitable mounting location (Figure 5F) using stainless steel straps, similar to automotive hose clamps, but available in lengths of 4 feet or longer. An I-beam of 2 x 4 lumber, securely screwed together and placed between the stilling well and piling, provided a stable mount with a suitable standoff distance. The field crew carefully monitored the gauge's elevation relative to the piling to check for vertical slippage or other problems.

Tide gauge vertical control, relative to NGVD29 or NAVD88, was determined by differential leveling (double running) conducted by project personnel. When the benchmark was located on a seawall, simultaneous measurements to the water surface from both the gauge and benchmark were used to establish gauge elevation. The average of three or more measurements, made under calm conditions, was used to establish the gauge elevation. From other benchmarks, not located on seawalls, the gauge elevation was established via differential leveling. The MLLW tidal datum was determined in reference to an historical NOS tidal benchmark located in the study area. The NOS tidal benchmark sheet provided elevations of tidal and geodetic datums referenced to MLLW (feet). Tidal benchmark sheets were obtained from the following NOAA web site: http://co-ops.nos.noaa.gov/bench.html.

During installation of the tide gauge, critical parameters were recorded, including benchmark characteristics and a record of the procedures and measurements obtained during tide gauge calibration and leveling procedures. This information was of vital importance when correcting depth measurements to the MLLW tidal datum.

Tide corrections were performed by means of a computer program, Survey Tide Correction (SURVCORR.exe), developed by the University of Florida (UF) Coastal and Oceanographic Engineering program. SURVCORR was developed to correct depths within a winding canal or river system. The program, with inputs of spatially referenced soundings and tide gauge readings, determines and applies depth corrections based on time and relative location. Tide data are interpolated to each centerline, or user-constructed baseline point, by assuming a linear variation of the tide through the system. Weighting the interpolation by the distance from a gauge provides correction for non-linear effects, such as viscous dissipation. A more detailed description of the program can be found in the Appendix B.

Setting the Tide Gauge Data Logger

After the tide gauge stilling well was secured in its operating position and nearby benchmarks identified to serve as elevation references, the data logger was set for a 6-minute logging interval, in accordance with the Infinities user manual (Infinities USA, Inc. 1999), using a Hewlett–Packard HP48GX calculator. Several data logger readings and nearly simultaneous staff gauge or tape measure determinations of drop to the water surface from the stilling well rim (which corresponds to the logger's transducer height) were made. The readings were recorded and compared, and if the logger sounding error exceeded the specified limit (1 percent of reading), the logger was calibrated using the logger's built-in calibration routine.

Each tide station data logger was downloaded at least weekly, preferably more often, in order to ensure data were not lost due to "wrapping," which occurs when the logger's memory is full and each new record causes deletion of the oldest record in storage. Frequent visits to a tide station were made to reveal problems (malfunctions, stilling well movement, theft, vandalism, etc.) to avoid loss of many days of soundings taken that could not be corrected for tides.

DSM212H DGPS Parameter Settings

Feature positional accuracy obtained during data collection depended on several factors including the number of satellites, multipath, distance between base station and the rover, Positional Dilution of Precision (PDOP), Signal-to-Noise Ratio (SNR), and satellite elevation (Trimble Navigation Ltd. 1995). These factors were controlled and monitored via software and hardware settings. The following discussion describes the parameter settings used for field data collection

The Trimble DSM212H and its integrated dual-channel MSK beacon receiver were configured using Trimble Standard Interface Protocol (TSIP) TALKER software installed on the AMREL laptop. The TSIP TALKER software was used to configure key GPS operating parameters (DGPS input and output and NMEA-0183 output messages) as well as to monitor the status of receiver processes. The Elevation Mask was set to 15 degrees, PDOP Mask to 6.0, Dynamics Code to land, and the Positioning Mode to Manual 3D. The Positioning Rate, which was set to 1 Hertz (Hz), determined the rate at which the DSM212H output position reports to the HYPACK hydrographic software. Radio-broadcast USCG DGPS stations served as the DGPS Source for position corrections. Beacon Mode was set to automatic, which allowed the receiver to acquire the best signal from available USCG DGPS stations. DGPS Mode, which determines receiver behavior when DGPS corrections are received from a radiobeacon station, was set to 'On' to assure that the receiver computed positions only when DGPS corrections were available. The Max PRC Age was set to 20 seconds to eliminate older PRCs from position calculations, since they quickly age and lose accuracy. The External DGPS Source was set to 'Any Station' to automatically acquire DGPS corrections from any radiobeacon in the area.

Depth Sounders

Bathy-500MF—the Bathy-500MF echo sounder is controlled using the 16 keys located on the front panel. The settings described below are those that were found appropriate during the hydrographic survey. The field crew used only digital depth output, not the paper chart capability, of the sounder. During startup, the LCD display was viewed to determine if the unit was set to the proper transducer frequency (200 kHz transducer). The RANGE setting depends on the range of depths encountered during a particular survey; a consistent setting of 0–30 ft was used during the survey. The PHASE setting was 0–120 ft, the GAIN was set to 'Auto', and TVG set to 100.

A daily bar check determined whether corrections were needed due to variations in sound velocity. When there was a difference between the sounder depth reading and the bar depth, sound velocity (SV) was adjusted until the two depths matched. A data output I/O format of NMEA dbs was used to transmit depths to the HYPACK software. The depth of the transducer below the waterline was determined under normal load conditions and the measurement entered into the Bathy-500MF using the OFFSET key. Alarms were set to notify the operator when sounder readings were above or below specified limits. Alarms were useful to notify the operator when the sounder gave false readings.

Potential causes of false readings include turbulence, temperature gradients, density variations, and biological layers.

Horizon DS150—the procedures for entering settings into the Horizon echo sounder are described in the user manual (Standard Communications 2001). The keel offset (depth of the transducer below the waterline) was determined under normal load conditions (equipment and personnel) and the measurement entered into the HYPACK Hardware driver settings for the Horizon.

The Display Damping setting controls for rough water conditions, schools of fish, and thermal layers, all of which can cause erratic depth readings. Display damping controls the rate that the displayed depth changes and will help remove these variations. There are three levels of damping, with d1 having the least effect and d3 having the greatest effect. When operating in shallow or at high speeds it is best to use a low level of damping. The Horizon DS150 setting for damping was set to D1.

The Turbulence Setting provides three settings of turbulence rejection: t1, t2, and t3. A setting of t2 should be used unless a problem occurs while underway. A setting of t1 enables the instrument to work in water as shallow as 3 feet at an increased susceptibility to water turbulence and surface noise. A setting of t3 provides maximum immunity to water turbulence and surface noise at the expense of shallow water (less than 4 feet) performance.

Survey Procedures

Prior to conducting the depth survey, tide gauges were installed and checked to make sure they were working properly. There were a number of corrections that needed to be applied to the raw soundings to account for error sources attributable to systematic and system-specific instrument errors, static and dynamic variations in boat draft, environmental conditions, and tidal variations (National Ocean Service 1999; U.S. Army Corps of Engineers 2001).

Instrument Error and Sound Velocity Corrections—To determine corrections for sound velocity and instrument error, bar checks were performed within the survey area. A minimum of two bar checks was conducted during each survey day to verify the depth reading from the Bathy-500MF and DS150 transducers.

Bar checks took place at the start and end of each survey day. The bar consisted of a metal plate lowered to set distances, at 5-foot intervals, below each transducer. The sounder depth reading, at each 5-foot interval, was compared to the bar depth and, if necessary, the appropriate correction factor was entered into the DS150 instrument as one component of the keel offset, along with the static draft correction (see below). To apply the correction to the Bathy-500MF, the sound velocity setting was adjusted until the depth reading equaled the bar depth. At the end of each day, the two daily bar checks were compared. If the difference were greater than 0.3 foot, the survey was to be repeated; this was never necessary during the survey.

Static draft corrections—The static draft correction accounts for the depth of the transducer face below the waterline. The measurement was made at least to the nearest 0.1-foot as determined under normal load conditions with boat personnel in their survey positions. A person standing on a dock next to the survey vessel made the measurement. The correction was entered into the Bathy-500MF as a component of the offset, along with any necessary sound velocity correction (see Instrument Error and Sound Velocity Corrections). The correction was entered into the DS150 as a "Keel Offset".

Squat and Settlement—Differential leveling conducted under normal load conditions (including personnel, fuel, and equipment) determined squat/settlement corrections to the nearest 0.1-foot for the range of survey operating speeds (0 to 6.2 knots). Squat/settlement corrections varied from 0.0 to 0.2 foot.

Squat/settlement corrections were determined under calm conditions, in depths that equaled the average expected for the study area. To determine squat/settlement corrections a level was set-up on a dock and the boat run parallel to the shoreline in front of the level, at various speeds. A rod was held over the transducer and a series of observations taken with the vessel standing still, and at the range of survey operating speeds. The squat/settlement correction factor for each operating speed was based on the average of a minimum of three runs at each speed. Squat/settlement corrections were automatically applied during the depth survey by installing the Draft Table Driver within the HYPACK hydrographic survey software. The Draft Table is a listing of correction values with their corresponding vessel speeds. The average boat velocity, as determined from the DGPS, was recorded for each RPM level.

Motion Corrections—The depth survey was conducted in protected, near shore waters under calm sea conditions, and correction for heave, the only motion correction applicable for a single-beam survey (National Ocean Service 1999), was unnecessary. During bathymetry data collection in the residential canal systems, the primary weather considerations were crew safety (especially with regards to lightning), collision avoidance (when maneuvering near other vessels in heavy sustained or gusty winds), and efficient operation of instrumentation (particularly in heavy rain). On workdays when conditions were suitable in those regards, the weather did not significantly affect boat dynamics in the canals, and data quality remained high.

Error Budget—The following table gives the estimated measurement accuracy for depths less than or equal to 15 feet.

Depth Measurement Error Budget

Echo Sounder Measurement Error	0.15 feet
Bathy-500 Resolution	0.1 feet
Bar Check Calibration	0.15 feet
Static Draft	0.1 feet
Squat/Settlement	0.1 feet
Tide and vertical datum	0.2 feet
Resultant RMSE	0.35 feet

HYPACK Software Settings

A number of HYPACK software settings were necessary to conduct the depth survey.

The GEODETIC PARAMETERS settings depend on the projection parameters and the coordinate system of the background imagery used for a project. The depth survey used USGS DOQQs in Albers Equal Area projection and the parameters were set as shown in the following table.

HYPACK GEODETIC PARAMETERS.

Geodetic Parameters	
Predefined Grids	None
Distance unit	Meter
Depth unit	same as horizontal

Ellipsoid	WGS-84
Orthometric Height Correction	0.00
Projection	Albers Equal Area
Central Meridian	84º 00' 00.0000''W
Reference Latitude	24º 00' 00.0000''N
North Parallel	31º 30' 00.0000''N
South Parallel	24º 00' 00.0000''N
False Easting (X)	400000.0000
False Northing (Y)	0.0000

Hardware Setup—Four device drivers were installed for the depth survey equipment to communicate properly with the HYPACK software. These included the two echo sounders: the Bathy-500MF and the DS150; and the DSM212H DGPS. A fourth device consisted of a table to quantify the relationship between boat speed and squat/settlement. The table was used to apply real-time squat/settlement corrections to raw depths during the survey.

The relative location of each sensor that provides input to the HYPACK software was determined by selecting a point on the survey boat to serve as the "boat origin." Each sensor was then referenced based on its location relative to the origin: "to starboard"(X-direction) and "forward" (Y-direction). The offset units were the same as those used to record depths (e.g., meters). Figure 6 illustrates the Key West survey vessel as configured during the depth survey, with two echo sounders and one DGPS

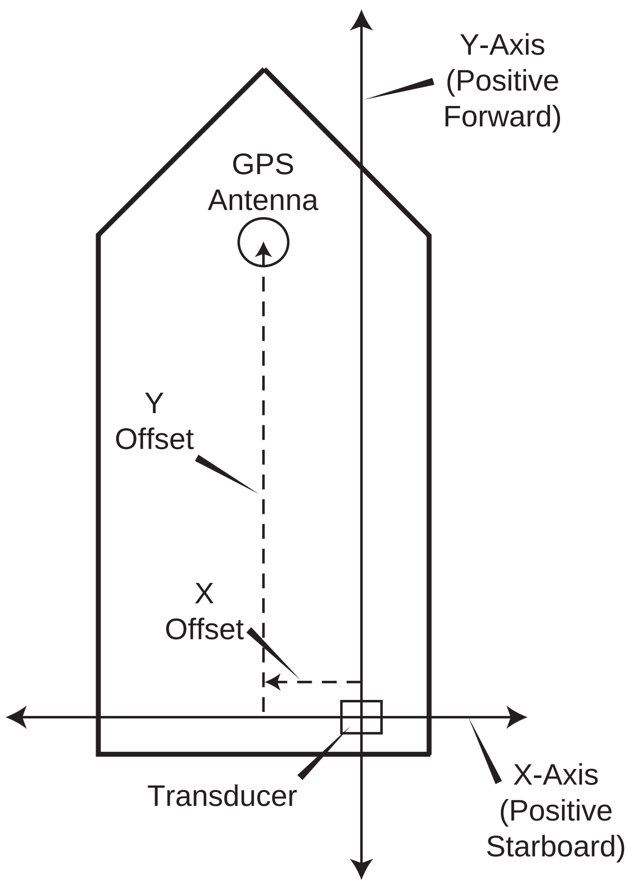


Figure 6. Boat Equipment Layout Schematic

antenna. The boat origin was positioned directly over the Bathy-500MF transducer, above which was mounted the DGPS antenna. All offsets forward and starboard of the boat origin have a positive value. The DS150 Horizon transducer was located aft of (negative offset) and to the port (negative offset) of the boat origin.

Once the preliminary tasks are completed, the device driver installation process was initiated. The specific settings for each survey device are detailed below. The Update frequency for the Bathy-

500MF controls the rate (ms) at which HYPACK requests a depth reading from the echo sounder and was set to 500 ms for the survey. The horizon outputs depths at a slower rate than does the Bathy-500MF and the setting was left at 50 ms. The latency time offset for the DSM212H was set to -0.3 as determined in consultation with Coastal Oceanographics, Inc, manufacturer of the sounder.

A “matrix” file for the study area was constructed in the HYPACK Max Matrix Editor. As soundings were collected, the Survey program filled in the matrix cells with pre-selected sounding colors, allowing continual monitoring of data goodness and enabling the crew to see a track generated over the background imagery as the boat moved.

The survey was initiated after performing the initial bar check for each sounder. The boat followed a planned course, to sound centerlines and each side of waterways. Three parallel lines were surveyed at 25, 50, and 75 percent of the canal width. The data collector monitored the progress and directed the boat operator as required. The boat stopped when soundings were missed due to absence of DGPS positions or other causes. Audible and visible alarms alerted the crew to data dropouts. The data collector paused logging when the boat stopped or maneuvered off the planned course to avoid traffic or other hazards.

When the water was too shallow for sounder operation, the data collector or boat operator manned the staff gauge. Manual soundings were noted on the aerial photomap, along with the date and time. If soundings could not be logged automatically due to excessive PDOP or loss of the beacon under bridges, near large buildings, etc., sounder readings were recorded on the map, again with the date and time. At the end of the day, a second bar check was conducted.

Upon completion of the bathymetric survey, cross lines checks were performed on a different tidal cycle to verify the bathymetric data. Cross lines were at a 45 degree angle to original survey lines, their length was equal to fifteen percent of the total linear extent of the bathymetric survey, and they were distributed throughout the study area. The criterion for acceptance was an expected mean difference of ±0.2 feet between comparable survey points.

NOAA/NOS CO-OPS

Retrieve Observed Water Levels and Associated Ancillary Data

CO-OPS has updated to a new National Tidal Datum Epoch (1983-2001). For more information click HERE

Important Notice:

- **List of Stations that are Scheduled for EPOCH Update**
- **List of Stations that are Not Scheduled for EPOCH Update**

Inventories

- Station Inventory
- Data Inventory
- Great Lakes Data Inventory
- Presently Operating Stations
- Station Index

Verified / Historical Water Level Data

- U.S. and Global Coastal Stations
- Great Lakes Stations
  - Max/Min Report
  - Monthly Means

Key West, Florida

Click **HERE** to check current Database status.

Having problems retrieving data?
Click **HERE** for help.

Preliminary Water Level Data

- U.S. and Global Coastal Stations
- Great Lakes Stations
  - 7 Day Report - Single Station
  - 7 Day Report - All Stations
- Unlisted Stations
- U.S. and Global Coastal Station Data Plots
- Great Lakes Station Water Level Plots

Ancillary Data

- Unlisted Stations
- Monthly Means
- Monthly Extremes
- Station Extremes

Other

- Sea Level Trends
- Benchmarks- NEW EPOCH (1983-2001)
- Accepted Datums- NEW EPOCH (1983-2001)
- Harmonic Constants
- Predicted 6 min. Data
- Astronomical Data

- Meteorological/ Oceanographic Data
- Great Lakes Met. / Oceanographic Data
- Met and Ocean Data for Unlisted Stations

This is a listing of on-line data currently provided by the Center for Operational Oceanographic Products and Services. Please read our **disclaimer.**

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FAQ Station Locator Publications About CO-OPS Product Info.

Page last updated on undefined

Post-processing of Survey Data

Tidal Datum Determination

The NOS control tide station chosen to compute NTDE equivalent tidal datums for the project area is located at Fort Myers (Station ID: 8725520) on the Caloosahatchee River, and is part of the National Water Level Observation Network (NWLON). The tidal datums computed for Fort Myers are for the 1960-1978 Tidal Epoch, and are based on a series length of 18 years (1966-1984). The primary control tide station that was used to compute the Fort Myers tidal datums is located at St. Petersburg (8726520). The Fort Myers station was selected as the control station because it better reflects the local tidal influences within the Caloosahatchee River than does the St. Petersburg gauge. The NOS accepted tidal datums (feet), referenced to station datum, for the Fort Myers gauge are as follows (http://co-ops.nos.noaa.gov/data_res.html):

Station	MHHW	MHW	DTL	MTL	MSL	MLW	MLLW	GT	MN	DHQ	DLQ
8725520	5.44	5.24	4.85	4.81	4.82	4.37	4.25	1.19	0.87	0.2	0.12

NTDE equivalent tidal datums within the project area were determined by reducing water level data obtained from numerous tertiary water level stations that were installed by FSG personnel (Figure 4). The FSG stations operated anywhere from 6 to 119 days, depending on the time required to complete soundings in the vicinity of the gauge(s). Equivalent tidal datums were determined through "mathematical simultaneous comparison" of station high and low water levels with those recorded at the control station (Fort Myers). The siting of FSG gauges was such to cover "significant changes in tidal characteristics such as: changes in tide type, changes in tide range, changes in time of tide, changes in daily mean seal level."

Water level data for the NOS Fort Myers gauge was obtained from the website maintained by the Center for Operational Oceanographic Products and Services (http://co-ops.nos.noaa.gov/data_res.html). NOS implements standard operating procedures to verify the quality of water level data published at the website. Verified water level data for the Fort Myers gauge is found under the link titled "Verified/Historical Water Level Data for U.S. and Global Coastal Stations." As a control, an FSG gauge was installed in the same basin as the NOS Fort Myers gauge.

The following steps were taken to determine the NTDE equivalent tidal datums for each FSG gauges installed within the study area. The computational procedures followed are those specified by the NOS (Center for Operational Oceanographic Products and Services 2000). Since water levels at FSG gauges were recorded for less than a year, and since tides are mixed in the area, a comparison of simultaneous high and low waters (Tide by Tide Analysis) was performed. The steps followed to perform the tide-by-tide analysis are as follows.

For each FSG station, a spreadsheet application worksheet was constructed using the following format:

FSG Gauge Date/Time	Gauge Drop (Inches)	Gauge NGVD29 (Feet)	Slope	FSG Tide	NOS Tide	NOS Gauge Date/Time	NOS MLLW (Feet)
7/13/01 13:24	-67.93	1.095			L	7/13/01 21:06	0.63
7/13/01 13:36	-68.01	1.088	-		H	7/14/01 2:24	1.12

The primary purpose of the worksheet was to determine when specific high and low tide levels occur at each FSG station. Tide levels are designated as HH (higher high water), H (lower high water), L (higher low water), or LL (lower low water). Tide levels at FSG gauges were determined using the designated high and low waters at the NOS gauge as a guide.

The information contained in each spreadsheet column is as follows:

Col. 1: Dates and time, at 6 minute intervals, when a water level was recorded at the FSG gauge.
Col. 2: The drop, in inches, from the FSG gauge transducer to the water level surface (i.e. station datum).
Col. 3: The FSG gauge water level adjusted to the NGVD29 vertical datum (feet).
Col. 4: Using an MS Excel formula [IF((C2-C1)<0,"-","+")] the direction of water level change was determined. This was used as a visual aid to locate high and low waters.
Col. 5: A tide designator (HH, H, L, LL) is entered for each FSG gauge record that corresponds to a high or low water.
Col. 6: The tide designator (HH, H, L, LL) as assigned by NOS CO-OPS personnel, and downloaded from the CO-OPS web site.
Col. 7: The date and time that high and low waters were recorded at the NOS primary station (Fort Myers). This entry is downloaded from the CO-OPS web site.
Col. 8: The high or low water level, in feet, recorded at the NOS primary station (MLLW). This entry is downloaded from the CO-OPS web site.

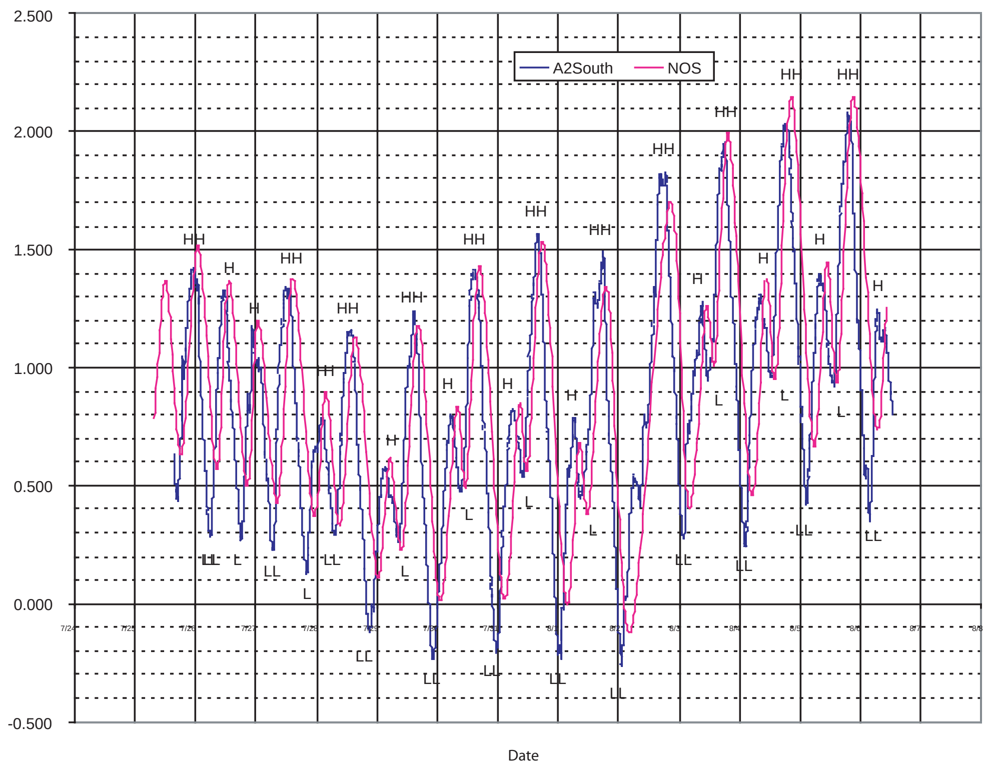
According to the published benchmark sheet for the Fort Myers station (http://co-ops.nos.noaa.gov/bench.html), the NGVD29 vertical datum and the MLLW tidal datum are at the same elevation. Therefore, recorded water levels at FSG gauges were adjusted to the NGVD29 geodetic datum prior to calculating tidal datums. High and low water levels referenced to the MLLW tidal datum were obtained for the Fort Myers gauge. This allowed for easy comparison of resulting tidal datums for the FSG gauges to the accepted tidal datums published for the Fort Myers station.

ELEVATIONS OF TIDAL DATUMS REFERRED TO MEAN LOWER LOW WATER (MLLW), IN FEET:	
HIGHEST OBSERVED WATER LEVEL (06/19/1972)	4.05
MEAN HIGHER HIGH WATER (MHHW)	1.19
MEAN HIGH WATER (MHW)	0.99
MEAN TIDE LEVEL (MTL)	0.56
MEAN LOW WATER (MLW)	0.12
NATIONAL GEODETIC VERTICAL DATUM-1929 (NGVD)	0
MEAN LOWER LOW WATER (MLLW)	0
LOWEST OBSERVED WATER LEVEL (01/16/1972)	-2.04

Once the spreadsheet worksheets were complete, corresponding time periods from the FSG gauge series and the Fort Myers gauge were plotted, as shown below. The plot was used to guide the determination of high and low waters at the FSG gauge, as outlined for column 5 above. The first step was to label the NOS tide curve with the high/low designators assigned by CO-OPS. Next, each high and low water for the FSG gauge was entered in column 5, using the same tide designator as the corresponding high or low water on the NOS tide curve.

Once high and low water designators were entered into column 5 for the FSG gauge, the results (columns 1 through 5) were pasted into database management software (MS Access) and that subset of FSG gauge records selected that consisted of high and low waters (HH, H, L, LL) that correspond to the NOS tide gauge. The subset was pasted into a second spreadsheet workbook with the following structure:

FSG GAUGE			NOS GAUGE			FSG Gauge minus NOS Gauge
Date/Time	**NGVD29 (feet)**			**Date**		**NGVD - MLLW**
7/13/01 17:54	0.39	L	L	7/13/01 21:06	0.63	-0.243
7/14/01 0:24	0.98	H	H	7/14/01 2:24	1.12	-0.143
7/14/01 7:06	0.54	L	L	7/14/01 9:00	0.65	-0.107



The information contained in each spreadsheet column was as follows:

Col. 1: Date and time that high and low waters were recorded at the FSG station.
Col. 2: The FSG gauge high and low water levels, in feet, referenced to the NGVD29 vertical datum.
Col. 3: The tide designator (HH, H, L, LL) for each high and low water at the FSG gauge.
Col. 4: The tide designator (HH, H, L, LL) as assigned by CO-OPS personnel for the NOS gauge. This entry was downloaded from the CO-OPS web site.
Col. 5: The date and time that high and low waters were recorded at the NOS primary station (Fort Myers). This entry was downloaded from the CO-OPS web site.
Col. 6: The high or low water level, in feet, recorded at the NOS primary station (MLLW). This entry was downloaded from the CO-OPS web site.
Col. 7: The difference between the water level recorded at the FSG gauge (column 2) and the corresponding water level recorded at the NOS gauge (column 6).

The worksheet data was then pasted into a database management program (e.g. MS Access) to generate the sums needed to calculate the tidal datums.

Tide Corrections

A specialized computer program, Survey Tide Correction (SURVCORR.exe), created by the University of Florida Coastal and Oceanographic Engineering Program, was used to correct soundings for the local state of the tides at the time each depth was recorded. The complete SURVCORR operator's manual, found in the Appendix, details the functionality of the program and specifies the required content and formatting for each input file.

SURVCORR output is a text file containing the raw depth, corrected depth, date/time, and XY coordinates for each sounding. This was used to generate an ArcView event theme and/or ArcInfo coverage of corrected depths. Figure 7 is a diagram of data flow from the tide gauge and sounder outputs through generation of tide-corrected ArcView GIS shapefiles.

Each SURVCORR session requires three ASCII-text-formatted input files: (1) uncorrected soundings (Survey Data File); (2) a "baseline" of georeferenced points, along which time and tide interpolation algorithms operate (Baseline Location File); and (3) tide gauge readings with interpolated time and location tags (Baseline Tide Data File). The program can correct soundings taken near a single tide gauge in the "one-gauge case" (with interpolation based only on time) or between pairs of gauges in the "two-gauge case" (interpolating over both time and distance).

Soundings Cleanup

Soundings processed using the procedures described above resulted in a distribution of data points suitable for display. Very rarely there were obvious errors in the DGPS positions, manifested by soundings that are displayed in the wrong place, perhaps on land. When present, such errors were not subtle, but readily apparent. The data collector looked carefully at the location of soundings over the entire study area and, if such anomalies were observed, re-surveyed the affected part of the study area. Note: Soundings collected in new canal systems or near inlets where storm events have caused shoreline changes since the background imagery was created may appear to be on land. These were verified,

Several error sources can affect depths measured by echo sounders. Common were excessively deep soundings caused by multiple bounces of the transducer signal from the bottom, back to the boat hull, and off the bottom again, which resulted in doubling (or even quadrupling) the true depth. If the sounder failed to record a depth for a position, it sent a zero reading to the survey software. Raw soundings (before boat squat/settlement corrections) of exactly zero are always bogus, because sounders have minimum operating depths greater than zero.

An initial step in cleaning up sounding data—after creating the shapefile with thinned data point and all attributes, but before creating text files for tide corrections—was to select and delete all data points with a raw depth value of zero. The appropriate ArcView queries were constructed and raw depths of less than approximately three feet were studied carefully and deleted if questionable, based on field notes and knowledge of actual minimum depths in a study area and the characteristics of the sounder(s) being used.

The maximum depth reasonably expected in an area was estimated, and a query built to select all depths deeper than that value. The selected soundings were examined and deleted if appropriate. A color-coded legend was applied to the depths to make changes in depth categories visually obvious. Depths were then carefully examined for sporadic, unlikely values. Simultaneously displaying depths from the two different sounders proved very useful, since, overall, the colors displayed from the sounders should be very similar. A series of points with differing colors from the two sounders were

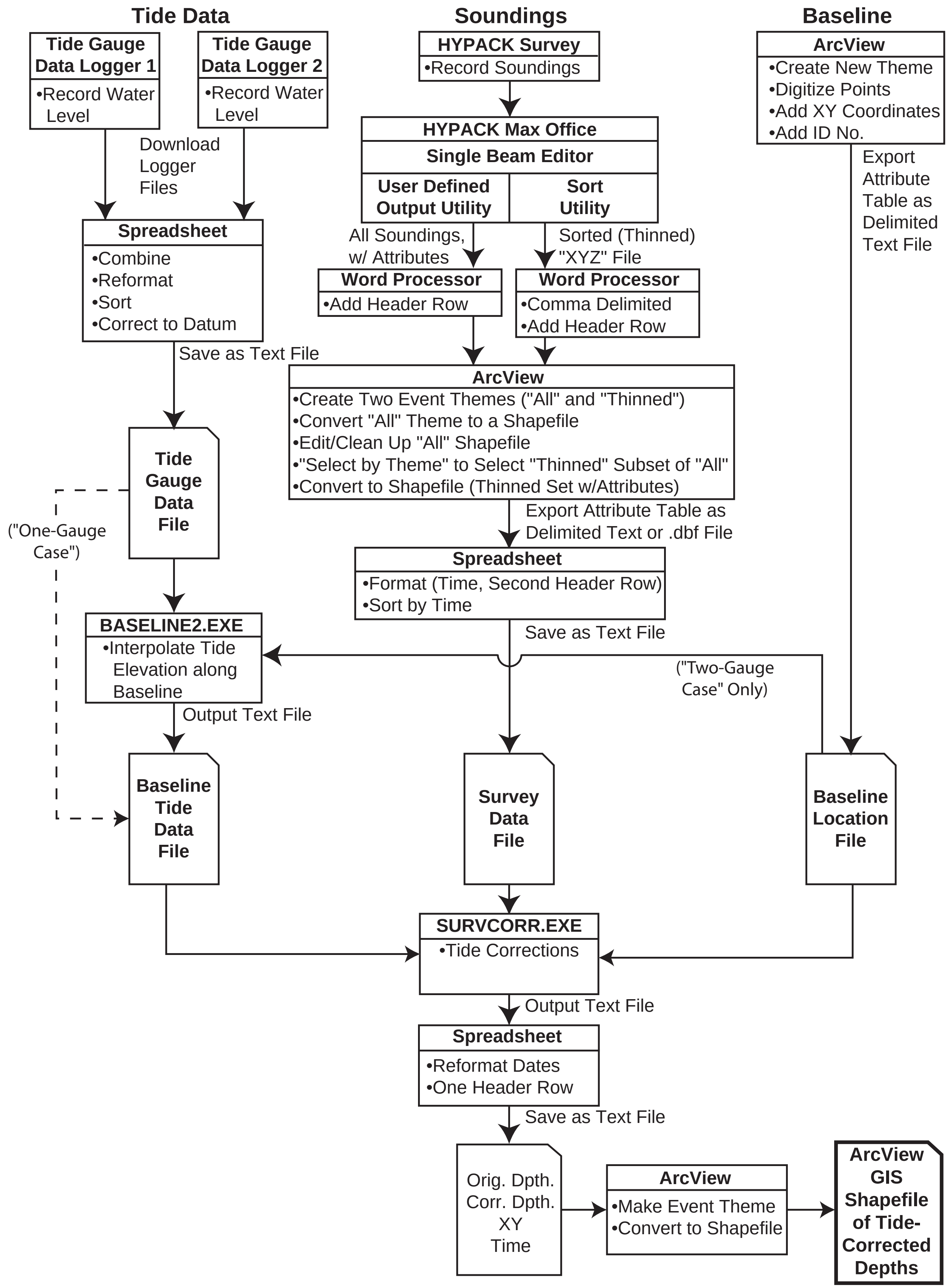


Figure 7. Tide Correction Data Flow

investigated. Normally, only one of the two sounders “doubled,” and the difference was obvious. Additionally, PERL and AML scripts were developed to automatically tag potentially anomalous soundings, which were then cleaned. With reference to field notes and aerial photo annotations, soundings were digitized to fill in gaps caused by shoals or loss of DGPS positions around buildings or under trees and bridges. Soundings were displayed along with a line shapefile of the waterways planned for surveying to ensure no areas had been missed.

Results and Conclusions

The bathymetric GIS data set contained on the accompanying CD has information on over 700,000 point depths recorded for all channel center-lines and approaches to boating facilities, in an area extending from the mouth to the Lee/Hendry County boundary, and the canals, rivers, and creeks that drain into this reach of the Caloosahatchee River. The mean depth of the study area is 6 feet. The data were collected by an on-the-water survey conducted between June 2001 and April 2002, using a Trimble DSM212H 12-channel receiver, with integrated dual-channel MSK differential beacon receiver and Bathy-500MF and Horizon DS150 sounders.

All depths in tidal waters are referenced to the navigation datum, mean lower low water (MLLW), and are rounded to the nearest 0.5-foot. In non-tidal areas (above locks), the datum is the National Geodetic Vertical Datum of 1929 (NGVD29). Tide gauges were installed at 28 locations (Figure 4) during the period of data collection, and depths were corrected to MLLW or NGVD29 using computer programs prepared by the University of Florida Department of Coastal Engineering.

Depths recorded with the Bathy-500MF were used to verify the soundings recorded simultaneously by the DS150. The DS150, a low cost sounder, was evaluated for potential use in future shallow-area surveys conducted by third party entities under the supervision of the WCIND and FSG. Survey results revealed that the DS150 provided depths that were more consistent and reliable than those provided by the Bathy-500MF. The Bathy-500MF was subject to regularly occurring, short series of depths that were several feet deeper or shallower than were actual depths. Scripts were developed to identify and clean the anomalous depths recorded by the Bathy-500MF, however the procedure was tedious and time consuming.

The shallow water limit of both sounders was similar. The lower limit of the Bathy-500MF was approximately 3.6 feet and that of the Horizon DS150 approximately 3.8 feet. Since the WCIND surveys shallow recreational boating areas, the lower limit of both sounders presents problems. Current WCIND/FSG survey methods involve mechanical sounding of shallow areas with a sounding pole or lead line. Alternative methods/sounders will need to be developed/evaluated to resolve this time-consuming and inefficient technique.

The DS150 output depth values of 0.0 when the instrument’s lower limit was reached. A value of 0.0 on the instrument display provided field personnel with a clear indicator as to when mechanical soundings were necessary. Post-processing of Horizon data also was simple, since all depths with values of 0.0 feet could easily be eliminated. The Bathy-500MF, however, tended to produce spurious readings below 3.6 feet and would continue to output a depth value (e.g., 3.4 feet) even though the actual water depth was shoaling beyond the lower limit of the sounder. As a result, post processing of Bathy-500MF data was considerably more difficult than for Horizon data.

A cross line analysis was conducted to verify the accuracy and reliability of the bathymetric data. Cross line soundings collected on a different tidal cycle were contrasted with comparable soundings collected during the primary survey. The criterion for acceptance was an expected mean difference of ±0.2 feet between comparable survey points. A total of 100,808 soundings were collected during implementation of the cross line survey, which represents 14 percent of the total number of soundings collected during the primary survey. Paired cross line and primary soundings were identified by GIS spatial analysis. The mean difference of the resulting 517 paired soundings was 0.04 feet, which is less than the maximum allowable bias of 0.2 feet. The standard deviation was ±0.20 feet, resulting in a 95% estimated accuracy of ±0.4 feet.

The results obtained from the bathymetric survey indicate that the WCIND could reasonably continue bathymetric survey operations with third party participants using low cost, less complex survey equipment such as the Horizon DS150. Regardless of the type of equipment used, a minimum of two sounders should be operational during a survey as a check. A manual that explains all the procedural phases of the bathymetric survey, including quality control and assurance steps, was developed for the WCIND. Adherence to the manual guidelines will assure the accuracy and quality of bathymetric data collected.

GIS Data Sets and Imagery

A CD-ROM accompanies this report and contains all geographic data sets as ARC/INFO® export files and ArcView® shapefiles (ESRI). The geographic data sets include: 1) soundings, reduced to Mean Lower Low Water (MLLW) or NGVD29 in areas behind locks, and recorded to the nearest 0.5-foot, 2) the location of the water level recorders used to correct soundings to MLLW, and 3) channels, created from soundings and represented as line features. Collection times are recorded in Coordinated Universal Time (UTC) for soundings. The projection parameters for all geographic data sets are as follows:

Projection:	Albers
Datum:	NAD83
Units:	Meters
Spheroid:	GRS1980
1st Standard Parallel:	24.0
2nd Standard Parallel:	31.5
Central Meridian:	-84.0
Latitude of Projection's Origin:	24.0
False Easting (meters):	400000.0
False Northing (meters):	0.0

The CD-ROM contains resampled USGS Digital Orthophoto Quarter Quadrangles at 1, 3, and 6-meter resolutions in JPEG format. Metadata, compliant with standards outlined by the Federal Geographic Data Committee, is provided on the CD-ROM for each geographic data set. The ArcView project (e.g., /ProjectDataCD/leephase3.apr) was created with a view containing all data sets and imagery. The included JPEG imagery requires that the JPEG (JFIF) extension be invoked from the available extensions.

The data sets and imagery that are included are described as follows:

a. DEPTHS—information on depths points recorded for all channel centerlines and approaches to boating facilities and referenced to the navigation datum, MLLW (or NGVD29 in areas behind locks), and reported to the nearest 1/2 foot.
b. CHANNELS—boating access channels, classified according to depth (nearest 1/2-foot; MLLW) and degree of restriction.
c. TIDE GAUGE—the locations of tide gauges used to correct soundings to MLLW or NGVD29 (soundings behind locks).
d. BOATS—boats berthed in the water or stored on salt-water accessible parcels. Information includes boat type, length, age, make and model, draft, facility, mooring type, the date the boat was surveyed, and the level of restriction.
e. MOORINGS—moorings, including information on facility, mooring type, and the date the mooring was surveyed.
f. DERELICTS—derelicts vessels, including information on condition, whether the vessel is beached or afloat, percent of submersion, and the date the vessel was surveyed.
g. SIGNS—boat-related signs in the water and along the waterfront and visible to boaters. Information includes site, type, message, status, condition, and the date the sign was surveyed. The signs are grouped into the following classes: hazard warning, municipal mooring, navigation guide, private ownership, resource protection, and speed regulation.
h. TRAFFICSHEDS—trafficsheds (navigable waterways that serve as boat source areas). Trafficsheds serve as units of analysis and allow the county to prioritize waterway management efforts. Information provided for each trafficshed includes the numbers of boats,

moorings, signs, and derelict vessels that were present in the trafficshed at the time of the field surveys. Trafficsheds range from complex canal systems to short, one-segment channels that provide access from shore to open-bay waters.

i. ATLASINDEX—tiles constructed from a digital map index of USGS quarter quadrangles. Each tile represents 1/16th of a quarter quadrangle and is labeled with the quadrangle name, the quadrangle quarter (NW, NE, SW, SE), the Florida Department of Environmental Protection quadrangle number, and a page number that corresponds to the project mapping extent.
j. Background imagery derived from USGS 1-meter digital orthophoto quadrangles is included in the directory labeled Images. Each image is provided JPEG formats, and the JPEG images are available in 1, 3, and 6 meter resolutions.

Metadata is provided for all data sets in HTML format.

Appendix A

Equipment Specifications

Bathy-500MF Multi-Frequency Survey Echo Sounder

- Depth Range: 0-15, 0-30, 0-60, 0-120, 0-240, 0-480, 0-1920 Feet; 0-10, 0,20, 0-40, 0-80, 0-160, 0-640 Meters
- Phasing: 0-120, 60-180, 120-140, 180-300, 240-360, 300-240, 360-480 Feet, Auto; 0-40, 20-60, 40-80, 60-100, 80-120, 100-140, 120-160 Meters, Auto
- Accuracy rating: ±0.5 percent
- Chart Record: 8.5 inch X 90 feet high-contrast thermal paper
- Digital Display: LCD (4 line X 16 characters) 0.25 inch characters; Depth display: 0.75-inch characters; Back-lighting: Electro-luminescent Resolution: 0.01 units for depths less than 100 meters; 0.01 for depths greater than 100 meters; 0.1 feet on all ranges
- Frequency: Any single frequency (user selectable & changeable via keypad) from these: 33Khz, 40Khz, 50Khz, 200Khz (Acoustic output=600 watts)
- Depth Alarms: Shallow and deep (selected by keypad)
- Sound Velocity: 4600-5250 feet/second (1393-1590 meters/second); user selected by keypad
- Offset: 0 to +30 feet or meters (allows the user, via keypad, to adjust for the transducer depth)
- Geographic Position: NMEA-0183 GGA or GLL format for GPS/DGPS
- Data I/O Compatibility: COM1 provides bi-directional interface to PC or other peripheral device; this port accepts external annotation from external sources such as hydrographic software. This port also allows remote control of all echo sounder functions using Ocean Data's Windows 95/98/NT based software. Com2 accepts GPS/DGPS inputs and provides additional (from COM1) data outputs.
- Data Outputs: ODEC PMS dt (True Depth & Status); Atlas DESO-25; Odom Digitrace; Odom Echotrac; NMEA DBT; NMEA DBS
- Input Power: 11-30 volts d.c. (1.5 amps @ 12v. 0.5 amps @ 30v.)
- Dimensions: Height (including handle) 19 inches; width 17.5 inches; depth 9 inches
- Weight: 35 lbs (recorder with transducer)
- Operating Temperature: -10 ^{o}C to +50 ^{o}C / Humidity 95% non-circulating

Bathy-500MF Transducer (P/N P01540)

- Resonant Frequency: 208 KHz
- Nominal Impedance: 50 ohms
- Beamwidth (@ 3 dB point): 8 degrees
- Cable: 30 feet (with plug to mate with recorder)
- Housing Material: Brass (with urethane acoustic window)
- Piezo Material: Barium titanate

Horizon DS150 Single-beam Echo Sounder

- Power Supply: 0.7 to 16.6 VDC 15 mA nominal,
  35mA with backlight on
- Operating temperature: 32^{o} to 114^{o} F (0^{o} to 45^{o} C)
- Accuracy rating: ± 2 percent

•Size of display: 4.4 x 4.4 x 1 inches (112 x 112 x 20 mm)
•Overall depth: 1.4 inches (35 mm) behind panel
•Display type: Twisted Nematic (TN), gray background)
•Illumination: Red LED
•RF Interference: Less than 6 dB maximum quieting on any marine radio channel with 3 dB gain antenna within 1 meter of instrument head
•Depth: 3 to 400 ft, 1 to 120 meters, or -.5 to 67 fathoms
•Alarms: Shallow and deep water, Audio and LCD flag
•Display unit selection: Feet, meters or fathoms, keypad selectable
•Display damping: Three levels keypad selectable
•Keel Offset: Keel/propeller or waterline, ±9.9 ft, ±1.6 fathoms or ±3.0 meters, user selectable trend indication
•NMEA outputs: DPT, DBT
•Proprietary Outputs: Alarm and Trend arrows
•Transducer: 201 kHz, 600 ohm, 1500pF parallel capacitance

Infinities USA Model 220 ultrasonic water level loggers

•Number of measurements in memory: 3906
•User programmable interval: 1-reading/second to 1-reading/6 months
•User interface to Logger: PC or opt. HP 48GX or 48G+ calculator w/ software
•Data logger power: Four AA alkaline batteries
•Data logger battery life, typical: 4 years
•Data logger range: 18 feet
•Minimum target distance: ~16 inches
•Ranging environment: inside 1 1/4" to 3" PVC sch. 40 pipe
•Temperature compensation: 0F to 120F
•Humidity: to 100%
•Accuracy: +/- 1% of distance measured
•Resolution: ~0.04 inches or 1mm
•Ultrasonic Frequency: 49.7kHz
•Data download rate: 150 measurements per second
•Download medium: serial cable
•Hewlett-Packard 48GX storage: multiple data loggers, 40,000 measurements

Trimble DSM212H Integrated GPS/MSK Receiver

Standard Features

•12-channel GPS receiver
•Integrated GPS and dual channel MSK beacon receiver
•Outputs positioning reports at 1, 5, or 10 Hz
•Isolated power supply
•Positioning based on carrier-phase filtered L1 pseudo-ranges
•Two programmable RS-232 serial ports:
  - o NMEA-0183 output or RTCM SC-104 output
  - o RTCM SC-104 input
  - o TSIP input and output

•1PPS output
•Windows configuration software
•DSM212 operation manual
•Compact L1 GPS and MSK H-field loop antenna
•15 meter RG58 antenna cable
•Power/data cable
•12Pin to data cable

Performance Characteristics

•12-channel, parallel tracking, L1 C/A code with carrier phase filtered measurements and multi-bit digitizer
•Differential speed accuracy: 0.1 knt (0.1 mph, 0.16 km/h, 5.6 cm/s)
•Differential position accuracy: Less than 1 meter horizontal RMS (at least 5 satellites, PDOP < 4 and RTCM SC-104 standard format broadcast from a Trimble DSM12RS or equivalent reference station
•Time to first fix: < 30 seconds, typical
•NMEA messages: ALM, GGA, GLL, GSA, GSV VTG, ZDA, RMC, MSS

Physical Characteristics

•Size: 14.5cm W x 5.1 cm H x 19.5 cm D
•Weight: 0.76kg (1.68 lb)
•Power: 5W (max), 10 to 32 VDC
•Operating temperature: -30 °C to +65 °C
•Storage temperature: -40 °C to +85 °C
•Humidity: 100% condensing, unit fully sealed

MSK Beacon Dual-Channel Receiver

•Frequency Range: 283.5 KHz to 325.0 KHz
•Channel spacing: 500 Hz
•MSK modulation: 50, 100 & 200 bits/second
•Signal strength: 10 μV/meter minimum @ 100BPS
•Dynamic range: 100 dB
•Channel selectivity: 70 dB >500 Hz offset
•Frequency offset: 17 ppm maximum
•3rd order intercept: +15 dBm @ RF input (min. AGC setting)
•Beacon acquisition time: <5 sec, typical

AMREL Rocky II Plus

•CPU: Intel Pentium, 366 MHz Pentium II
•Ram Memory: 64MB SDRAM standard
•Storage: Removable 2.5” HDD (available 6GB up to 10GB); Removable 3.5” 1.44MB FDD
•Display: 12.1” 800 x 600; AGP compliant 128-bit video engine with 256-bit bus 2.5MB embedded SDRAM
•Keyboard: 89-key KB standard keycap with dust cover and Windows 95 keys ready; PS/2 compatible touchpad
•Power System: Removable 10.8V 4500mAH Lithium ion primary battery; secondary 10.8V 4500mAH Lithium ion battery pack (DR202 compatible) swappable with FDD; smart battery and smart charger

•I/O Ports: 2S, 1P, CRT, external kb, eternal FDD, Fax/Modem (RJ-11), LAN (RJ-45), Audio, PS/2 mouse, USB, port replicator; 2 PCMCIA type II slots or 1 type III slot; LAN, radio modem etc, Cardbus and ZV port support; IrDA-compliant infrared transceiver (fast IR 4 MB/sec transfer rate)
•Dimension: 312 mm x 246 mm x 62.5 mm; Weight approximately 4.7 kg; rain and dust proof, shock resistant structure; magnesium case

Dell Dimension XPS T750MHz Pentium III

•768MB DSRAM Memory with ECC
•V.905/56K PCI DataFax Modem
•8x/4x/32x CD-RW
•32MB NVIDIA geForce Plus AGP Graphics Card
•18GB 10K SCSI Hard Drive
•3.” Floppy Drive
•3Com US Robotics 3C905C-TXM 10/100 Remote Wake Up Nic

Appendix B

Survey Tide Correction Program
Conceptual Description

The Survey Tide Correction program developed in the University of Florida Coastal and Oceanographic Engineering Department by Bill Miller under the direction of Dr. Max Sheppard consists of three Fortran 90 programs. The basic program is survcorr.f90 which performs the linear interpolations and corrects the survey data. The other programs, baseline1.f90 and baseline2.f90, may be used to provide "SURVCORR" with its baseline files.

The basic concept is to provide a means of correcting a survey of water depth within a winding canal or river system using a limited amount of tidal data. To do this a "baseline" of correcting reference points is constructed along the survey path within the system. In an ideal case, tide gages would be located at each baseline point and the survey could be corrected using a linear interpolation to the two gages nearest to the survey point.

However, setting up so many tide gages is not practical. Therefore, a baseline tide data file is constructed using two gages at either end of the system. The data is interpolated by program "BASELINE2" based on the distance of the point from each gage. The baseline data is then used to correct the survey data. By using this "baseline method," the distance between the gages within the winding path of the system may be considered, rather than the direct distance from the survey point to the gages. This direct distance will likely cut across the system and not reflect the true distance seen by the tide as it propagates along the baseline path.

Thus, the baseline points are best located at the corners and bends in the system and the file describing the locations must list the points in sequence along the path of the system. The diagram below illustrates such a baseline.

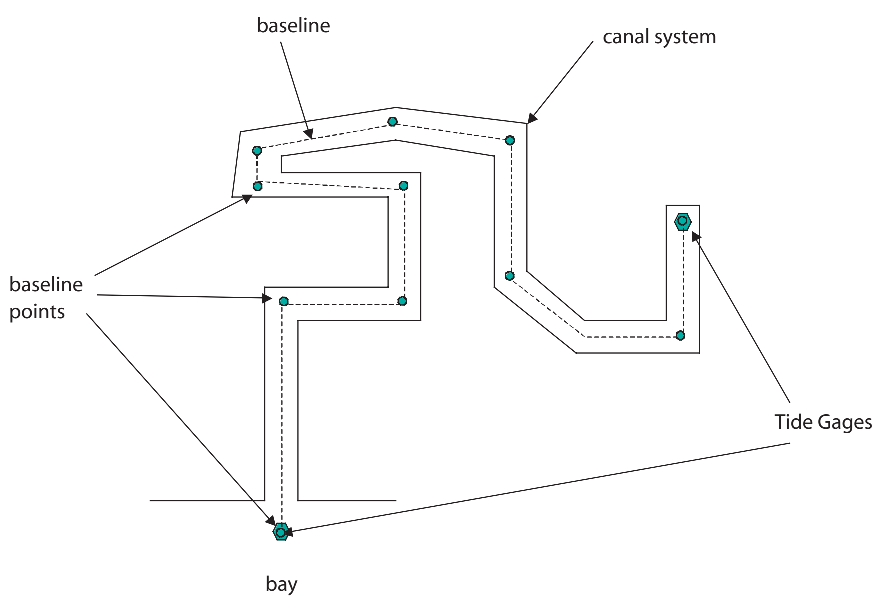


Figure 1. Canal System and Baseline Development

If a branch to the canal system exists, a branch to the main baseline may be developed using the "BASELINE1" program. The figure below illustrates this situation.

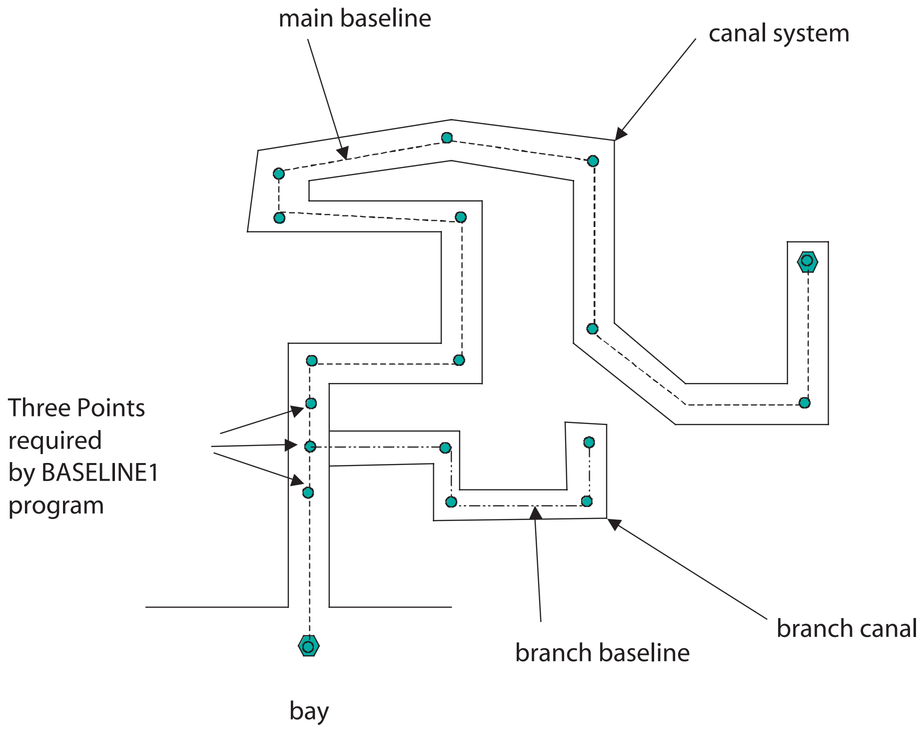


Figure 2. Branch Canal Case

The three baseline points are used to determine a water surface slope (time dependent). This slope is then applied along the branch baseline to determine the appropriate tidal correction with distance.

If the tide is the same throughout the system, using a single baseline point in "SURVCORR" will result in a direct interpolation of the survey to this one point. In other words, only the time will be considered and interpolated and not the distance from the point.
Instructions for Correcting a Survey

A. Correction between two tide gages

1. Divide the survey data into appropriate paths and format in an ASCII file described under the "SURVCORR" Program section of these instructions.

Per Fig. 1, plot a baseline on a chart of the survey area and record the locations of each point. The first and final points of the baseline should be tide gages. Each bend and corner in the canal system should be marked by A BASELINE POINT. RECORD these points in an ASCII data file described under the "SURVCORR" Program section of these instructions.

Use the "BASELINE2" program to interpolate the tide data from the two tide gages and develop the "Baseline Tide Data" file used by the "SURVCORR" program.

Use these files as the inputs to the "SURVCORR" program described under the "SURVCORR" Program section of these instructions.

The output file of the "SURVCORR" program should be examined to verify reasonableness of the corrections made to the survey data.

B. Corrections to a canal branch

Per Fig. 2, determine the three main baseline points to be used in the "BASELINE1" program and build their location and data files. These files must have the form described under the "BASELINE1" Program section of these instructions and be saved in ASCII format.

Plot a branch baseline on a chart of the survey area and record the locations of each point. The first point must be the middle point of the three points chosen above. Each bend and corner in the canal system should be marked by a baseline point. Record these points in an ASCII data file described under the “BASELINE1” Program section of these instructions.

Use these files as inputs to the “BASELINE1” program. The output of this program will be the “Baseline Tide Data” file used by the “SURVCORR” program.

Use the “Baseline Tide Data” from (3), the Baseline location file from (2) and the survey data file as the inputs to the “SURVCORR” program described under the “SURVCORR” Program section of these instructions.

The output file of the “SURVCORR” program should be examined to verify reasonableness of the corrections made to the survey data.

C. Corrections to a system with one tide gage

If only one tide gage is used, no reference exists for how the tide varies with distance. In this case, the survey cannot be corrected for distance. Use the tide gage location and tide data as the only baseline point and repeat steps 4 and 5 of section A above.

“SURVCORR” Program

Input Files. This program requires 3 input files.

1. Survey Data File. This is the actual survey data file to be corrected. The file must be in 4 columns with two column headers.

$$\begin{bmatrix} time1 & id1 & x1 & y1 & depth1 \\ time2 & id2 & x2 & y2 & depth2 \\ time3 & id3 & x3 & y3 & depth3 \\ time4 & id4 & x4 & y4 & depth4 \\ \vdots & \vdots & \vdots & \vdots & \vdots \end{bmatrix}$$

The time should be in a continuous sequential format (i.e. seconds, minutes or hours) from a common reference time. Depth must be measured from the water’s surface, positive downward.

2. Baseline Location File. This file locates (in x, y coordinates) the baseline points used to interpolate and correct the survey data. The file must be in three columns with two column headers.

$$\begin{bmatrix} po\operatorname{int} number1 & x1 & y1 \\ po\operatorname{int} number2 & x2 & y2 \\ po\operatorname{int} number3 & x3 & y3 \\ po\operatorname{int} number4 & x4 & y4 \\ \vdots & \vdots & \vdots \end{bmatrix}$$

The “point number” must be an integer value, but will not be used in the calculations. The x and y coordinates must have the same reference as the survey data. The rows of this file correspond to the location of the tide data in the columns of the “Tide Data File” described below.

3. Baseline Tide Data File. This file contains the tide information used in the correction calculation. Either the BASELINE1 or BASELINE2 programs described later may generate the file. If the baseline points consist only of known tide gages, the data developed from these gages may be used. Only one time column may be used, therefore actual tide gage data should be interpolated to this common time series. The file has the following format, again with two column headers.

$$\begin{bmatrix} time1 & \eta 11 & \eta 21 & \cdots \\ time2 & \eta 12 & \eta 22 & \cdots \\ time3 & \eta 13 & \eta 23 & \cdots \\ time4 & \eta 14 & \eta 24 & \cdots \\ \vdots & \vdots & \vdots & \ddots \end{bmatrix}$$

The time must have the same form and reference as the time in the survey file. The time series must also precede the minimum survey time and exceed the maximum survey time. The value corresponds to the tide level at each baseline point (by column) and should be referenced to the desired vertical datum (i.e. NGVD, MTL, etc.). The interpolation will subtract the appropriate tide level from the survey. In other words, at a high tide level (h > datum, i.e. h positive), the program will subtract the tide level from the survey depth. At a low tide level (h < datum, i.e. η negative), the program will add the absolute value of the tide level to the survey depth.

Output File. The program output file will have the following form.
The left five columns will be identical to the survey file described in (1) above. The sixth column will contain the corresponding survey depth corrected for the tide.

$$\begin{bmatrix} time1 & id1 & x1 & y1 & original-depth1 & corrected-depth1 \\ time2 & id2 & x2 & y2 & original-depth2 & corrected-depth2 \\ time3 & id3 & x3 & y3 & original-depth3 & corrected-depth3 \\ time4 & id4 & x4 & y4 & original-depth4 & corrected-depth4 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \end{bmatrix}$$

Single Point Baseline Construction Program ("BASELINE1")

This program will interpolate the tide data, based on distance, for a baseline which branches off of a main baseline. If only one baseline point is used, distance will not be used in the interpolation, only time. In this case, the entire system will be assumed to have the same tide.

Input Files. This program requires 3 input files.

1. Three Point Tide Data File. The three points used here will typically be chosen from a baseline file previously constructed from the BASELINE2 program. The file has the following format with no column headers.

$$\begin{bmatrix} time1 & \eta 11 & \eta 21 & \eta 31 \\ time2 & \eta 12 & \eta 22 & \eta 32 \\ time3 & \eta 13 & \eta 23 & \eta 33 \\ time4 & \eta 14 & \eta 24 & \eta 34 \\ \vdots & \vdots & \vdots & \vdots \end{bmatrix}$$

   The time must have the same form and reference as the time in the survey file. The time series must also precede the minimum survey time and exceed the maximum survey time. The η value corresponds to the tide level at each baseline point (by column) and should be referenced to the desired vertical datum (i.e. NGVD, MTL, etc.).

2. Three Point Baseline Location File. This file locates (in x, y coordinates) the three baseline points whose tide data was input in (1) above. The file must be in three columns without column headers.

$$\begin{bmatrix} po\operatorname{int} number1 & x1 & y1 \\ po\operatorname{int} number2 & x2 & y2 \\ po\operatorname{int} number3 & x3 & y3 \end{bmatrix}$$

   The "point number" must be an integer value, but will not be used in the calculations. The x and y coordinates must have the same reference as the survey data. The rows of this file correspond to the location of the tide data in the columns of the "Tide Data File" of (1) above.

3. Baseline Location File. This file locates (in x, y coordinates) the new baseline points. These new baseline points must begin with the middle (number 2) point in the three-point list above (i.e. "*point number1*" of this file is "*point number2*" of the above file).

$$\begin{bmatrix} po\operatorname{int} number1 & x1 & y1 \\ po\operatorname{int} number2 & x2 & y2 \\ po\operatorname{int} number3 & x3 & y3 \\ po\operatorname{int} number4 & x4 & y4 \\ \vdots & \vdots & \vdots \end{bmatrix}$$

Output File. The program output file will have the following form.

$$\begin{bmatrix} time1 & \eta 11 & \eta 21 & \cdots \\ time2 & \eta 12 & \eta 22 & \cdots \\ time3 & \eta 13 & \eta 23 & \cdots \\ time4 & \eta 14 & \eta 24 & \cdots \\ \vdots & \vdots & \vdots & \ddots \end{bmatrix}$$

This file corresponds to the Baseline Tide Data File described in the "SURVCORR" program and may be used directly in this program.

Two Tide Gage Baseline Construction Program ("BASELINE2")

This program will interpolate the tide data for a set of baseline points located between two tide gages. The interpolation will be a weighted linear interpolation based on the distance between the two gages.

Input Files. This program requires 2 input files.

1. Tide Gage Data File. This file contains the actual tide information used in the interpolation calculation. Only one time column may be used, therefore the time for each tide gage data should be interpolated to this common time series. The file has the following format, again with two rows of column headers.

$$\begin{bmatrix} time1 & \eta 11 & \eta 21 \\ time2 & \eta 12 & \eta 22 \\ time3 & \eta 13 & \eta 23 \\ time4 & \eta 14 & \eta 24 \\ \vdots & \vdots & \vdots \end{bmatrix}$$

The time must have the same form and reference as the time in the survey file. The time series must also precede the minimum survey time and exceed the maximum survey time. The η value corresponds to the tide level at each tide gage (by column) and should be referenced to the desired vertical datum (i.e. NGVD, MTL, etc.). The "SURVCORR" program will subtract the appropriate tide level from the survey. In other words, at a high tide level (η > datum, i.e. η positive), the program will subtract the tide level from the survey depth. At a low tide level (η < datum, i.e. η negative), the program will add the absolute value of the tide level to the survey depth.

2. Baseline Location File. This file locates (in x, y coordinates) the baseline points used to interpolate and correct the survey data. The file must be in three columns with two rows of column headers.

$$\begin{bmatrix} po\text{int}\ number1 & x1 & \cdot \\ po\text{int}\ number2 & x2 & \vdots \\ po\text{int}\ number3 & x3 & \cdot \\ po\text{int}\ number4 & x4 & \vdots \\ \vdots & \vdots & \end{bmatrix}$$

The "point number" must be an integer value, but will not be used in the calculations. The x and y coordinates must have the same reference as the survey data. The first and last point in this file should be the two tide gages from the Tide Gage Data File of (1). The first point corresponds to the first data column (i.e. not the time column) of the Tide Gage Data File and the last point corresponds to the second data column.

Output File. The program output file will have the following form.

$$\begin{bmatrix} time1 & \eta 11 & \eta 21 & \cdots \\ time2 & \eta 12 & \eta 22 & \cdots \\ time3 & \eta 13 & \eta 23 & \cdots \\ time4 & \eta 14 & \eta 24 & \cdots \\ \vdots & \vdots & \vdots & \ddots \end{bmatrix}$$

This file corresponds to the Baseline Tide Data File described in the “SURVCORR” program and may be used directly in this program.