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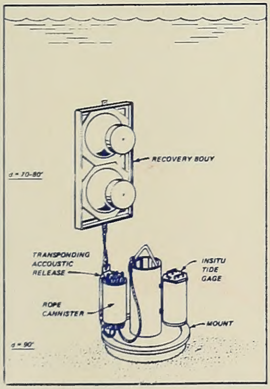

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LOS ANGELES AND LONG BEACH HARBORS MODEL ENHANCEMENT PROGRAM

TIDAL CIRCULATION PROTOTYPE DATA COLLECTION EFFORT

Volume I

MAIN TEXT AND APPENDIXES A THROUGH C

by

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Coastal Engineering Research Center

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A tidal circulation study of the Los Angeles and Long Beach Harbors was conducted by the US Army Engineer Waterways Experiment Station. Field data were collected from 5 tide gages and 16 current meters for use in calibration and verification of a numerical circulation model. The methods and results of the field data collection effort are presented. Analysis was performed to verify the quality of the tidal data and the flow patterns revealed by the current data.

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A limited number of copies of Volumes II (Appendixes D through I) and III (Appendix J) were published under separate cover. Copies of Volume I (this report and Appendixes A through C) are available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

PREFACE

This report was prepared by the Coastal Engineering Research Center (CERC), US Army Engineer Waterways Experiment Station (WES), and is a product of the Los Angeles and Long Beach Harbors Model Enhancement (HME) Program. The HME Program has been conducted jointly by the Ports of Los Angeles and Long Beach (LA/LB); US Army Engineer District, Los Angeles (SPL); and WES. The purpose of the HME Program has been to provide state-of-the-art engineering tools to aid in port development. In response to the expansion of oceanborne world commerce, the LA/LB are conducting planning studies for harbor development in coordination with SPL. Ports are a natural resource, and enhanced port capacity is vital to the Nation's economic well-being. In a feasibility study being conducted by SPL, the LA/LB are proposing a well-defined and necessary expansion to accommodate predicted needs in the near future. The CE will be charged with responsibility for providing deeper channels and determining effects of this construction on the local environment.

This investigation involved collection of prototype tidal circulation data for use in the calibration and verification of a three-dimensional numerical circulation model. Data collection occurred between June and October 1987 by personnel of the Prototype Measurement and Analysis Branch (PMAB) and the Field Research Facility (FRF) Group, Engineering Development Division. Design and installation of the measurement system were under the supervision of Messrs. William Kucharski and William E. Grogg, Equipment Specialists, PMAB, with the assistance of the University of Southern California Marine Support Facility. The PMAB personnel involved in data collection were Messrs. Michael S. Dickey, Douglas C. Lee, Jeffery A. Sewell, C. Ray Townsend, and Ralley Webb. The FRF personnel were Messrs. Kent K. Hathaway, Michael W. Leffler, and Brian Scarborough and Ms. Adele Militello. Data collection was performed under the supervision of Mr. David D. McGehee, PMAB. Data analysis was performed by Mr. James P. McKinney, PMAB, and Mr. McGehee. Technical supervision was provided by Mr. Gary L. Howell, PMAB, and technical assistance by Dr. S. Rao Vemulakonda, Coastal Processes Branch, Research Division, WES, and Mr. William C. Seabergh, Wave Processes Branch, Wave Dynamics Division, WES. Additional data were provided by the US Air Force Technical Applications Center and the Sea and Lake Levels Branch of the National Ocean Service. The

PMAB personnel were under the direction of Mr. Thomas W. Richardson, Chief, Engineering Development Division, and Mr. J. Michael Hemsley, Acting Chief, PMAB. This study was under the general supervision of Dr. James R. Houston, Chief, CERC, and Mr. Charles C. Calhoun, Jr., Assistant Chief, CERC.

During the course of the study, liaison was maintained between WES, SPL, and LA/LB. Mr. Dan Muslin, followed by Mr. Angel P. Fuertes, was SPL point of contact. Mr. John Warwar and Ms. Lillian Kawasaki, Port of Los Angeles, and Mr. Michael Burke, Mr. Rich Weeks, and Dr. Geraldine Knatz, Port of Long Beach, were LA/LB points of contact and provided invaluable assistance.

COL Larry B. Fulton, EN, was Commander and Director of WES during the publication of this report. Dr. Robert W. Whalin was Technical Director.

CONTENTS

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* A limited number of copies of Appendixes D-I (Volume II) and Appendix J (Volume III) were published under separate cover. Copies are available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
inches	2.54	centimetres
knots (international)	0.5144444	metres per second
pounds (mass)	0.4535924	kilograms
pounds (force) per square inch	6.894757	kilopascals

TIDAL CIRCULATION PROTOTYPE DATA COLLECTION EFFORT

PART I: BACKGROUND

1. The Ports of Los Angeles and Long Beach (LA/LB), California, are conducting planning studies for harbor development in coordination with the US Army Engineer District, Los Angeles. The US Army Corps of Engineers (CE) is charged with the responsibility for providing deeper navigation channels and determining the effects of harbor expansion on the environment. To upgrade the CE's capability to determine these effects based on state-of-the-art modeling technology, the US Army Engineer Waterways Experiment Station (WES) is executing the Los Angeles/Long Beach Harbors Model Enhancement Program.

2. This program is separated into two major studies. The first will address long-period wave energy in the harbors and its effect on moored vessels. The second will provide improved tidal circulation modeling with a more efficient numerical model system that will couple hydraulics and water quality variables (CE 1987). The prototype data for model calibration and verification have been collected by the Prototype Measurement and Analysis Branch of the Coastal Engineering Research Center (CERC), WES. This report describes the methodology and results of that data collection effort.

3. Los Angeles and Long Beach Harbors are adjacent ports situated behind a rubble-mound breakwater in San Pedro Bay, California (Figure 1). In the initial WES study of the harbors, a fixed-bed three-dimensional (3-D) physical model (McAnally 1975) and a depth-averaged-flow, two-dimensional numerical model (Raney 1976) were developed. Advancements in the state of the art of prototype measurement and hydraulic simulation provided the means to enhance the models. The upgraded numerical model of this program provides simulation of the time series of the resultant 3-D water currents and water surface elevations in the harbors given the physical boundaries and the water surface elevations in the open ocean outside the harbor breakwater.

4. Boundary conditions are established by obtaining the positions of the shoreline, including structures, and the bathymetry of the area modeled. Water surface elevations measured using tide gages placed outside the harbor provide the input forcing function that drives the system. Measurements of tidal elevation and water currents at selected positions inside the harbor are compared with predicted values to calibrate and verify the model.

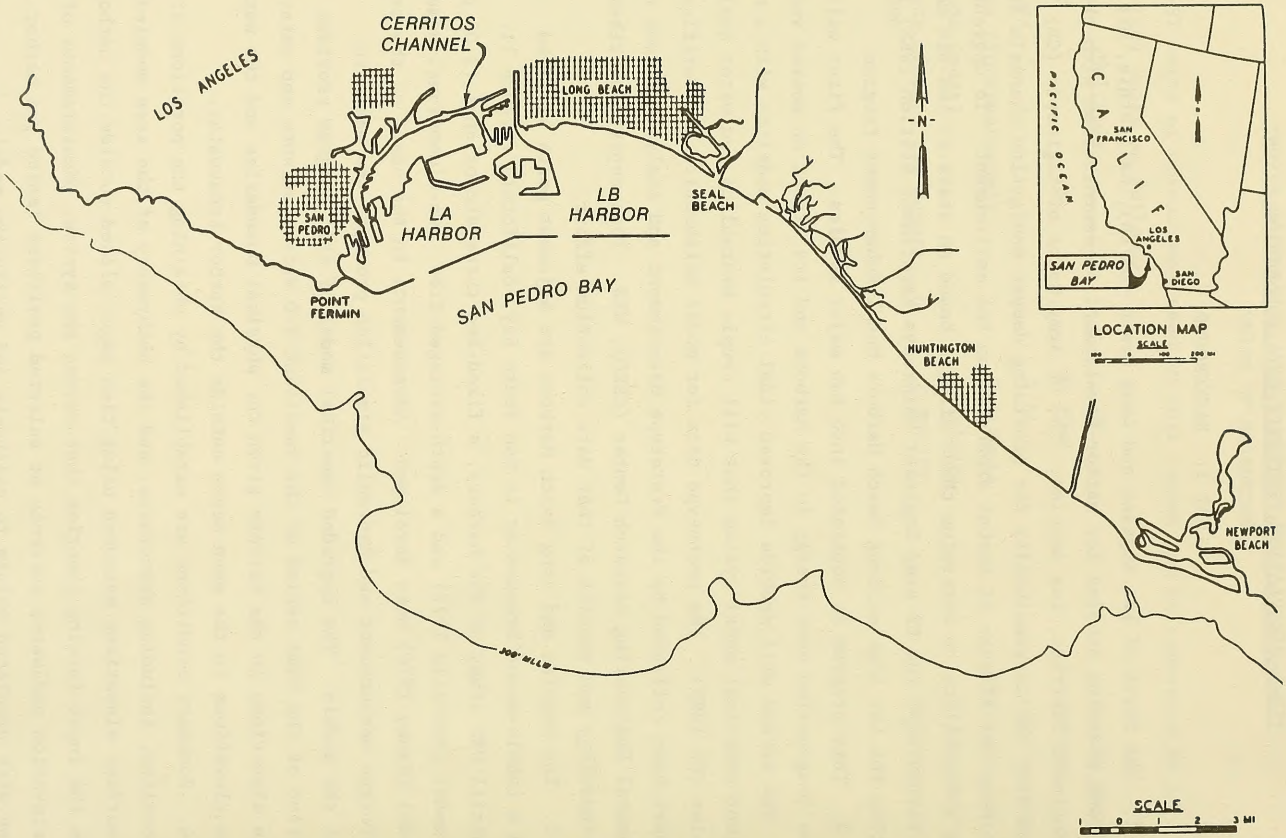

Figure 1. Study site location map

PART II: DATA COLLECTION

5. The general requirements and schedule for each task in the program were prescribed in the Management Plan for the Model Enhancement Program. Data collection was divided into three subtasks: tidal, in situ current, and current profile data. Data were collected for varying intervals between 10 June and 14 October 1987 (Table 1). Measurement intervals for each subtask varied, but deployment times were nested to provide a period of simultaneous data from all three elements from 6 to 14 August 1987. Requirements for the final data sets and the instrumentation and techniques used to obtain them are discussed in this section.

Tidal Data

Requirements

6. The requirement of the tidal data subtask was to obtain time series of water surface elevations at two outside and two inside locations for a minimum of 90 days. Each data set was to be a continuous record of elevations relative to a Mean Lower Low Water (MLLW) datum at 6-min intervals with an accuracy of at least 0.05 ft.*

7. Figure 2 shows the positions of the tidal measurement sites; geographic coordinates and depth of each measurement site are listed in Table 1.

Method

8. For the offshore sites, potential cable runs of several miles made hard wiring of power and signal to shore uneconomical. Erecting structures in water depths of 60 to 100 ft would be very expensive, and proximity to the shipping lanes and the heavy traffic volume precluded platforms and buoys because of the risk of collision. The remaining option was bottom-mounted pressure transducers with self-contained power and data storage capability. This option allowed a wide latitude in positioning and reduced the risk of unintentional and deliberate interference. The same approach was used at sites in the harbor for consistency of deployment/recovery techniques and data format.

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* A table of factors for converting non-SI units of measurement to SI units is presented on page 4.

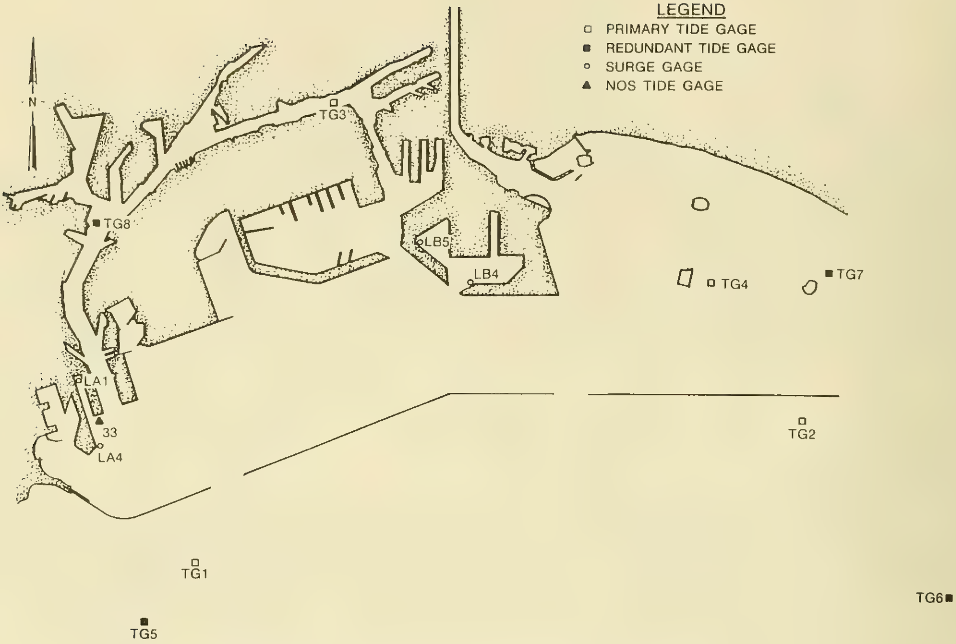


Figure 2. Tide gage deployment site map

9. The flexibility and relative security of this type of gaging are always offset by the potentially lower reliability of data recovery since gage nonperformance is only apparent after removal of the gage. To enhance reliability, redundant gages (TG5-TG8) were deployed for each of the four primary gages (TG1-TG4).

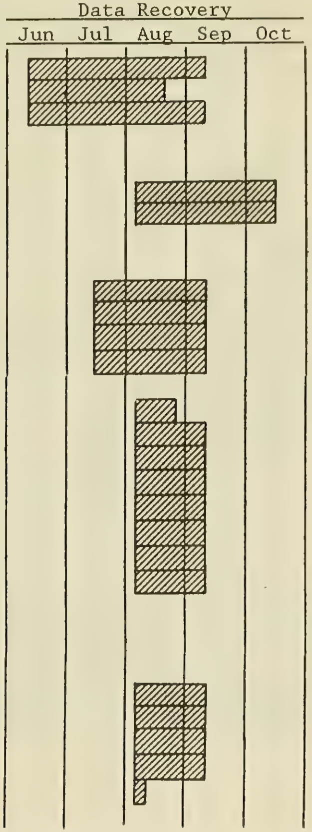
Instruments

10. Details on all instruments, including manufacturer's specifications are found in Appendix A. The tide gage selected uses a vibrating quartz crystal pressure transducer whose output is proportional to absolute pressure. Oscillations of the crystal are counted over some selected sample interval, and this integrated pressure is averaged over that interval to filter wave frequency signals. The average pressure is recorded as a 16-bit digital word on a magnetic tape along with a time word from a quartz clock. Shorter sample intervals retain more information but require more storage on the tape, shortening deployment time. To obtain the required 3 months of data on one

Table 1

Gage Deployment Locations and Schedule

Site	Type	Position, deg N. Lat.	Position, deg W. Long.	Depth, ft MLLW Site	Depth, ft MLLW Gage	Instal. Date	Recov. Date
TG1	Tide	33° 41.80′	118 15.25′	75	72	6/10/88	9/9/87
TG2		33° 43.10′	118 08.50′	57	54	6/10/88	9/13/87
TG3		33° 46.08′	118 13.58′	28	25	6/10/88	9/9/87
TG4		33° 44.43′	118 09.45′	37	34	6/10/88	9/9/87
TG5		*	*			8/3/88	NA
TG6		33° 41.70′	118.07.00′	62	59	8/3/88	10/15/87
TG7		33° 44.50′	118.08.00′	25	22	8/3/88	10/15/87
TG8		33° 44.80′	118 16.43′	39	36	8/3/88	10/15/87
LA1	Wave	33° 42.56′	118 16.51′	24	18	7/15/87	9/7/87
LA4		33° 42.92′	118 16.51′	56	33	7/15/87	9/7/87
LA4		33° 44.42′	118 12.09′	43	30	7/15/87	9/7/87
LA5		33° 44.82′	118 12.71′	20	18	7/15/87	9/7/87
CM1S	Current	33° 46.13′	118 14.00′	30	5	8/3/87	9/9/87
CM1B					24	8/3/87	9/9/87
CM2S		33° 43.38′	118 16.06′	35	10	8/3/87	9/13/87
CM2M					17	8/3/87	9/13/87
CM2B					29	8/3/87	9/13/87
CM3S		33° 44.60′	118 12.69′	60	7	8/4/87	9/11/87
CM3M					32	8/4/87	9/11/87
CM3B					54	8/4/87	9/11/87
CM4S		33° 43.72′	118 14.35′	30	8	8/4/87	NA
CM4B					24	8/4/87	9/10/87
CM5S		33° 42.58′	118 15.36′	40	8	8/4/87	NA
CM5B					32	8/4/87	NA
CM6S		33° 43.60′	118 11.53′	65	10	8/4/87	9/10/87
CM6B					50	8/4/87	9/10/87
CM7S		33° 43.83′	118 08.60′	46	14	8/4/87	9/10/87
CM7B					40	8/4/87	9/10/87
CM8M		33° 44.25	118 08.00′	30	15	8/4/87	8/9/87
CM9M		33° 44.48	118 16.60′	30	15	8/3/87	NA



* Gage not recovered.

deployment tape, an interval of 3.75 min (eight tide measurements/hour) was selected.

Mounting

11. The instrument housing is a 6-in.-diam. by 30-in.-long aluminum pressure case containing the transducer, electronics, data logger, and battery pack. The case was attached with stainless steel bolts to a vertical mount that was welded to a 600-lb railroad wheel. Gages inside the harbor had a subsurface retrieval buoy attached to the mount and an acoustic beacon for relocation by divers. Because of the depth outside the harbor, a subsurface buoy was attached to the wheel with a length of retrieval line coiled in a canister. The canister, in turn, was attached to the wheel with a transponder/acoustic release. The release served the dual purposes of a beacon, for locating the instrument package, and as a means of releasing the buoy and recovery line at the end of the deployment. Figure 3 shows a typical assembly in the deployed configuration.

Deployment/recovery

12. A temporary field office was leased on Terminal Island with adjacent dock space. This provided office and testing space, secure outdoor storage of heavy equipment and vessels, and a staging/loading area for operations.

13. All tide gages and in situ current meters were deployed from the University of Southern California research vessel "Sea Watch" through the cooperation of the USC Marine Science Laboratory on Terminal Island. An experienced crew, aided by the stern-mounted A-frame and ample work deck, installed the primary gages on 10 June and the backup gages on 3 August by lowering the mounts using the lift bail (Figure 4).

14. Positions were established with LORAN, radar bearings, and visual bearings to prominent targets on shore.

15. The planned recovery technique was to trigger the acoustic release, allowing the buoy to surface and enable retrieval from the surface without diver assistance. In the event of transponder failure, the gage positions could be relocated within ~100 ft, at which point a sweep would be made from the surface by dragging a chain between two vessels. Divers would then recover the gage by descending the sweep chain.

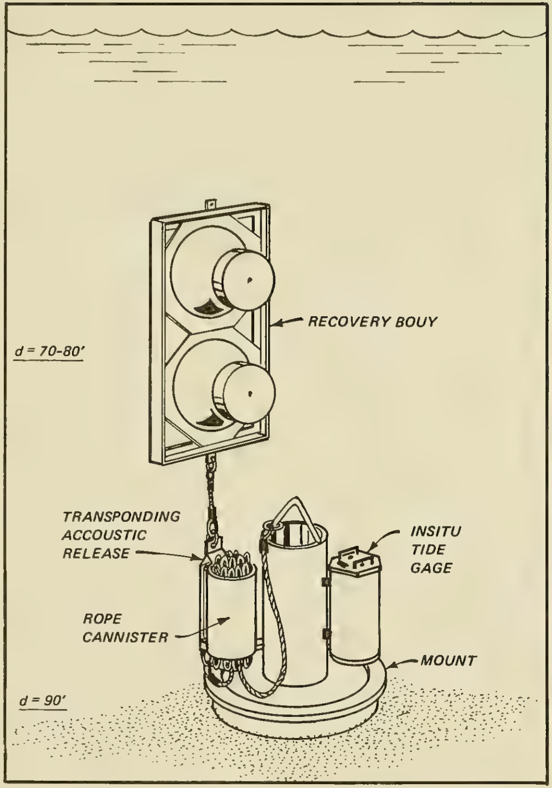


Figure 3. Tide gage mounting assembly

Figure 4. Tide gage deployment procedure

Additional tidal data

16. In addition to the eight tide gages specifically deployed for this study, data were available from a primary control tide station (33) located inside Los Angeles Harbor and from four pressure sensors located around the harbor perimeter (Figure 2). These four pressure sensors were installed by CERC to obtain long-term measurements of harbor surge events under a separate subtask of the Model Enhancement Program entitled Wave Data Acquisition. They were configured as low-frequency wave gages, but postprocessing of the time series also produces continuous tidal data.

17. These data were processed to provide additional boundary conditions for the model and for quality control checking of the primary tide data sets.

In Situ Currents

Requirements

18. The requirement for the in situ current subtask was a 30-day record of the vertical velocity profile at eight locations covering the major tidal exchange openings inside the harbor and at the harbor-complex perimeter. The acceptable resolution for the vertical stratification of the flow field was three points, representing a near-surface, middepth, and near-bottom cell at each site. Desired accuracy in speed and direction was ±0.1 knot and 2 deg, respectively. Samples were needed on a similar frequency to the tidal data, that is, continuous time series at average intervals near 3 min.

Method

19. The vertical profiles were obtained by deploying up to three current meters on a string supported by a surface buoy on a taut mooring. To reduce the risk of ship collision, the gage sites were moved to the sides of major entrances and channels. A total of 19 gages were available for the project. A deployment scheme was selected which increased the total number of sites to nine by reducing the number of meters on a string to one or two at certain sites not expected to have strong vertical gradients, while one meter was kept as a spare. Figure 5 shows the location of each site.

Instruments

20. The current meters were ducted-impeller type with an internal compass for direction (Figure 6 and Appendix A). Velocity is measured by counting impeller revolutions over the selected averaging interval, and an

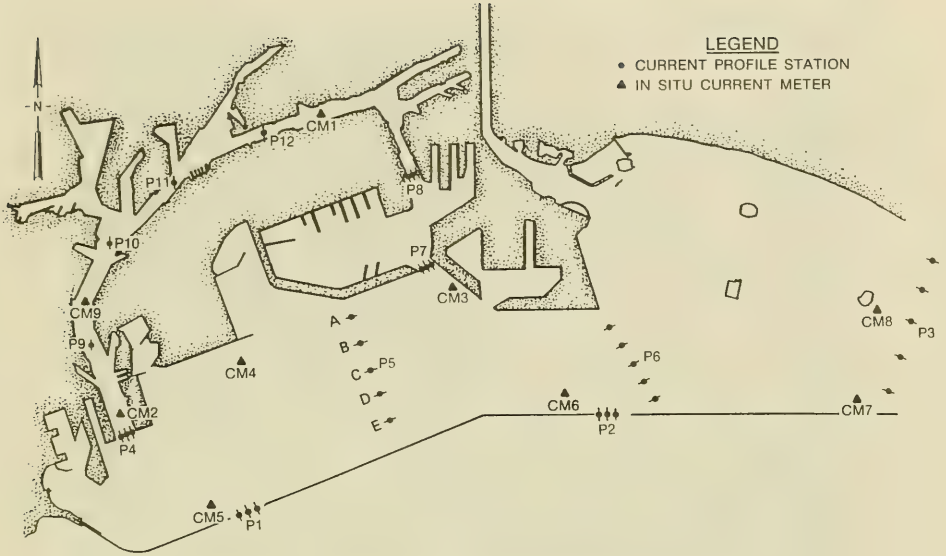


Figure 5. Current meter deployment site map

instantaneous direction is taken at the end of that interval. Both values, along with temperature and conductivity, are recorded on a magnetic tape. The averaging interval selected was 2 min, allowing a total tape capacity of 34 days.

21. Prior to deployment, each meter was calibrated at the US Geological Survey (USGS) calibration facility at the Stennis Space Center, Mississippi, by tank tow at three known velocities through still water. The calibration coefficients for each impeller/bearing combination were used in postprocessing the data. Compasses were bench checked and accepted if within manufacturer's tolerances without individual corrections.

Mounting

22. Figure 6 illustrates a typical current meter string in place. A spherical 36-in.-diam steel buoy was attached to a 900-lb railroad wheel with a 1/4-in.-diam mooring cable. A taut moor was maintained in spite of the tidal variation by including a length of 1-in.-diam rubber cord below the buoy. The cable was attached at either end with 3/8-in. screw-pin shackles. Each buoy supported an 8-ft mast with a radar reflector and amber marker light. For additional visibility, two or three "guardian" buoys of similar design

Figure 6. In situ current meter (inset) and typical current meter mooring string

(but without instruments) were placed around the instrumented buoy approximately 200 ft away.

23. To allow the meter to rotate around the mooring as current directions changed without fouling on the mooring, a split Teflon bearing sleeve was attached to the 1/4-in. cable at the appropriate depth for each string. A hinged stainless steel clamp went around the bearing and locked with a captive hinge pin. The meter was attached to a ring on the clamp with a 3/8-in. screw-pin shackle, safety wired after closure. This arrangement permitted rotational freedom and a means for diver changeout of the gage during inspection without recovering the entire mount.

Deployment/recovery

24. In addition to routine electronic predeployment testing, each gage was balanced for neutral buoyancy and horizontal trim. Adjustments for variations in gage construction, battery weight, and local water density were made by placing lead trim weights at the front and rear of the meter. This adjustment ensured that the meter aligned with the water flow, especially in the low-velocity conditions expected in the harbor.

25. Deployment was similar to the tide gage installation. All nine current meter strings were put in place on 3 and 4 August from the "Sea Watch." On 9 August, each meter was visually inspected by CERC divers to verify proper deployment and operation. Inspection included secure attachment and safety wiring of the shackles and sleeve/bearing assembly, neutral buoyancy and horizontal trim, no restrictions to either impeller or swivels, overall integrity of the mooring components, and functioning of the marker lights.

26. The first instrument casualty was discovered during the 9 August inspection. The buoy at current meter Site 8 (CM8) was not on station, but the meter was discovered shortly afterward washed up on the west jetty of Anaheim Bay Inlet. The wire cable (not, interestingly, the rubber cord) had parted near the lower end, most likely pulled by a vessel. The single meter was still attached, and though it was damaged, the data tape was recovered intact. The spare current meter was installed as CM8 on 15 August. The complete history of lost and damaged instruments is covered in the subsequent section headed "Data Recovery."

Current Profiles

Requirements

27. Since the current data collected by the in situ meters were limited by the available number of meters and the vessel traffic, a current profiling subtask was designed to provide supplementary information. The purpose was to collect vertical current profiles at major entrances and interfaces and within the Cerritos Channel at hourly intervals over half-tidal cycles. The measurements were to be made concurrent with deployment of the in situ meters and tide gages.

28. Figure 5 shows the selected locations of the profile ranges and stations. A range is a transect across an entrance or interface between major sections of the harbor, such as Range 7, and a station is one of three to five locations, depending on width, along a range, for example Station 5D. Stations 9-12 were along the Cerritos Channel and had a single profile, each midway across the channel.

29. A vertical profile consisted of a measurement of current velocity and direction at three depths, near surface, middepth, and near bottom, at each station of a range at 1-hr intervals for 13 continuous hours.

30. In addition to supplementing the other data, the profiles were expected to identify flow features not readily detectable from stationary measurements. A large-scale gyre was observed under certain conditions in the physical and numerical models in the outer Los Angeles Harbor. Range 5 was selected to augment data from a separate Lagrangian current experiment designed to verify the existence of the gyre. It entailed continuous tracking of drogues, or floats, that followed the path of the water particles at various depths. The results of the Lagrangian current study will be presented in a separate report under the Model Enhancement Program.

31. Stations 9-12 were intended to detect the nodal point for flow convergence of water entering opposite ends of the Cerritos Channel, also as predicted in the model.

Instruments

32. The current meter used for profiling was of the same manufacture and general design as the in situ meters, but was equipped with microprocessors to reduce the data internally into engineering units. The data could be stored onboard in RAM microchips or transmitted over a cable via standard RS

232 interface as an ASCII file. The internal memory was sufficient to hold a day's profiling record, but the latter mode was selected. By connecting the meter to a lap-top computer on the boat for the profiling experiment, the operator could verify operation and reasonableness of the data.

33. The backup gage for the profiling experiment was a second solid state meter, with cable and computer of the same design. Both profiling meters were calibrated prior to use at the USGS facility.

Method

34. A profiling schedule that included a flow reversal as well as a peak flood and ebb in the measurement interval was developed for the period 6-14 August 1987 (Figure 7).

35. Ranges 7 and 8 were combined in one interval because of their proximity, as were Stations 9-12; otherwise, one range was measured per "day." Because of the progression of the tidal cycle relative to the diurnal, subsequent intervals progressed, taxing the endurance and sleep habits of the crew. Including preparations, crew changes, equipment maintenance, data reduction, and inevitable unexpected occurrences, each shift lasted 14 to 16 hr.

36. Measurements were taken from a 26-ft, outboard-powered workboat fitted with a LORAN and depth sounder. Because of the constant ship traffic, separate radar reflectors were installed on the mast to increase target

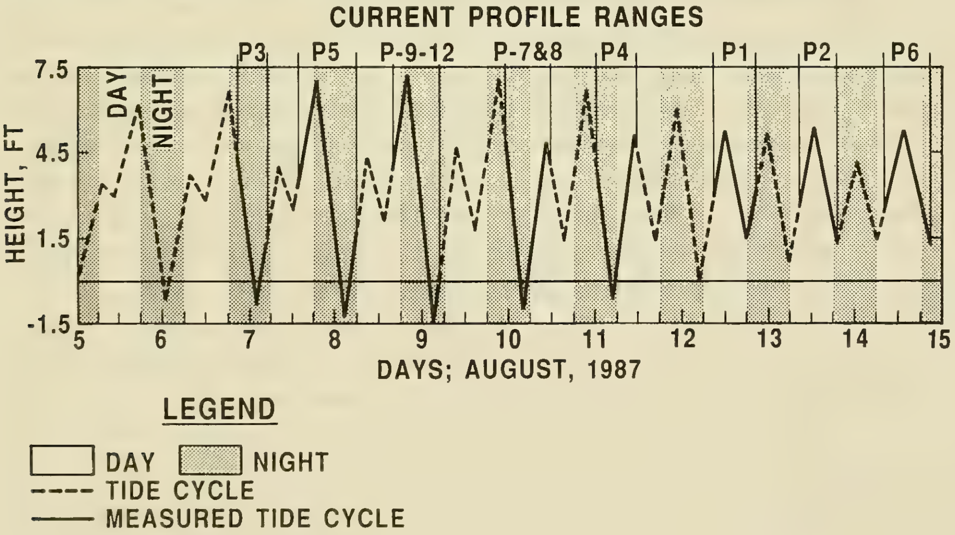


Figure 7. Current profiling schedule with predicted tides

strength for approaching vessels. Four people were aboard on each shift: a boat operator, a forward deck hand, a stern deck hand/meter handler, and a data recorder. Again because of the high traffic volume, safety dictated the need for at least two people (the operator and a deck hand) to have no other duties than the safe maneuvering of the boat, maintaining a lookout at all times, and being prepared to slip a mooring and be underway without hesitation--and without distraction by the profiling duties--if a ship approached too closely.

37. Every profile experiment started with the placement of temporary lighted mooring buoys at each station site. The buoys permitted each station to be rapidly and precisely recovered by the boat, which could use the buoy together with a bow anchor in a two-way mooring. This system was chosen to prevent the wind-induced "sailing" from side to side experienced by a boat moored only at the bow. Any boat motion would seriously affect the accuracy of the current data, particularly in the low-velocity regime of the harbor. Thus, a station was recovered by dropping the bow anchor upwind/current of the buoy and backing down until the stern deck hand could secure to the buoy.

38. At stations located in the center of a narrow shipping channel, even a temporary buoy would be an unacceptable hazard to traffic. In those cases, a stern clump anchor, lowered after the bow anchor had paid out sufficient scope, served the same purpose as the buoy.

39. Once the boat was secured on station, the meter was lowered to the bottom. The water depth was obtained from the meter's pressure transducer and compared with the graduated marks on the meter cable and to the boat's sounder to ensure accuracy. The meter was then raised to 90 percent of water column depth and allowed to stabilize, and the velocity and direction together with the time and depth of the reading were recorded from the surface display. After repeating the measurement at 50- and 10-percent depths, the meter was pulled aboard and the anchor(s) retrieved. For a range with five stations, each profiled at hourly intervals, the allotted time for that procedure was 12 min. To avoid data gaps at shift changes, a separate shuttle boat was used to transport crews between the measuring boat and shore.

Data Recovery

Positioning

40. Positions were obtained for all measurement sites with LORAN, supplemented when possible by visual and radar bearings to identifiable shore features. The LORAN was calibrated for local variance by occupying known locations with the boat and recording both time differences (TD) in microseconds and the LORAN's automatic conversion to latitude and longitude. The offset from true position was entered into the microprocessor-controlled LORAN for automatic adjustment of calculated position. After this calibration, known positions were again occupied on each day of operation. Thus, a correction factor for each region of the harbor, valid for each day's atmospheric conditions, was obtained and allowed an improvement from LORAN's normal error of ±300 to ±30 ft.

Tide gages

41. Of the eight tide gages deployed, seven were recovered. One of the redundant gages, number 5, had not been recovered at the time of this report's preparation; its acoustic transponder did not respond to surface interrogation, and a side-scan sonar search failed to show an identifiable target. Two other gages were located using side-scan and "sweeping" with a chain suspended between two vessels when acoustic releases failed to operate, but extensive diver searching verified that this gage was not in the immediate area. Since the subsurface float provides an easy target for both search methods, it seems likely that the gage and mount (or at least the buoy) were the victims of an encounter with a deep draft vessel. In that event, the gage may have been dragged off station, but could still be in the general harbor area. An expanded search of the harbor and surrounding offshore waters was conducted using the acoustic interrogator in subsequent months without success.

42. Tide Gage 2 (TG2) experienced a sudden electronic failure partway through its deployment. Data were recorded from installation on 10 June through 20 August. Tide Gage 4 (TG4) experienced a tape drive failure that made the entire data set unrecoverable. Tide Gage 8 (TG8) exhibited a drift in amplitude and phase because of electronic failure. Portions of the data set are recoverable, but can only be used for frequency analysis unless some arbitrary correction is made to the time axis. The remaining four gages had no failures, and their locations coincided with the requirements for two

outside and two inside gages operating during the period when the in situ meters and the profiling meters were operating.

43. Additional tidal records were made available by processing the pressure time series of four wave gages: LA1, LA4, LB4, and LB5. These four gages were serviced on 11 August 1987, resulting in two data sets over the period of interest. The first, designated by the suffix "A," extends from 15 July 1987 to 11 August at 0700 hr. The second, designated by the suffix "B," starts at 1800 hr, 11 August, and ends on 7 Sept 1987. Each data set had to be reduced and plotted separately, for example LB4A and LB4B, in the subsequent analysis.

In situ current meters

44. Of the 18 in situ current meters deployed at 9 sites, 13 were recovered between 9 and 12 September (Table 1). Only 1 of the 5 meters not recovered (the single meter at CM Site 9) was attributable to catastrophic loss of the mooring. The buoy at this site, in the Cerritos Channel near a major container ship berth, was reported adrift the week before the planned recovery. A diver search at the site on 11 September failed to locate the submerged mount or meter. Because of the proximity of ship and tug traffic in the area, the buoy and mooring were likely pulled off station by a vessel.

45. The remaining unrecovered gages were the upper meter at CM Site 4, both meters at CM Site 5, and the single meter at CM Site 8. The buoys at these sites were intact and the moorings undamaged, but the meters were removed at the shackle connecting the meter to the swivel. Since the shackles and their safety wires had been individually inspected a week after deployment, the most likely conclusion is that the meters were stolen by persons using dive gear.

46. The buoy from CM Site 2 was located onboard a commercial derrick barge moored adjacent to the meter site. The elastic section of the mooring had parted when the contractor attempted to move the buoy to accommodate repair work on a nearby wharf. Divers were able to recover the three meters, which were still attached to the mooring cable, and the weight at the deployed location.

47. One week of data was recovered from the initial deployment at CM Site 8.

Current profiles

48. Each range was profiled on the scheduled stage of tide to include a

peak flood or ebb and a tidal reversal. When a range contained only three stations, each station was profiled at approximately 1-hr intervals, as planned. The 1-hr return interval proved less attainable when a range contained five stations, and return intervals varied from 1-1/2 to 2 hr. Increased travel time between stations, increased anchoring time in deeper water, and occasional instrument malfunction contributed to the overall increase in return intervals. The complete data set is listed in Appendix B.

Wind data

49. An anemometer deployed on the outer Los Angeles breakwater failed to record data during the measurement interval. Wind and pressure data were obtained from daily logs of hourly surface observations compiled by the National Weather Service (NWS) at Long Beach Airport and provided through the US Air Force Environmental Technical Applications Center, Asheville, NC. (Appendix J). Data were also obtained from an anemometer located on the Port Authority building in San Pedro and provided by the Port of Los Angeles. These data were digitized and used as input to the model.

PART III: DATA ANALYSIS

Tidal Data

50. Raw data from the recovered tide gages were processed using SEA11.FOR, a program which converts raw ASCII data into tide, time, and wave record files. The wave data records were not used in this study but were archived for future reference. The tide file at this stage is a time series of pressure values in pounds per square inch, absolute (PSIA). To convert raw tide pressure files into a time series of tidal elevation, several steps must be performed. Error checking of pressures and time values (editing) will be described, and the reduced data presented in time-series plots.

Conversion of time data

51. Time files of each data set are in decimal hours relative to the individual gage reset time. To be of use in a numerical model, all data sets must have a common time origin. The decimal hour equivalent of individual reset times relative to 1 January 1987 was added to each time word in respective time files. All data used in this study are in decimal hours relative to 1 January 1987.

Conversion of PSIA data to depth data

52. Conversion of the raw pressure files to hydrostatic pressure requires the removal of the atmospheric pressure component. Rather than assuming atmospheric pressure to be constant during the sampling period, observed atmospheric pressure over the deployment interval was obtained from the NWS daily logs for Long Beach Airport. Pressure, in inches of mercury, was recorded on an hourly basis from 0500 to 2300. Pressure was considered constant over the hourly interval between observations, except for the 6-hr intervals when no hourly observations were made. During these periods, linearly interpolated pressures were assigned on an hourly basis. The conversion factor used to convert from inches of mercury to pounds per square inch was 0.489525.

53. Each raw pressure word has a time word associated with it. Using these time words, hourly time intervals corresponding to the observed or linearly interpolated atmospheric pressures were located. Atmospheric pressure in pounds per square inch was removed from raw pressure words whose time words fell within the appropriate time intervals. The pressure data time

series is converted to a depth time series by using a conversion factor based on average temperature and salinity, since their variance over the study period did not warrant a time synchronized adjustment in density. The factor used in the conversion was 2.246 ft/psi.

Datum assignment

54. The required datum for all tidal time series was MLLW. Since it was impractical to level each gage from shore using traditional surveying techniques, a simplifying assumption was made that the average free surface elevation over the deployment interval was constant throughout the harbor region. This is valid over a limited area with insignificant freshwater inflow and where no net transport can occur within the area over the time interval. Each tidal depth time series had the average depth of that time series subtracted, converting it to a time series relative to the average free surface at that site over the deployment interval.

$$D(t) = d(t) - \overline{d(t)} \qquad (1)$$

where $D(t)$ is the "de-meaned" time series and $d(t)$ is the measured-depth time series. Under the assumption above, $D(t)$ is referenced to the same datum for all gages. To convert the depth time series to a tidal time series, $T(t)$, relative to MLLW, a constant equal to the difference between the average free surface elevation over the measurement interval and MLLW,can be added to the depth time series.

55. Mean Sea Level (MSL) and MLLW are defined as the arithmetic mean elevation of the sea surface and of the lower low water heights, respectively, observed over a specific 19-year metonic cycle (Harris 1981). Means calculated over shorter intervals will vary and are calculated by the National Ocean Service (NOS) for monthly (m) and annual (a) departures from MLLW at each primary control tide station. Thus an average free surface elevation for the deployment interval is not necessarily MSL.

56. A primary tide station, 33, is located in Los Angeles Harbor (Figure 2). Its tidal record is referenced to MLLW datum. If the exact elevation of the free surface at any time and place relative to MLLW was of primary importance, then the average monthly departure, m, of Gage 33 would be the required constant. However, since the monthly average varies, its use as a constant would produce discontinuities in the records each month.

Discontinuities would interfere with spectral analysis of the signal and cause artificial oscillations in the numerical model.

57. To obtain a continuous time series, the values of m were obtained from NOS* for June through September for tidal Station 33 and averaged (Table 2). The result, 3.09 ft, was added to each de-meaned depth series to produce the tidal time series relative to MLLW.

$$T(t) = D(t) + 3.09 \tag{2}$$

Error checking

58. To validate the supposition of constant average sea level throughout the harbor, monthly means relative to MLLW were also calculated for each tide gage. Means, the average mean and the difference in means (Δ) between months, are listed in Table 2 for the NOS tidal Station 33 and the CERC tide gages. Direct comparison is valid only for those months when the gage was operational for nearly the entire month.

59. With the exception of TG2, which failed before recovery, the cumulative average water levels at each station are within 0.03 ft. The individual monthly averages show more variation, though the differences between months indicate that the same trends are occurring at each site.

60. To verify clock accuracy (nominally ±1 ppm), deployment, recovery, and shutoff times, as recorded in the field, were checked against the indicated times of the data sets. Deployment and recovery are apparent from pressure records and shutoff time from the last time word in the series. Agreement within the 3.75-min sampling interval was considered adequate verification. Verification was not possible when the gage was not operating at recovery, as for TG2.

61. Tidal accuracy is addressed in more detail under Part IV.

Output

62. Two files from each data set were generated. The first, TG*W, was of the entire time series. The second file, TG*S, was of a "specified" time interval for which current meter data were available. The * symbol refers

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* Personal Communication, Wolfgang Scherer, February 1988, US Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), NOS, Sea and Lake Levels Branch.

Table 2

Monthly Mean Sea Surface Levels, Sea-Level Variations and Differences (Δ), June-October 1987

Month	TS-33	Δ	TG-1	Δ	TG-3	Δ	TG-6	Δ	TG-7	Δ
Jun	2.88		2.95		2.90		--		--	
		0.21		0.15		0.22				
Jul	3.09		3.10		3.12		--		--	
		0.05		0.05		0.03		0.15		0.16
Aug	3.14		3.15		3.15		2.99		2.99	
		0.09								
Sep	3.23		--		--		3.14		3.15	
Cum Avg	3.09		3.07		3.06		3.07		3.07	

Note: Elevations are in feet relative to MLLW.

to the number of the particular gage. Both of these file types had one tidal elevation word as well as the corresponding time word in each data record. The date-time interval of the "specified" files was from 4 August 1987 at approximately 0700 hr to 7 September 1987 at approximately 0000 hr. The full-length data set intervals varied, depending on individual gage deployment and recovery times. Both were unformatted, sequential access files of record length 2. The first 56 records are character strings concatenated into seven 64-character information strings. A typical open statement for a tide elevation file is as follows:

```
OPEN(UNIT=1,FILE='TGIW.DAT',FORM='UNFORMATTED',STATS='OLD',RECORDLENGTH=2)
```

63. Plots of tidal elevation for the full data set, the "specified" data set, and a representative 2-day interval (7 and 8 August) and a 4-hr interval (0000 to 0400 hr, 8 August) are shown for tide Gages 1, 2, 3, 6, and 7 in Appendix D.

64. Similar analysis was carried out on the eight data sets from the wave gages. A "specified" data set was not plotted since the specified interval overlapped the two data sets. The whole time series, a 2-day plot on 7 and 8 August for the "A" data sets, a 2-day plot on 16 and 17 August for the "B" data sets, and the same 4-hr interval are also plotted in Appendix D.

In Situ Current Data

65. Raw data in ASCII format are converted to separate velocity (feet per second), direction (degrees from magnetic north), temperature (degrees C), and conductivity files. Direction data words were converted to true north by adding the magnetic variation specific to the LA/LB area, -13.55 decimal degrees.

Clock correction

66. Unlike the tide gages, the current meters do not record sample times as a separate file. Each parameter is recorded at the selected interval of 2 min, and this rate is assumed to be constant throughout the entire deployment. The specified accuracy of the clock is 1.5 sec a day, or roughly two orders of magnitude less accurate than the tide gage clock. Since correlation of the tides and currents in time is one of the goals of the study, the current time series were checked as described in the following paragraph.

67. The reset, deployment, and shutoff times of the current meters were known. Therefore, an "expected" number of samples could be calculated. By counting the actual number of samples in a particular data set, a time correction factor for that data set could be accurately calculated, provided that the collecting current meter was still operating at the time of the shutoff. Time correction was deemed unnecessary if, when the tabular listing of each time series was examined, the "observed" deployment and recovery time coincided with the "recorded" deployment and recovery time. In most cases, these times agreed to within a few minutes. Inspection of discernible events such as a ship passage, or, as in the case of Site CM3, the destruction of the mooring, provided further verification that the gages of each string were in phase with each other.

68. Of the 14 gages recovered, 12 have usable data sets over the required 30-day interval, and 2, CM1S and CM8M, have time series of shorter duration.

Error checking

69. From previous studies and results of a reconnaissance profiling experiment performed prior to deployment, the expected current magnitudes were relatively low, on the order of 1 fps. To enhance the viewability of data during processing, a maximum of 2 fps was set for any data point. A solitary

occurrence of a value that differed from the previous value by more than 0.3 fps was attributed to an electronically induced spike and was edited to the average of the previous and succeeding values.

Output

70. The output files, CM*S, CM*M, and CM*B represent current meter station * at surface, middepth, and bottom, respectively, where * indicates the station number. They are unformatted, sequential access files of record length 5. Each record contains five data words: time, velocity, direction, temperature, and conductivity. The first 21 records are character strings that are to be concatenated into seven 60-character information strings. A typical open statement for a current file is as follows:

```
OPEN(UNIT=1,FILE=CM1S.DAT',FORM=UNFORMATTED',STATUS='OLD',RECORDLENGTH=5)
```

71. Various plots of the current velocity and direction time series were produced. Shaded rose plots of entire time series (Appendix E) show mean velocity and percent occurrence in each of 20 degree sectors. These plots are useful in displaying dominant directions and velocities associated with each site. Separate velocity and direction time series illustrate the trends of each data set and allow quick verification of data quality (Appendixes F and G).

Current Profile Data

72. The current profile data required no analysis since they were read directly in engineering units and entered as such into a file. Direction and velocity were subjectively averaged during observation of the analog output meters.

73. The entire profile data set is listed in tabular form in Appendix B. A sample plot of profile data from Range 5 is provided in Figure 8 as a vector time series for each depth. Figure 9 is a sample of direction and velocity time series of Station 5A for all three depths.

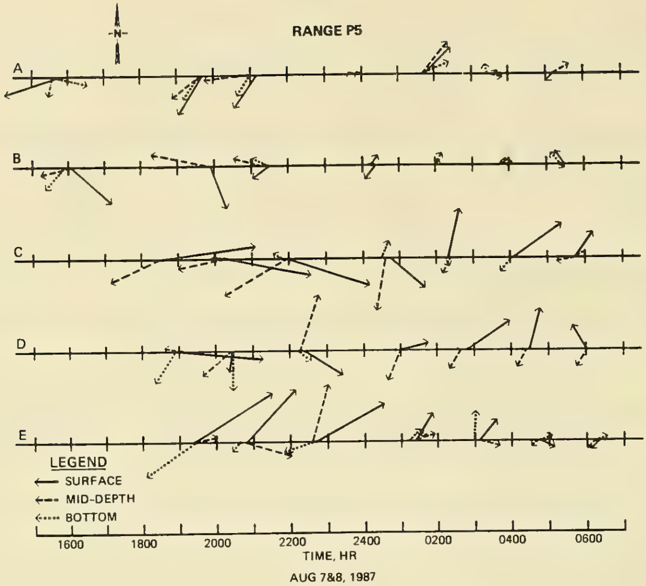

Figure 8. Current vector time series, Range 5. (A, B, C, D, and E = stations)

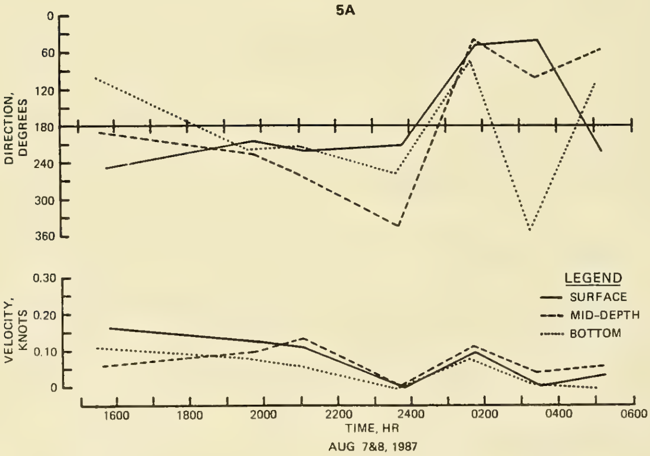

Figure 9. Current direction and velocity time series, Station 5A

PART IV: DISCUSSION

74. Before examining results of the data collected, certain confidence checks were performed. A rigorous statistical analysis could be performed in subsequent reports, but direct observations of trends and selected samples will provide adequate evaluation of the measurements. General characteristics of the observed harbor circulation patterns will be discussed.

Tidal Data

Predicted tide

75. Perhaps the most basic concern is the overall shape of the tide curves over the deployment. Classic semidiurnal behavior is evident in the time series of TG1S (Figure 10). Another obvious test is to compare the measured tidal data with the predicted tide for the same period. Exact agreement is never obtained, but given the proximity of the tide station and by selecting periods with low atmospheric anomalies, a close agreement can be expected between observed and predicted tidal elevations.

76. Figure 11 shows the predicted tide for 7 and 8 August (average atmospheric pressure = 29.8 in. Hg, average wind speed < 7.5 kt) (NOAA 1987) overlaid with measurements from TG1. A shift upward of the measured data, on the order of 0.3 ft, is evident, while the overall range of 8.3 ft is matched exactly. The average August departure from the annual sea level for NOS tide Station 33 between 1963 and 1981 is +0.20 ft. The remaining 0.1 ft of difference is due to some unknown combination of gage error and predicted tide error.

Residuals

77. A better indication of the final accuracy is obtained by comparing two tide gages at the same location. A residual is calculated between any two gages by subtracting one time series from another and is a plot of the instantaneous hydraulic head existing between them. Since each data set was de-meaned independently, the departure from zero of the residual from two gages at the same location is an indication of the overall accuracy of the instruments. The best approximation to this condition occurs with Sites 1, 2, and 6, all located outside the harbor breakwater at approximately the same depth.

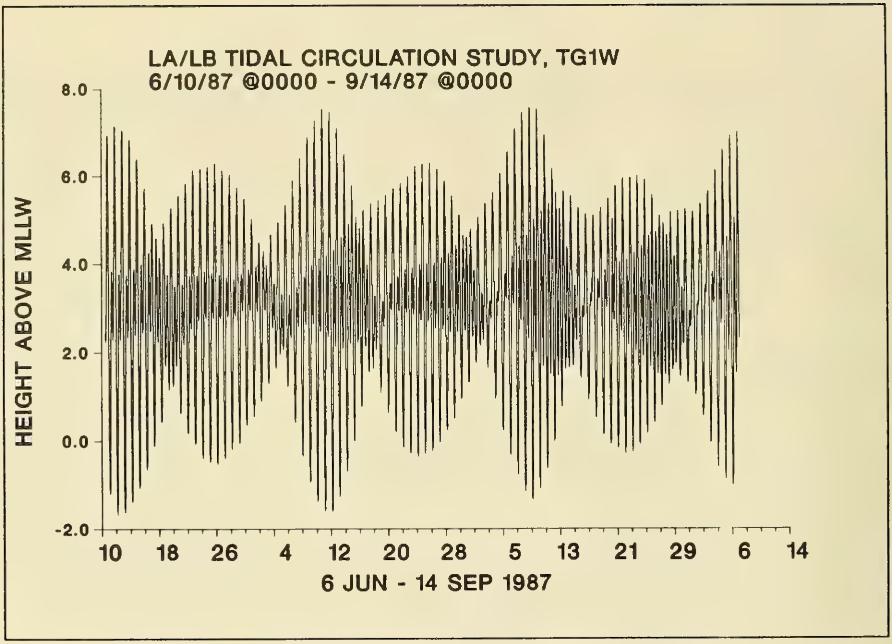

Figure 10. Tidal elevation time series, Gage TG1S

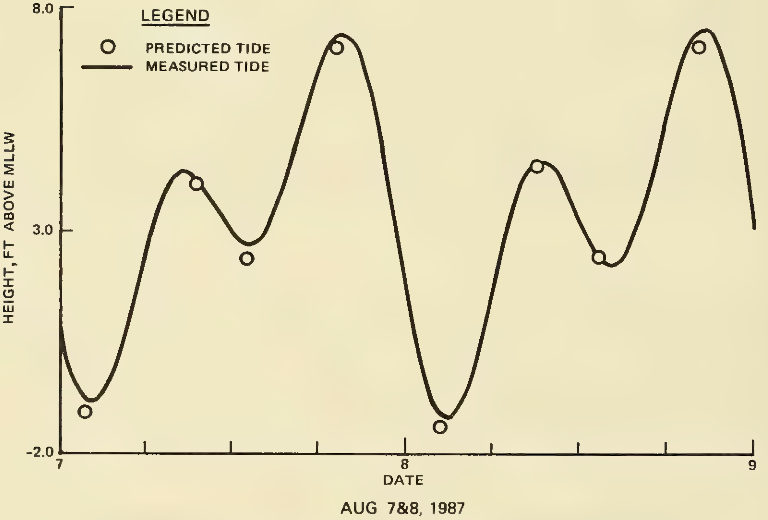

Figure 11. Predicted tide versus measured tide
7 and 8 August 1988

78. Residual time series plots comparing both tide and wave gages at various scales are contained in Appendix I. Residuals between selected pairs of tide gages over the specified interval are plotted in Plates 1-10. The mean of the residual is included, which would theoretically be equal to zero over a sufficiently long time interval if the assumptions made in selecting the datum are valid. As noted earlier, TG2 experienced a failure near 20 August, and redundant gages were deployed at a later date, so the intervals of simultaneous operation do not all coincide.

79. An obvious characteristic of residual TG1 - TG2 is that it is almost always positive, and the mean is in fact near +0.06 ft. To an optimist, this could be evidence of a continuous current from west to east along the outside of the breakwater, but the "current" is also evident in residual TG6 - TG2 at almost the same average head, this time flowing to the northwest, as well as in the remaining two residuals using TG2. Additionally, the trend is not verified in residual TG1 - TG6. Though its amplitudes appear reasonable, as indicated by the monthly mean elevations in Table 2, TG2 apparently suffered a timing error that placed it out of phase with the other gages--perhaps associated with its early failure--and should not be used for additional analysis.

80. Other residuals display diurnal and semimonthly harmonics indicative of tidal curents oscillaing on and off shore, but with low mean differences. The means of the residuals of over the entire deployment, which range from 0.0001 to 0.0038 ft, indicate an overall accuracy commensurate with the stated specifications of the sensor and well within the experimental requirements.

Benchmark check

81. Unlike the primary and backup tide gages, the wave gages were installed nearshore on harbor structures and were accessible (via diving rodmen) to standard leveling. LB4 was surveyed on two occasions to a nearby benchmark (Hicks 1987). Details are contained in Appendix C. The average of the two surveys is 17.60 ft below MLLW.

82. Two data sets, A and B, cover the period of consideration. A simple average of their two mean water depths gives

$$\frac{-20.65 + (-20.77)}{2} = -20.71 \tag{3}$$

83. Adjusting to MLLW by the constant used in the previous analysis,

$$-20.71 + 3.09 = -17.62 \tag{4}$$

84. The difference of 0.02 ft is on the same order as the difference between NOS and CERC calculations of the datum, but considering the less than ideal surveying conditions, is not significant.

Current Data

Overview

85. Illustration of the velocity and direction time series of the entire data set in one plot provides an overview of the data quality and trends. Some spikes remain in the velocity after removal of the solitary spikes by the error checking, or editing, routine. Before arbitrarily eliminating values, each instance should be evaluated to discriminate between random signal errors and hydrodynamic phenomena. Several high velocities appear in the record at CM2S (Plate 11), but given the proximity of the gage to ship traffic, they could be attributed to wake-induced turbulence. Most, however, are the result of noisy signals, such as CM3B,, which had 103 spikes over 2.0 fps before editing, approximately half of which could be removed by editing. Considering that a whole data set contains about 30,000 points, this is not a significant number of points. Gage CM6S recorded spikes nearly 2 percent of the time, so additional filtering/editing will be required before it can be completely used.

86. Anomalies can also indicate physical events. At site 2, all three gages clearly show the occurrence of the buoy failure on 30 August (Plates 11-16). Note the slow revolution of meter CM2S (Plate 12) over the next 2-week interval while lying on the channel bottom, most likely tangled in its own mooring line.

87. Semimonthly spring tidal currents are quite evident in all of the plots and correspond well to the spring tides measured in the specified tide data plots. Daily floods and ebbs are visible as diurnal peaks in velocity and as reversals in direction.

Statistics

88. The rose plots provide the most condensed display of the current data for statistical purposes. The average velocity in each sector is less than 0.5 fps, as expected. The site farthest away from boundaries, Site 4

(Plate 20), has a near circular distribution, though with some tendency towards the southwest. Those sites constrained in channels, such as Sites 1, 2, and 3, show a strong alignment that corresponds to the channel orientation (Plates 17-19). Before the rose plots were calculated for Site 2, all three data sets were truncated on 30 August, prior to the loss of the buoy.

89. Other characteristics of the flow pattern in the Cerritos Channel are apparent from these plots. At Site 3, the surface current is strongly skewed southeast, parallel to the adjacent mole. The strong afternoon sea breezes typical during that time of year might be expected to drive surface water eastward, and the mole would deflect it in the direction observed. At the middepth, the flow along the mole is nearly exactly balanced, while a defintite net flow towards the channel is evident at Site 3B.

90. At Site 1 at the back of the channel, the net flow is reduced on the bottom, but the continuation of the net transport is still apparent. At the surface, the directions are very nearly balanced. At the opposite end of the channel--Site 2--the counterclockwise flow has left the bottom, but is even more evident at the middepth and surface. A resultant transport pattern that starts near the bottom on the eastern entrance and exits near the surface at the opposite end of the channel is revealed. However, the flux is obviously not constant at the three measurement sites, most likely because of cross-channel variations in the velocity. A counterclockwise flow would result from wind setup against the mole at the eastern entrance and set down at the western entrance. Structures effectively block the wind in the Cerritos Channel itself. Other effects of the predominant sea breeze (from the west) are discussed in the next section.

91. In addition, the two ends of the Cerritos Channel allow the flow to flood or ebb from both ends more or less simultaneously, requiring a node to exist at some point along the channel. This will also be addressed in more detail in the next section.

92. Because Sites 6 and 7 are exposed to the sea breeze and are in the proximity of the east-west aligned breakwater, a net easterly flow would be expected at the surface, if the wind is a factor. This net easterly flow occurs at Sites 6S and 7S (Plates 21 and 22). At Site 7B, the tendency is just as strong westward, directly toward Site 6 and into the harbor. This tendency could represent a return flow necessary to balance an eastward flow on the surface, particularly since the only other entrances are the much smaller

channel passes in the breakwater. Even with only a week of data, Site 8 shows a trend to the northwest, perhaps because of sheltering and eddy effects from the nearby island (Plate 23).

93. The skewness observed in the rose plots are the result of statistical representation of cumulative events and do not imply a flow occurring at any one time. To see the instantaneous currents, time series representations are required, as shown in the next section.

Flow field details

94. To observe details of the harbor flow patterns and to illustrate the correlations between sites at simultaneous points in time, currents must be observed at a smaller scale. Two nested windows were selected for detailed observation: 7 and 8 August and 0000 to 0400 hr on 8 August. This coincided with the profiling of Range 5 and one of the Lagrangian, or drogue, tracking experiments. At these time scales, it is also convenient to combine the velocity and direction information into a single vector time series plot. Both types of plots were generated, and each has advantages (Appendixes F, G, and H).

95. To substantiate correlations between currents occurring simultaneously at separate locations, the current vectors should be examined to ensure that they are reasonable and actually in phase. Since the currents are primarily driven by the potential energy of the elevation difference existing at different places in the harbor at any instant, the residuals between selected tide gages should indicate expected current vectors.

96. When seen at this scale, the residuals display higher frequency oscillations as well as obvious diurnal harmonics. These could be due to random errors in the pressure sensor signal, phase shifts in the clocks of different instruments, and long-period (30 to 60 min) wave energy in some undetermined combination. A filtering scheme could remove selected components, but care should be taken in assuming that the actual residuals correspond to a preconceived smooth curve or evidence of higher order oscillations could be obscured.

97. The tidal elevation differentials can be seen in residuals TG1 - TG3 (Figure 12). Slopes approach $\sim 2 \times 10^{-5}$, and comparisons with the 2-day tidal plot (Figure 11) illustrate that rising, or inflowing, tides coincide with positive residuals, falling tides with negative, and residuals near zero occur near high and low water.

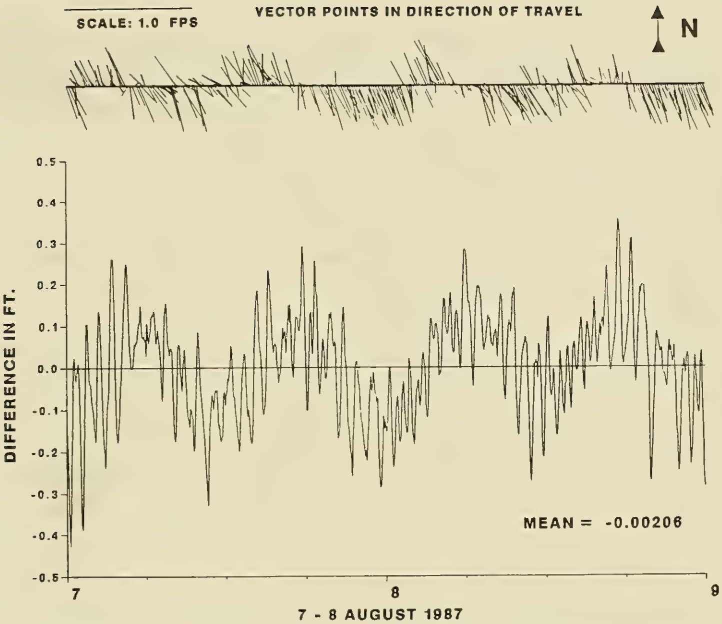

Figure 12. Residual time series Tide Gages 1 to 3 and resultant current vectors, meter 2S, 7 and 8 August

98. Current meters at Site 2 would be heavily influenced by the residual TG1 - TG3. Figure 12 shows the correlation regarding the directions and timing of reversals for currents at site CM2S. At 1700 hr on 7 August, the residual abruptly switched from positive to negative; the current switched from inbound to outbound at the same hour and increased in magnitude to a maximum 8 hr later, when the residual reached its minimum of -0.4 ft.

99. Examination of the three vector plots at Site 2 plainly shows that more water flowed out of the channel here than flowed in, particularly at the surface and middepth (Plates 24-26). This verifies the trend illustrated statistically in the rose plot.

100. A similar look at residual TG6 - TG3 (Plate 27) shows even better agreement with the meter at site 3 for all depths (Plates 28-30). At 0000 hr on 8 August, all three meters had peaked in their outward flow and had begun reversing inward after the peak (negative) residual. Similar correlation was maintained over the 2-day interval, but not without some phase shifts vertically. The trend of meter CM3S toward the southeast and of meter 3B to the

north, predicted in the rose plots, is verified.

101. Since these meters are not in the eastern side of Cerritos Channel but only near its entrance, the relative proportions cannot be assigned as either into or out of the channel. However, times of northwesterly flow likely correspond to periods of inflow into the eastern channel entrance, southeasterly to outward flow. These periods are roughly in phase with the western entrance periods. Thus the channel filled and drained from both entrances approximately in phase, requiring the existence of a node somewhere at the back of Cerritos Channel. Examination of the currents at site CM1 should indicate the location of the node.

102. If the nodal point occurs westward of Site CM1, floods will result in westerly or counterclockwise flow, ebbs in easterly; if eastward of Site CM1, the reverse. Plates 31 and 32, 2-day vector time series of surface and bottom currents, respectively, do not present such a simple pattern. On the morning of the 7th, the flood produced a southwesterly flow on the surface, but during the strongest ebb on either side of midnight, the current reversed several times. The subsequent flood produced much lower velocities in a variety of directions. Bottom currents are also capable of flowing in either direction during a flood or ebb.

103. Current profile Stations P9 through P12 were selected with the intent of locating the nodal point. If it were stationary, flows would converge at stations on either side of it during flood and diverge during ebb. Figure 13 is a simplified reduction of the profile data at the top, middepth, and bottom, respectively, wherein a vector represents the amplitude of the flow along the channel axis in either the clockwise (right) or counterclockwise (left) direction, or perpendicular to the channel axis (up or down).

104. Inspection reveals that the flow in the Cerritos Channel cannot be described as simply converging and diverging to a single, stationary nodal point. Not only does the node migrate along the channel, converging flows do not always produce a node at the same location as diverging flows. Both types are evident at the middepth at near 2000 hr on 8 August. Also, there is considerable vertical stratification of the flow and the nodal points. Modes of oscillation perpendicular to the channel axis become apparent as the longitudinal flow approaches zero. These and other higher frequency modes of oscillation are poorly defined at the sampling rate of one measurement every 20 to 30 min used in the current profiles. Examination of the in situ meter's time

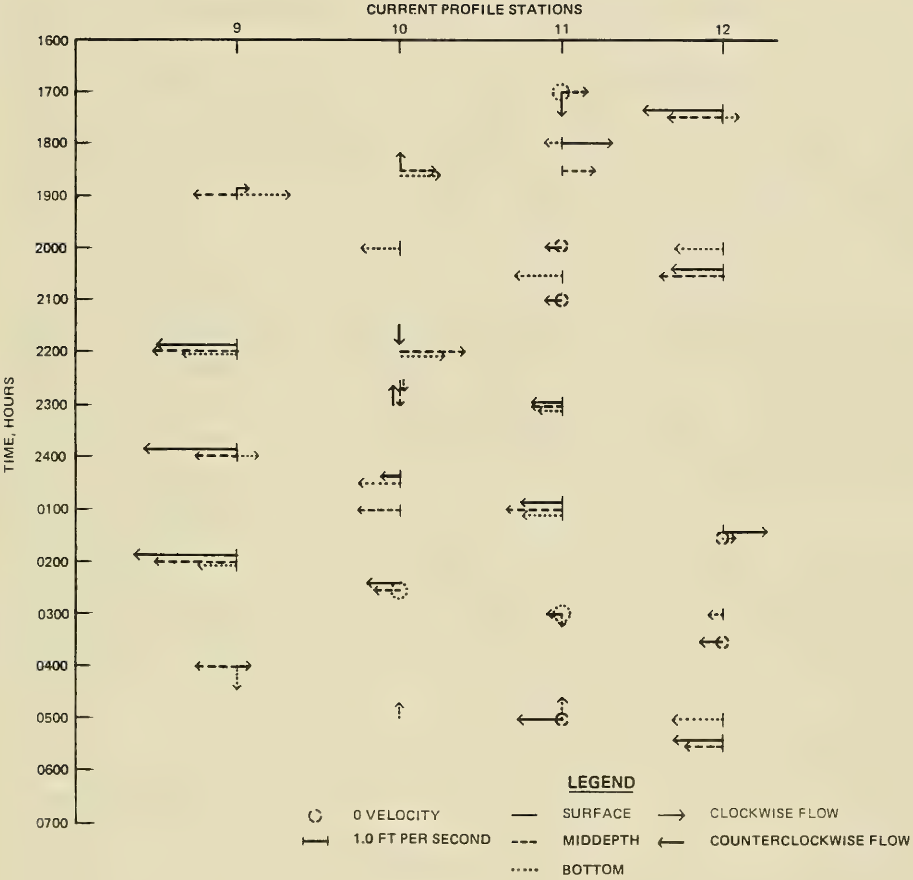

Figure 13. Simplified current vectors in Cerritos Channel

series at an expanded scale better illustrates the complexity of the flow in the channel.

105. A time series of the residuals at a 4-hr scale reveals higher frequency oscillations occurring between gage stations. Both TG1 - TG3 (Plate 33) and TG6 - TG3 (Plate 34) show an ascending series of roughly hourly pulses moving from negative (outward flow) to near zero. The curves are similar but not identical. It is the differences between the signals of these two gages, in fact, which illustrate the different hydraulic heads at each end of the Cerritos Channel. (A more direct measurement of the head difference

between the two ends of the channel is seen in Plate 51, described below.)

106. The same hourly pulsing is visible in the currents at CM2S, CM2M, and CM2B (Plates 35-40), and each pulse corresponds in phase, direction, and amplitude with the forcing residual, TG1 - TG3. The meters at Site CM3 are not strictly within the confines of the eastern entrance to Cerritos Channel and are influenced by flow in the harbor. As a result, phase dependence at the higher frequencies to residual TG6 - TG3 is less obvious, though the trend over the interval and the time of current reversal are well correlated (Plates 41-46).

107. Examination of currents at Site CM1 clearly illustrates the "sloshing" occurring near the back of the channel. While the flow is ebbing at both ends of the channel, both surface and bottom currents are reversing at approximately 25-min cycles (Plates 47-50). The migrating node evident in Figure 13 may be associated with these reversals if its excursions extend as far eastward as CM1.

108. Wave Gages LA4 and LB4 are located near the entrances to the channel, and, although not ideally sited, are good indicators of the hydraulic potential differences of the ends. Plate 51 is the residual between LA4 and LB4. Each 25-min pulse in the currents is associated with a peak in the residual. A phase lag, likely due to wind effects and multiple reflections in the numerous smaller basins, is evident.

109. In the outer harbor, the predominant westerly sea breeze has a more noticeable effect on surface currents. Plates 52 and 53 demonstrate the reason for the easterly skewness of the rose plots at Sites CM6S and CM7S. Rising tides cause weak, short-lived westerly flows or stronger flows to the north or even south, perpendicular to the nearby breakwater. Additional analysis may reveal whether this represents flow through the breakwater itself or vortices caused by currents transiting the nearby openings. Falling tides are characterized by strong easterly currents predominantly aligned with the breakwater.

110. Current profile data in Appendix B verify the strong easterly flow across the entire eastern entrance (Range P3) during ebb. Profiles across the two western entrances at Ranges P1 and P2 are flood dominated, rarely turning directly south (seaward) even during peak ebb. Thus the typical tidal cycle during the study can be characterized by flow through the western openings and to some extent through the breakwater during flood. During ebb, the harbor

drains primarily through the large eastern opening.

111. This pattern can be explained by examination of the daily wind pattern. The normal cycle during the study was an increasing breeze in the morning clocking from north to east, with a rapid switch to westward around midday (the sea breeze) and decreasing velocity after sunset (see Plate 54). These westerlies bracket the time from Higher Low to Higher High Water (Figure 11). The wind shear would influence, and perhaps dominate, this relatively weak flood stage--at least at the surface. With this initial set, the strong evening ebb from Higher High to Lower Low Water would tend to exit the harbor eastward, even though the winds are lower. A previous current measurement study conducted by NOAA in the summer shows similar trends (Smith 1989). This flow pattern may not be observed at other times without this relative phase relationship between the wind and tide. However, in a physical model study conducted by WES in the early 1970's that did not include wind effects, the net easterly flow was evident during spring tide conditions, but not at neap (McAnally 1975).

112. Another feature predicted by the physical model was a gyre in the Los Angeles Harbor. Figure 8 provides some evidence of a counterclockwise pattern occurring at the surface between 1800 and 2100 hr in the vicinity of Station B, but the predominant pattern is the easterly flow in the outer harbor associated with ebb conditions. Winds during this interval were generally blowing to the NNE between 5 and 10 knots, decreasing during the night. The flow is less organized and weaker at middepth and bottom, though reversals are evident in the water column. Low-velocity data from a profiling meter are inherently less reliable than an in situ meter because of the subjective averaging by the operator over a shorter interval. There is some evidence that rotational flow is occurring for short intervals, but not as a single, well-defined gyre extending through the water column. Many more data points would be required to characterize the flow pattern in the outer harbor more completely.

PART V: CONCLUSIONS

113. A synoptic data collection effort at LA/LB Harbors was completed that provides adequate data to calibrate and verify a 3-D numerical model of tidal circulation. Three months of tidal data, three months of wind data, one month of current data, and half-tidal cycle current profiles were obtained throughout the harbor. Project requirements and schedules as directed in the Management Plan were fully met.

114. Conclusions resulting from the study are:

- a. Use of a common mean water surface as a datum for synoptic tidal measurements over limited space and duration provided reasonable results and is a cost-effective alternative to independent leveling of offshore gages.
- b. Tidal circulation in LA/LB Harbors during the collection period was characterized by low velocities (rarely exceeding 0.5 ft/sec) and small-scale spatial and temporal variations, including frequent flow reversals in a vertical profile. Oscillations in the current were evident at periods as short as 30 min resulting from resonance of energy at frequencies not normally associated with tidal constituents reflecting from harbor boundaries.
- c. Flow in the Cerritos Channel was basically divergent/convergent from the two openings, but sufficient amplitude and phase differences existed to result in a net circulation counterclockwise. A migrating node existed at the back of the channel.
- d. In the outer harbor, locations near the breakwater experienced significant net transport because of unequal ebb and flood currents. The harbor tends to fill from the west during flood and drain to the east during ebb. This may be a seasonal phenomenon related to the relative phase between the tides and the daily sea breeze.

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LA/LB TIDAL CIRCULATION STUDY
RESIDUAL: TG1S - TG3S

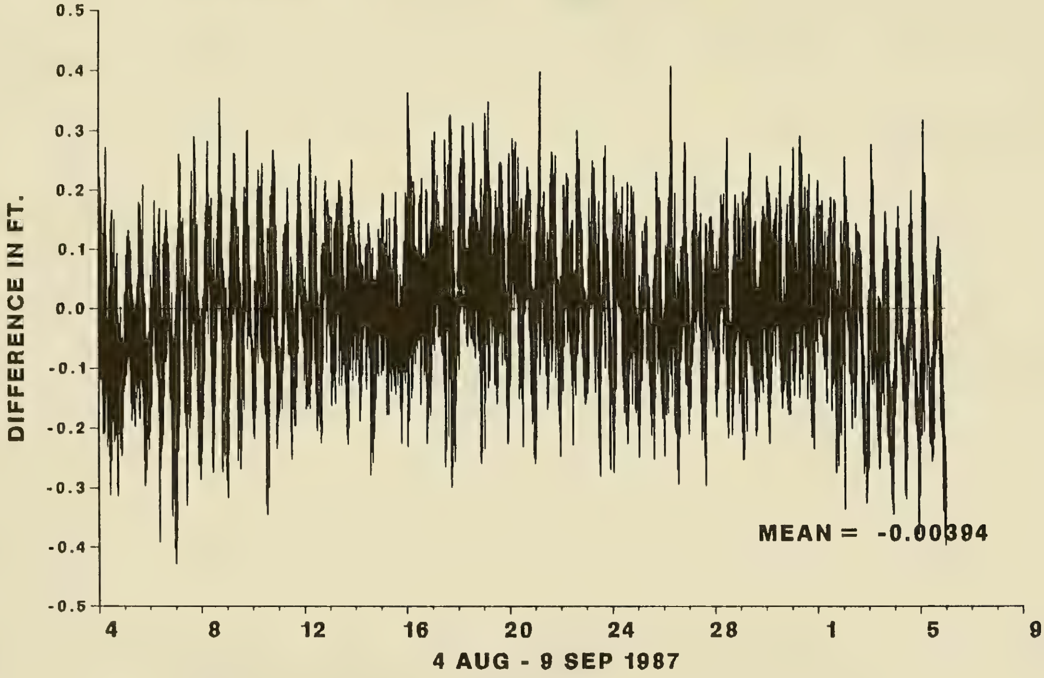
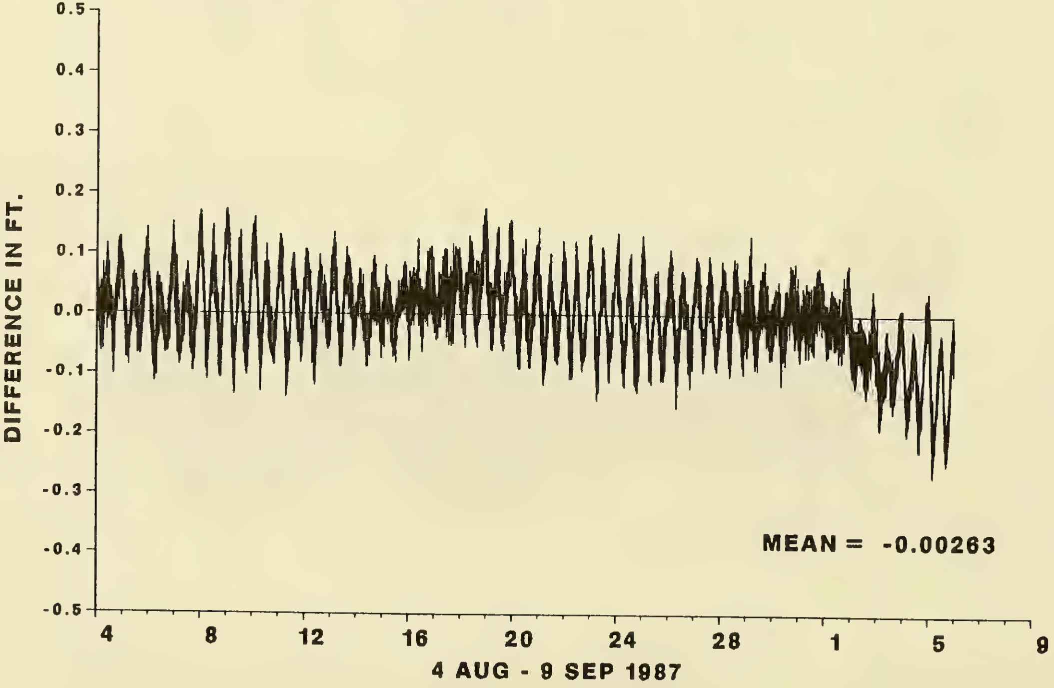


PLATE 1

PLATE 2

LA/LB TIDAL CIRCULATION STUDY
RESIDUAL: TG1S - TG6S



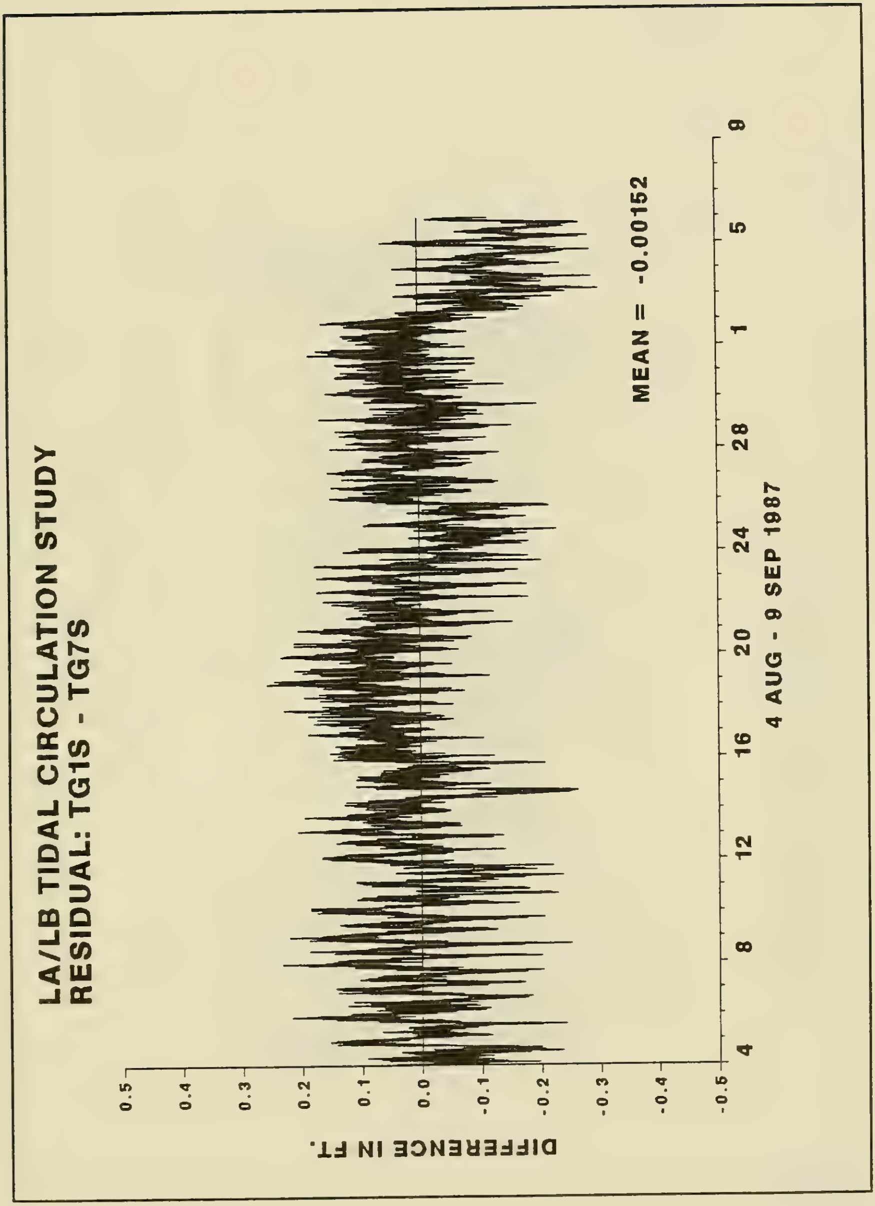

LA/LB TIDAL CIRCULATION STUDY
RESIDUAL: TG1S - TG7S
MEAN = -0.00152
DIFFERENCE IN FT.
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
4
8
12
16
20
24
28
1
5
9
4 AUG - 9 SEP 1987

PLATE 3

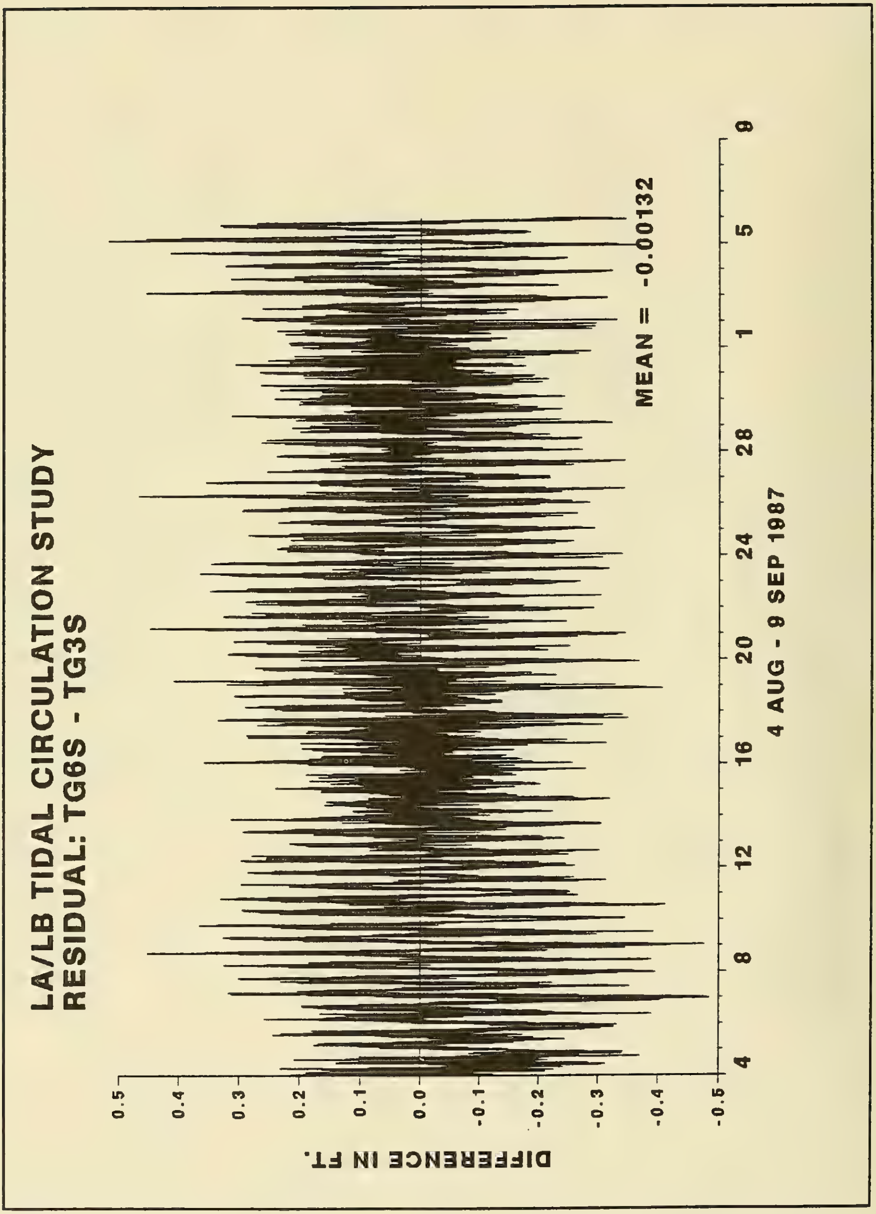

LA/LB TIDAL CIRCULATION STUDY
RESIDUAL: TG6S - TG3S
DIFFERENCE IN FT.
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
4
8
12
16
20
24
28
1
5
9
4 AUG - 9 SEP 1987
MEAN = -0.00132

PLATE 4

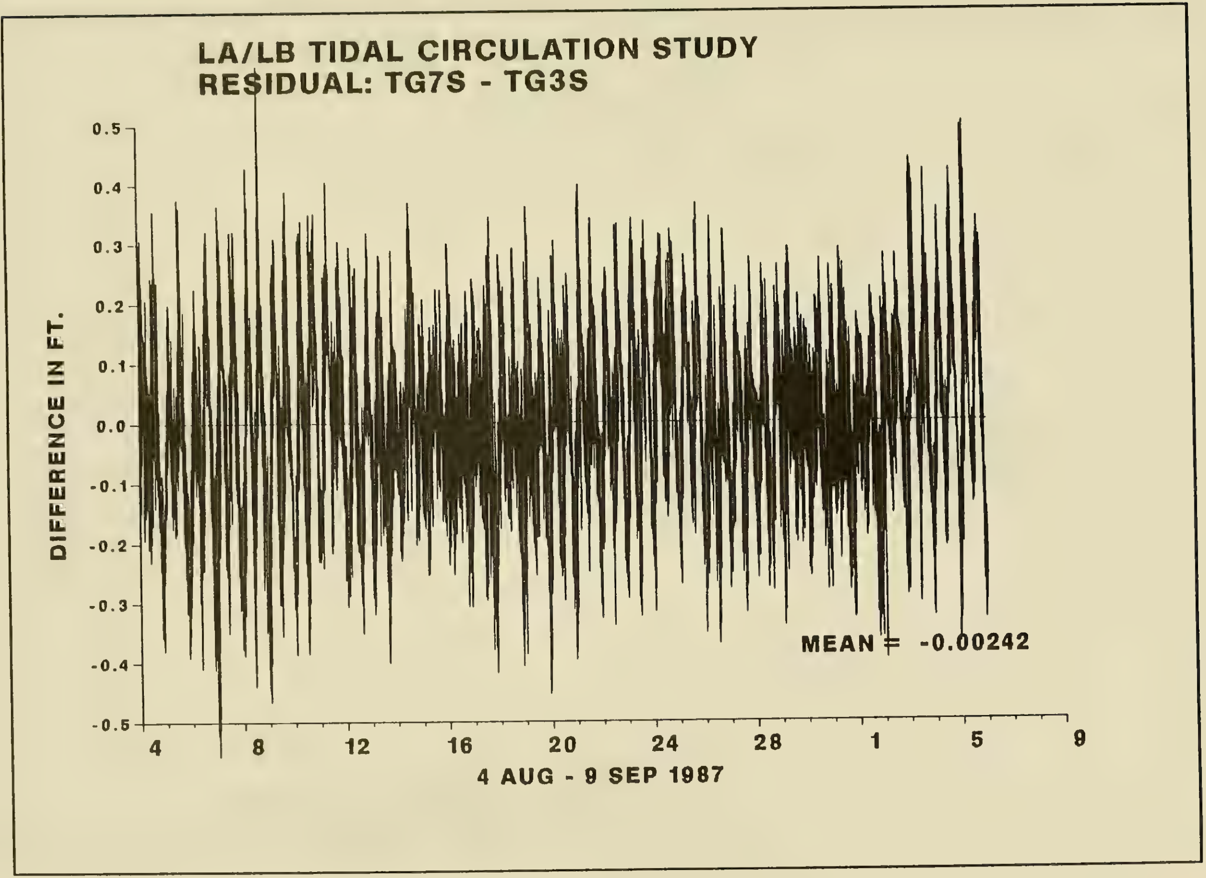
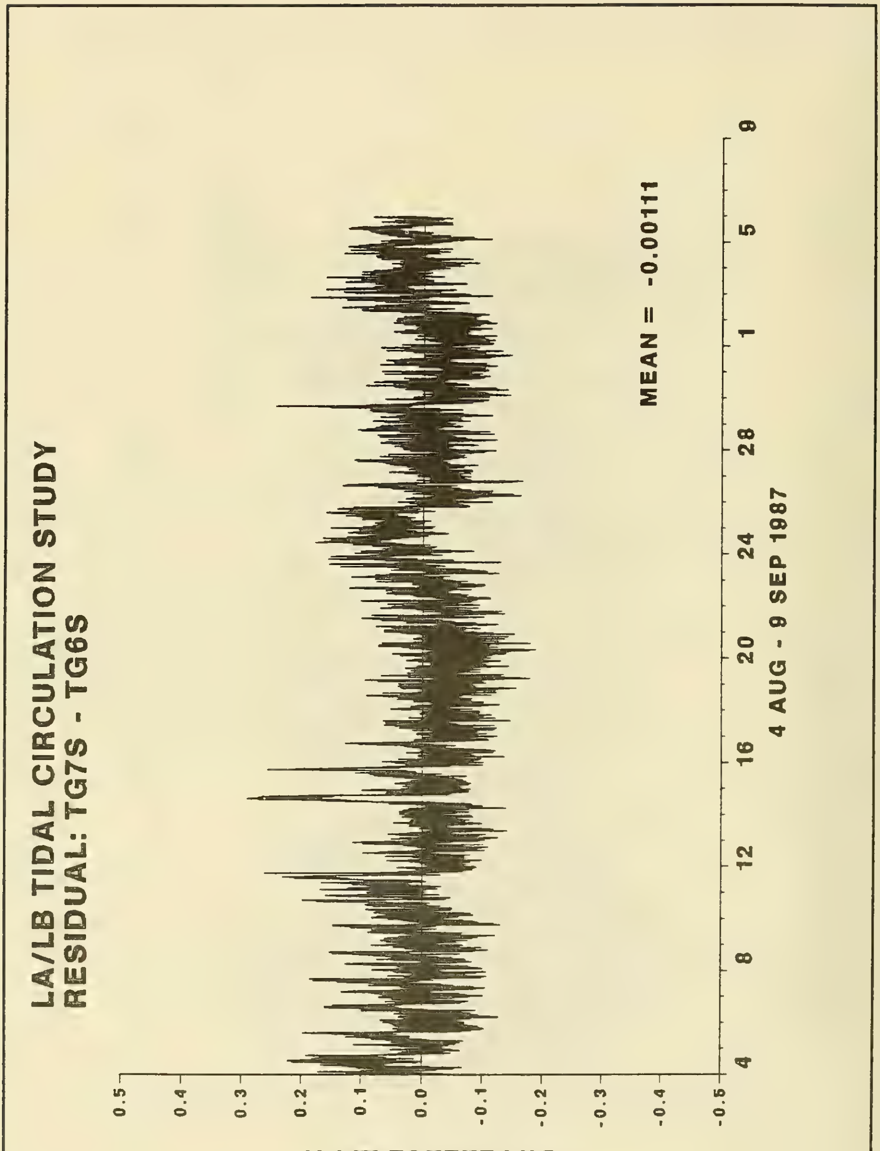

LA/LB TIDAL CIRCULATION STUDY
RESIDUAL: TG7S - TG3S
DIFFERENCE IN FT.
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
4
8
12
16
20
24
28
1
5
9
4 AUG - 9 SEP 1987
MEAN = -0.00242

PLATE 5



LA/LB TIDAL CIRCULATION STUDY
RESIDUAL: TG7S - TG6S

PLATE 6

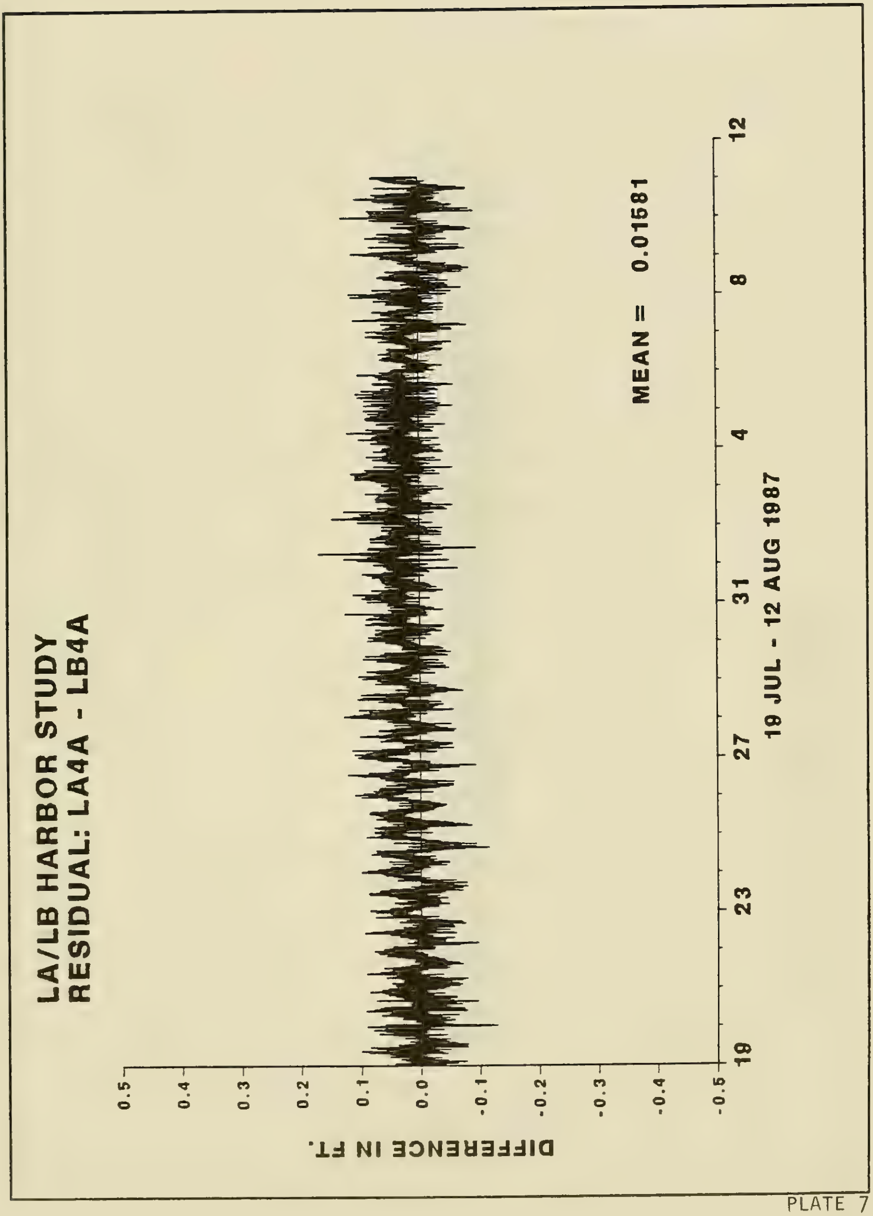
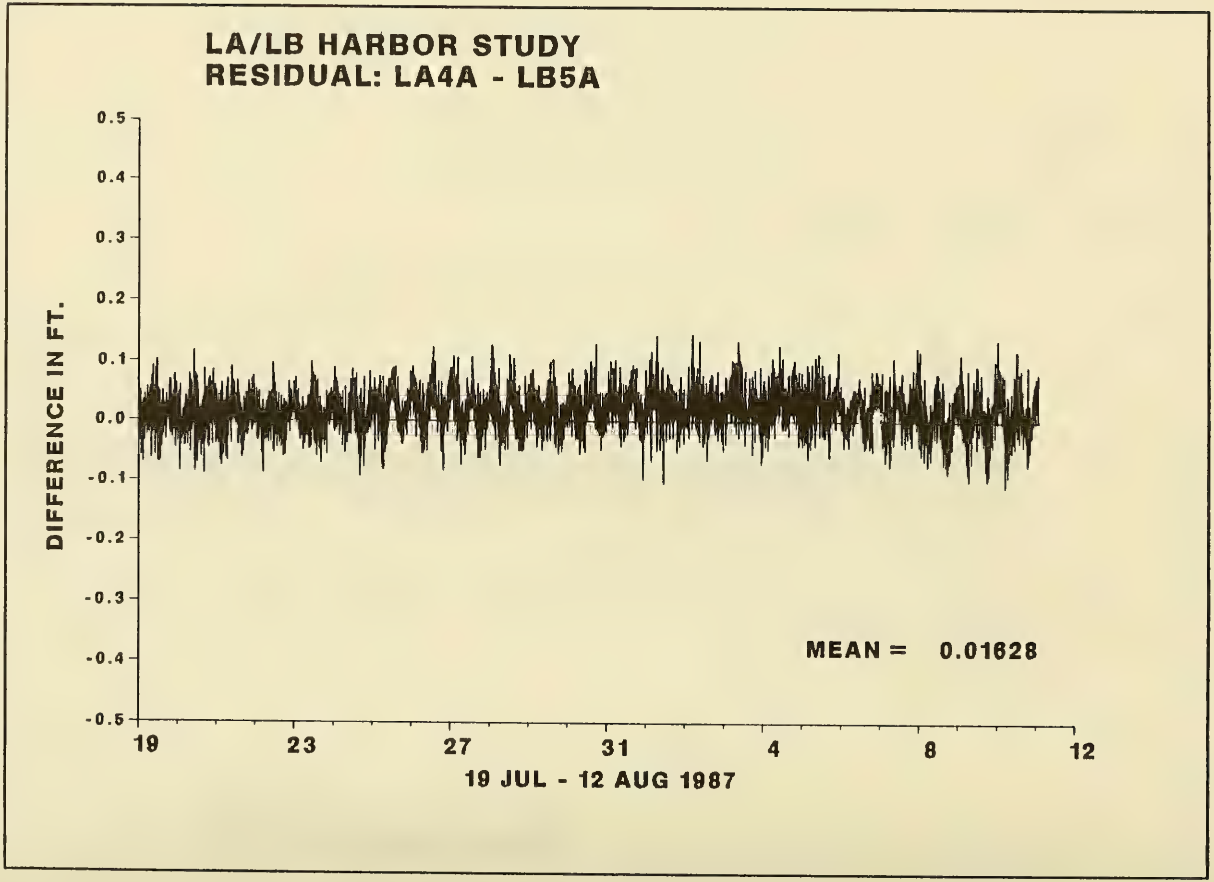

LA/LB HARBOR STUDY
RESIDUAL: LA4A - LB4A
DIFFERENCE IN FT.
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
19
23
27
31
4
8
12
19 JUL - 12 AUG 1987
MEAN = 0.01581

PLATE 7

PLATE 8


LA/LB HARBOR STUDY
RESIDUAL: LA4A - LB5A
DIFFERENCE IN FT.
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
19
23
27
31
4
8
12
19 JUL - 12 AUG 1987
MEAN = 0.01628

LA/LB HARBOR STUDY
RESIDUAL: LA4B - LB4B

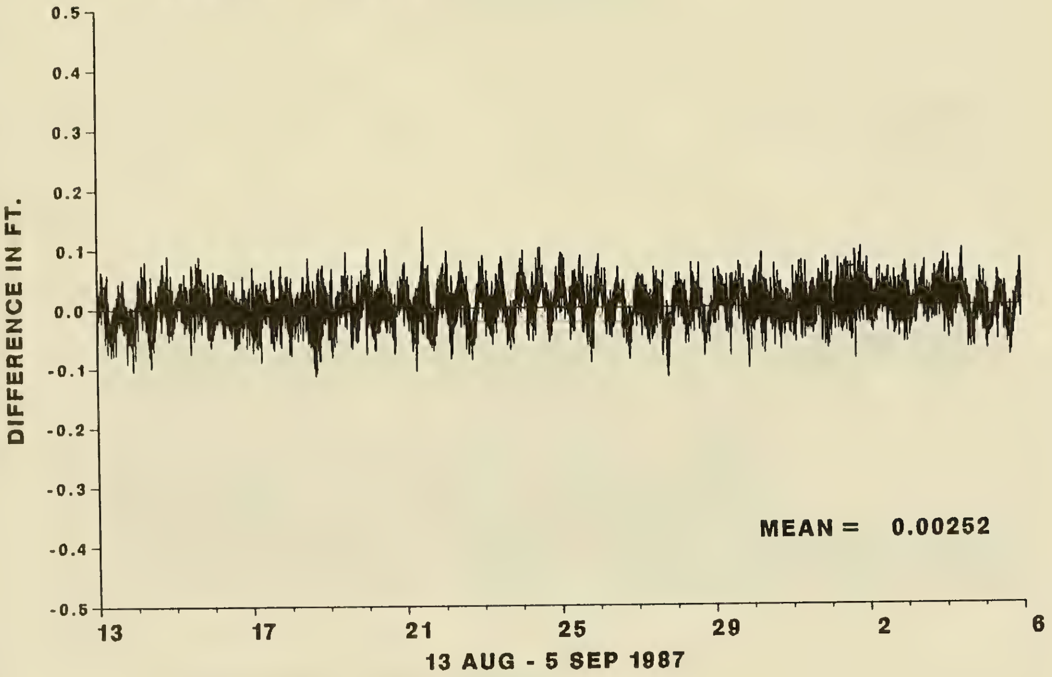
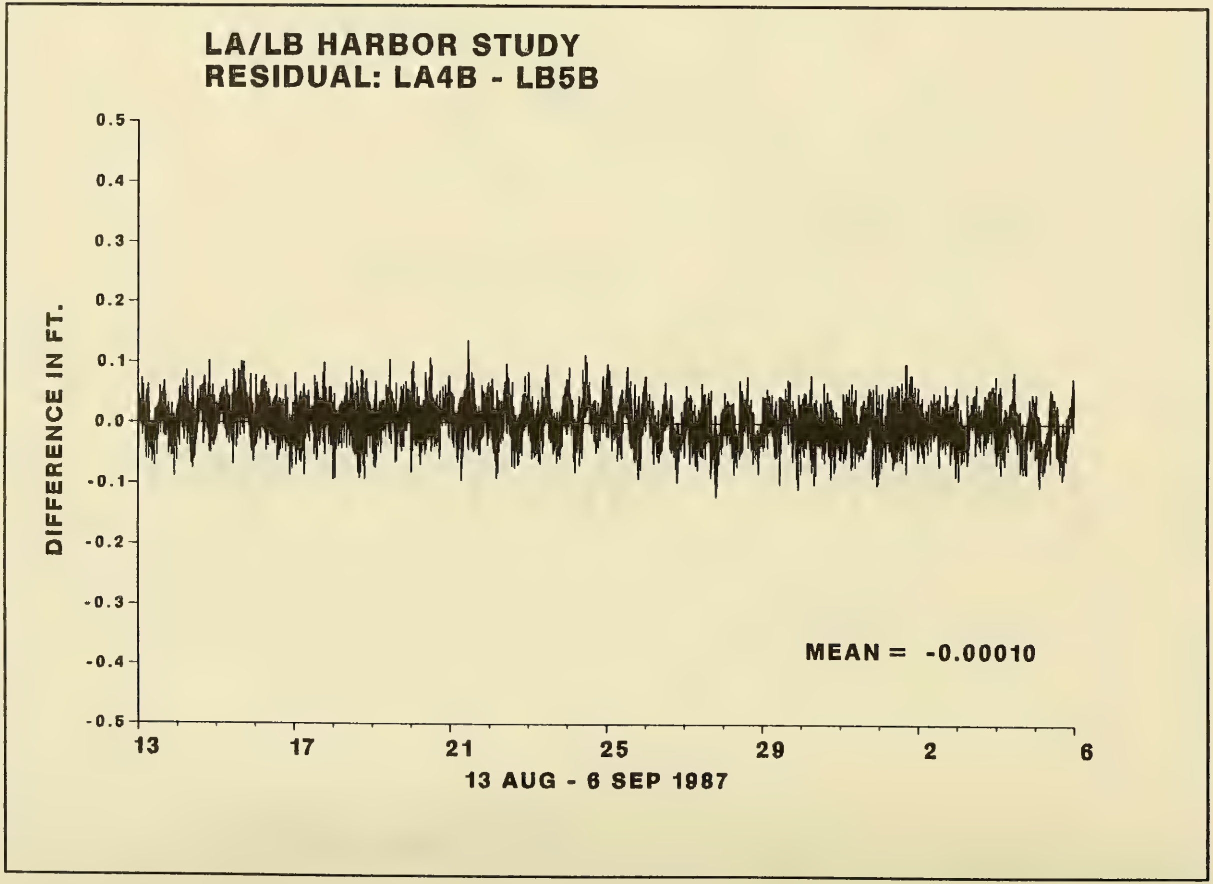


PLATE 9

PLATE 10


LA/LB HARBOR STUDY
RESIDUAL: LA4B - LB5B
DIFFERENCE IN FT.
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
13
17
21
25
29
2
6
13 AUG - 6 SEP 1987
MEAN = -0.00010

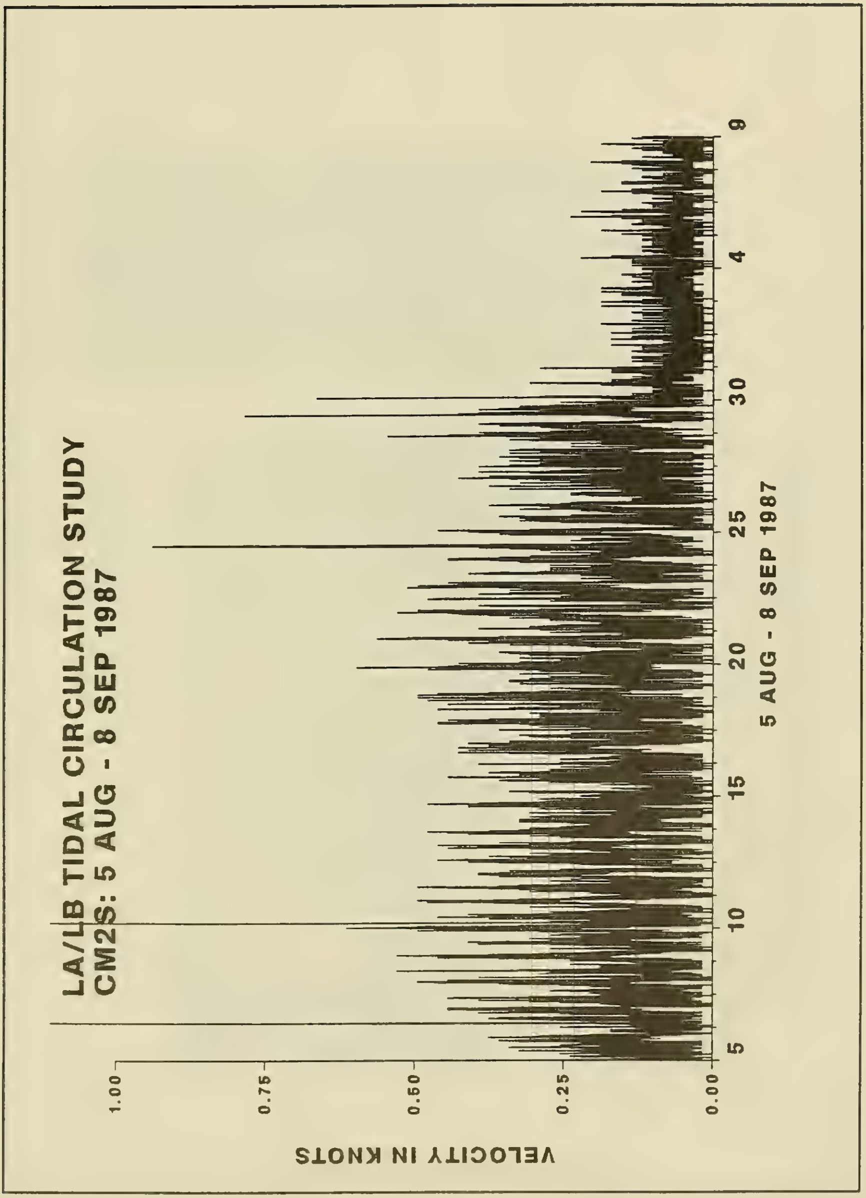
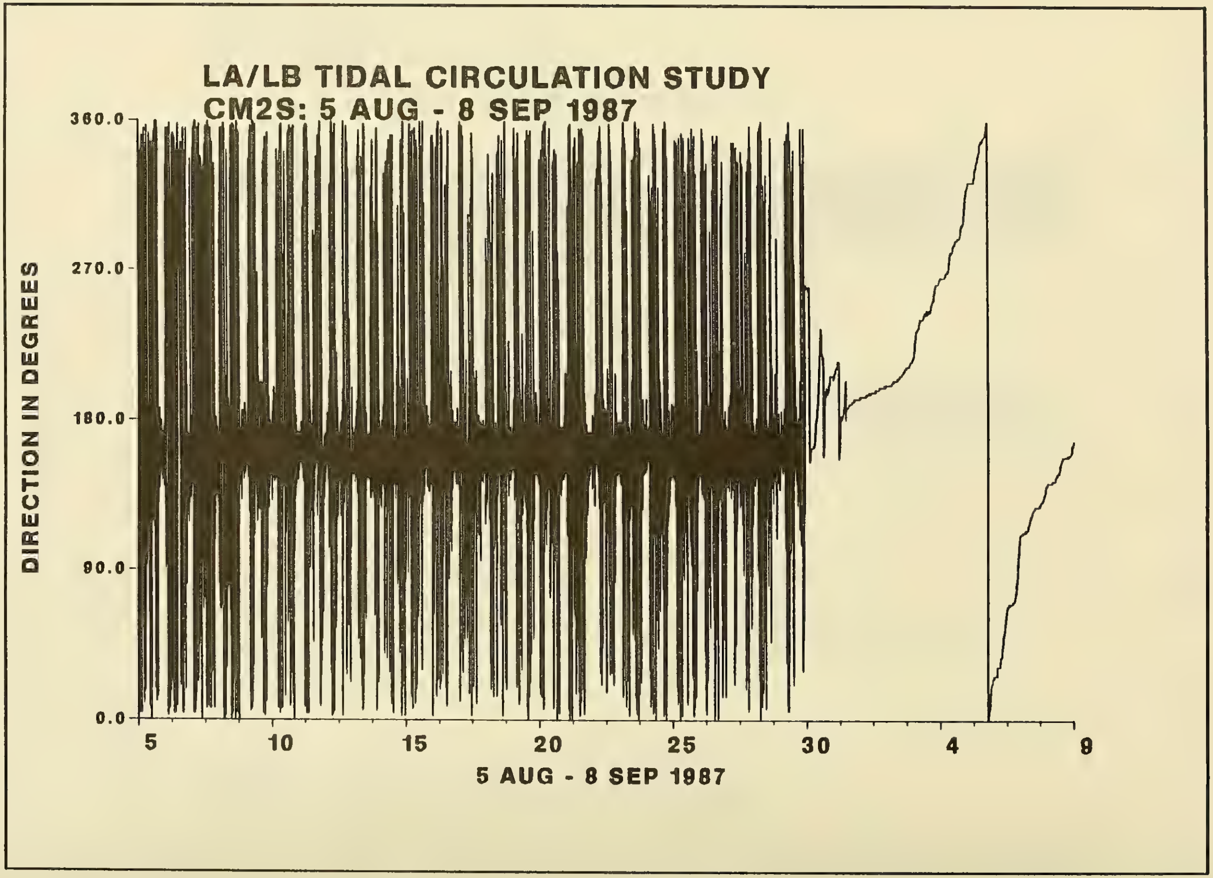

LA/LB TIDAL CIRCULATION STUDY
CM2S: 5 AUG - 8 SEP 1987
VELOCITY IN KNOTS
1.00
0.75
0.50
0.25
0.00
5
10
15
20
25
30
4
9
5 AUG - 8 SEP 1987

PLATE 11



LA/LB TIDAL CIRCULATION STUDY
CM2S: 5 AUG - 8 SEP 1987

PLATE 12

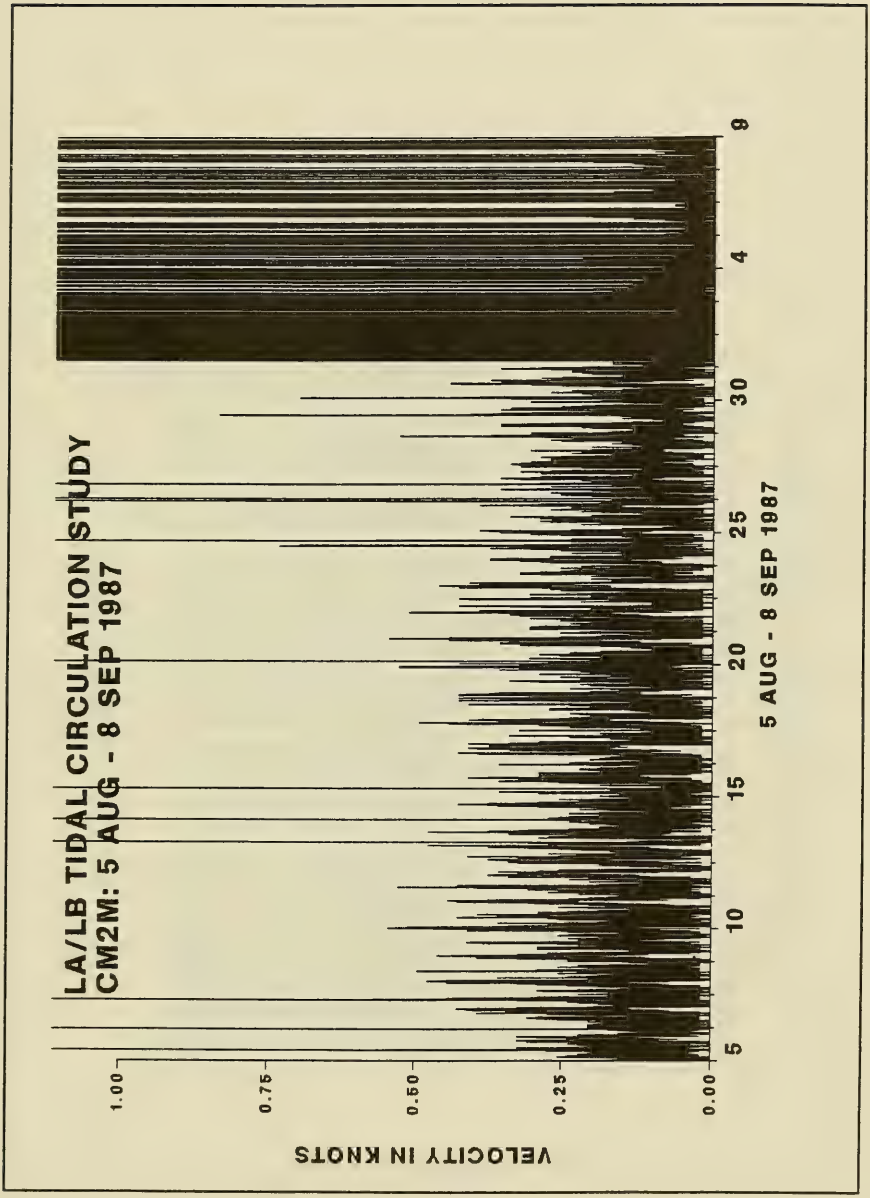

LA/LB TIDAL CIRCULATION STUDY
CM2M: 5 AUG - 8 SEP 1987
VELOCITY IN KNOTS
1.00
0.75
0.50
0.25
0.00
5
10
15
20
25
30
4
9
5 AUG - 8 SEP 1987

PLATE 13

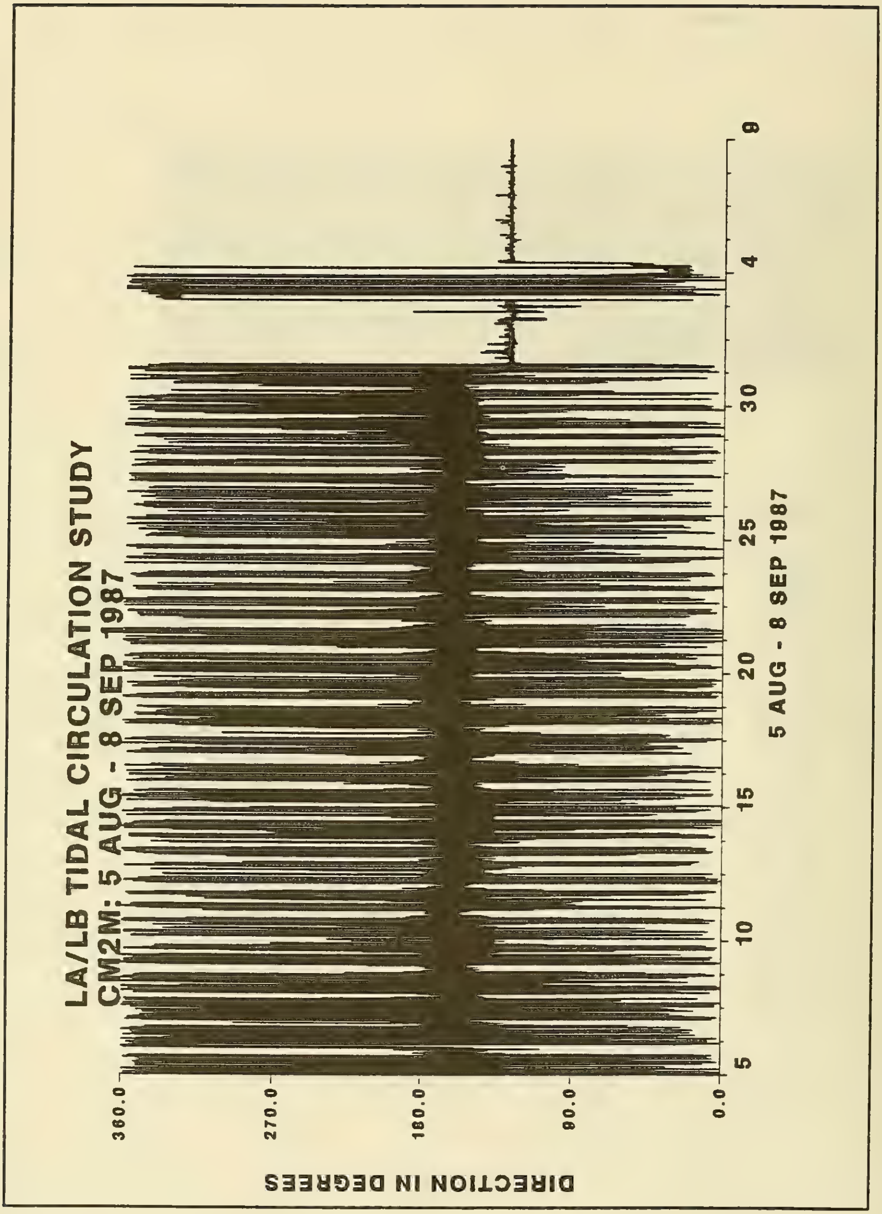

LA/LB TIDAL CIRCULATION STUDY
CM2M: 5 AUG - 8 SEP 1987
DIRECTION IN DEGREES
360.0
270.0
180.0
90.0
0.0
5
10
15
20
25
30
4
9
5 AUG - 8 SEP 1987

PLATE 14

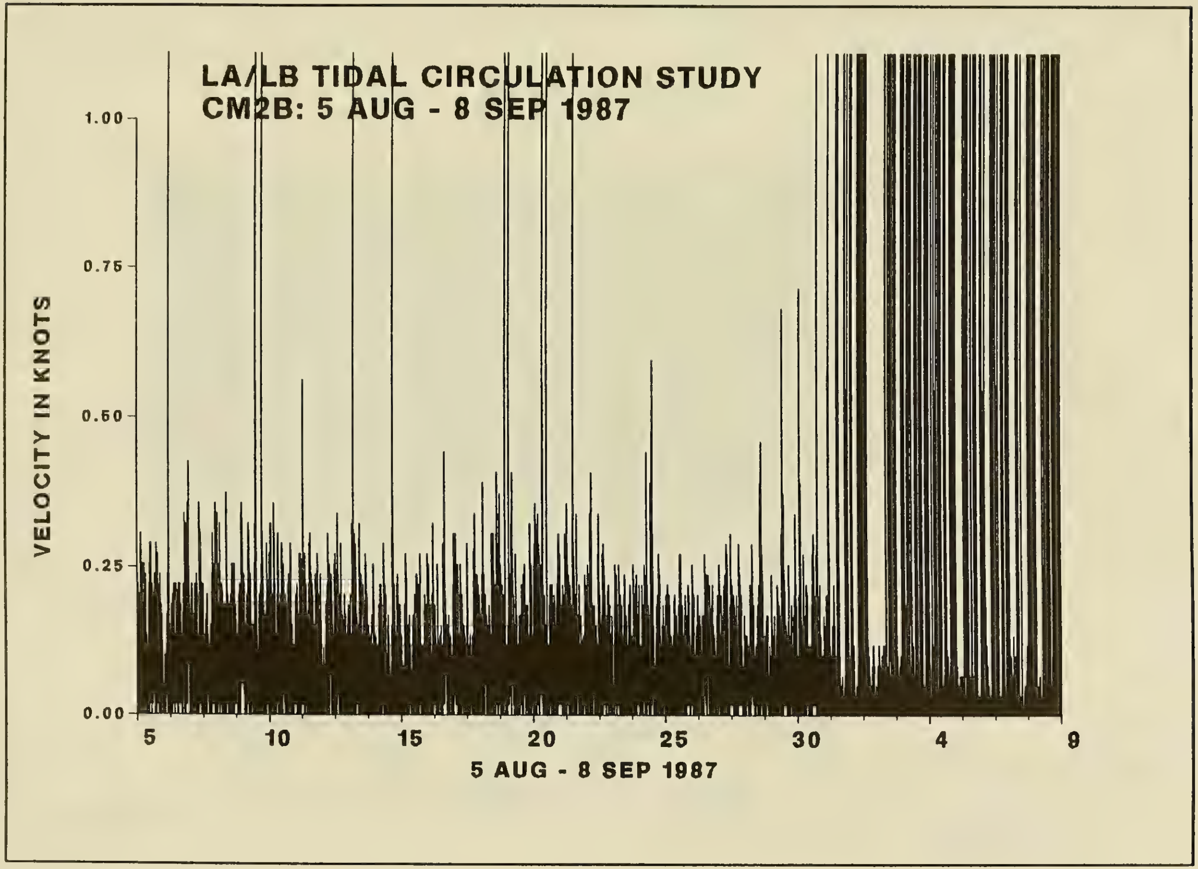

LA/LB TIDAL CIRCULATION STUDY
CM2B: 5 AUG - 8 SEP 1987
VELOCITY IN KNOTS
1.00
0.75
0.50
0.25
0.00
5
10
15
20
25
30
4
9
5 AUG - 8 SEP 1987

PLATE 15

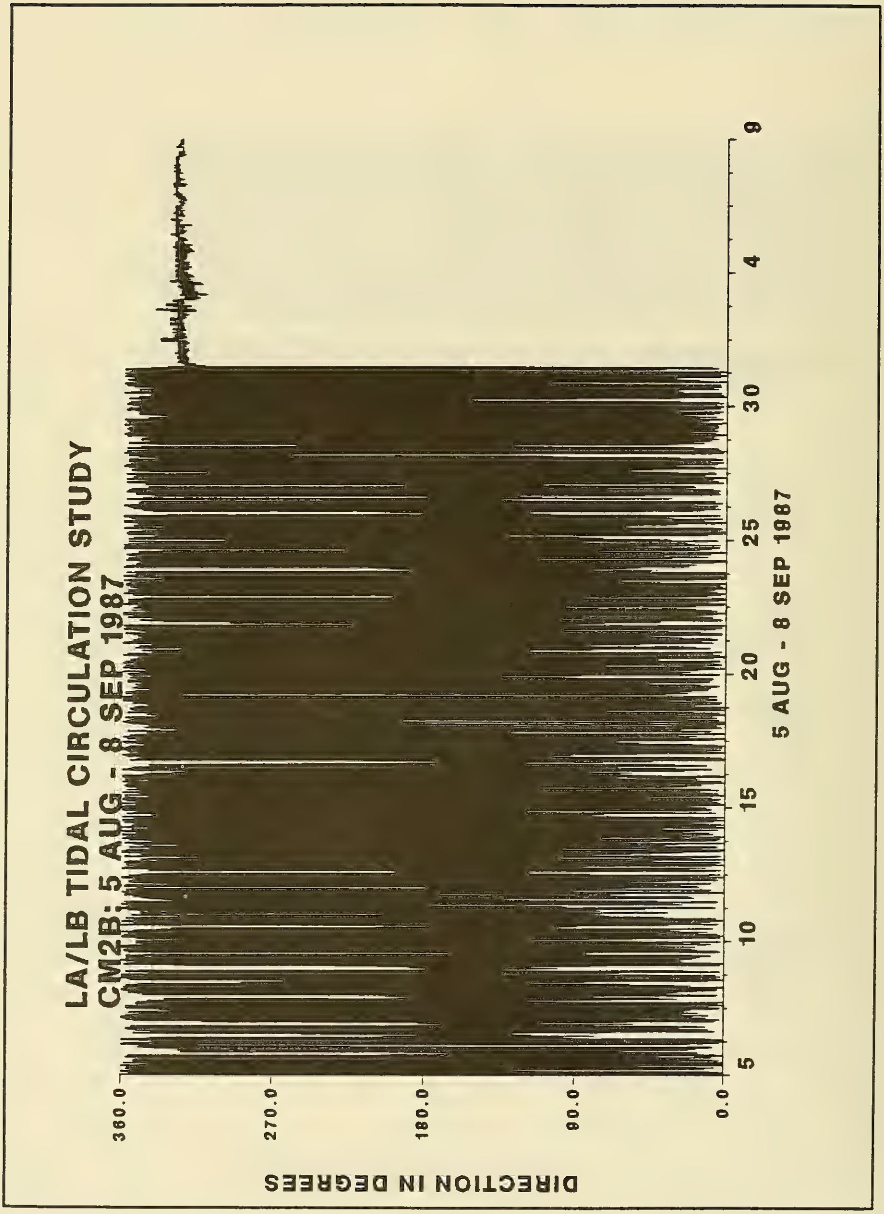
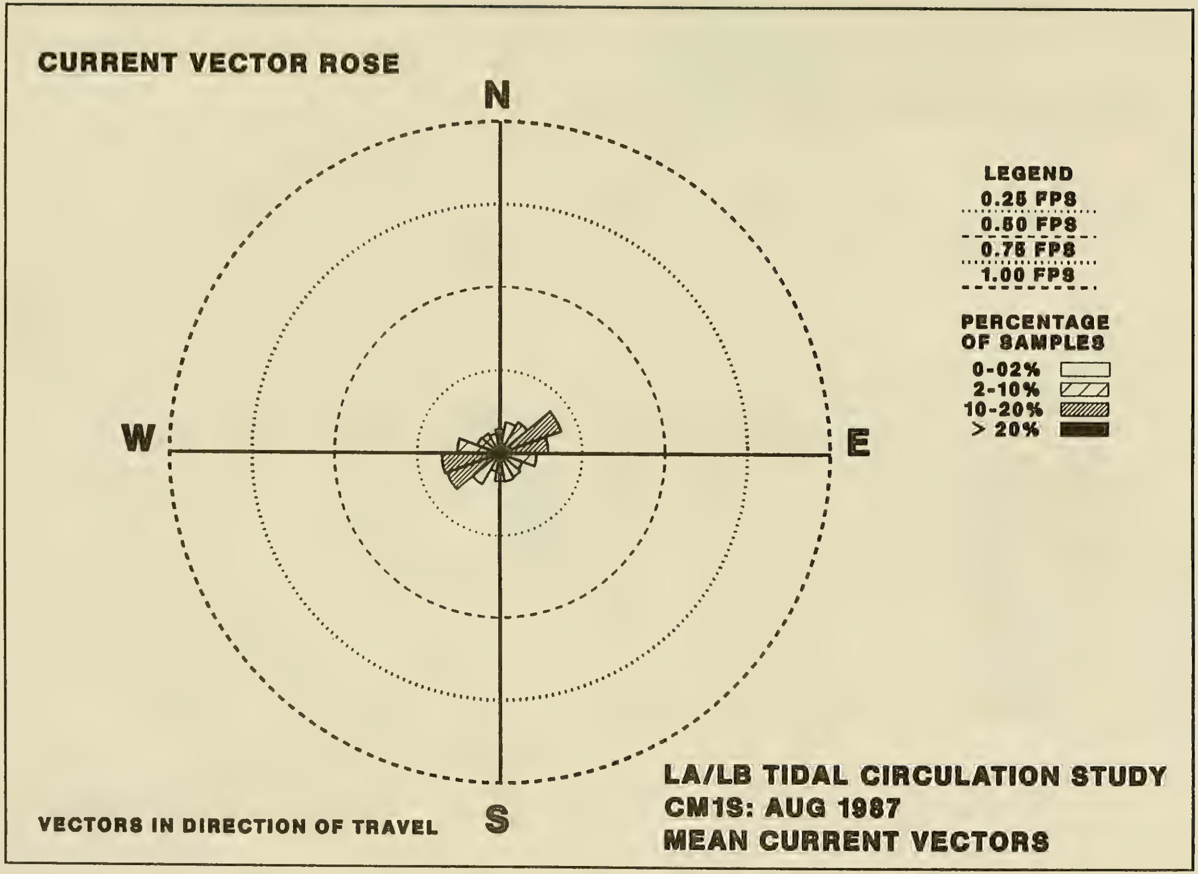

LA/LB TIDAL CIRCULATION STUDY
CM2B: 5 AUG - 8 SEP 1987
DIRECTION IN DEGREES
360.0
270.0
180.0
90.0
0.0
5
10
15
20
25
30
4
9
5 AUG - 8 SEP 1987

PLATE 16

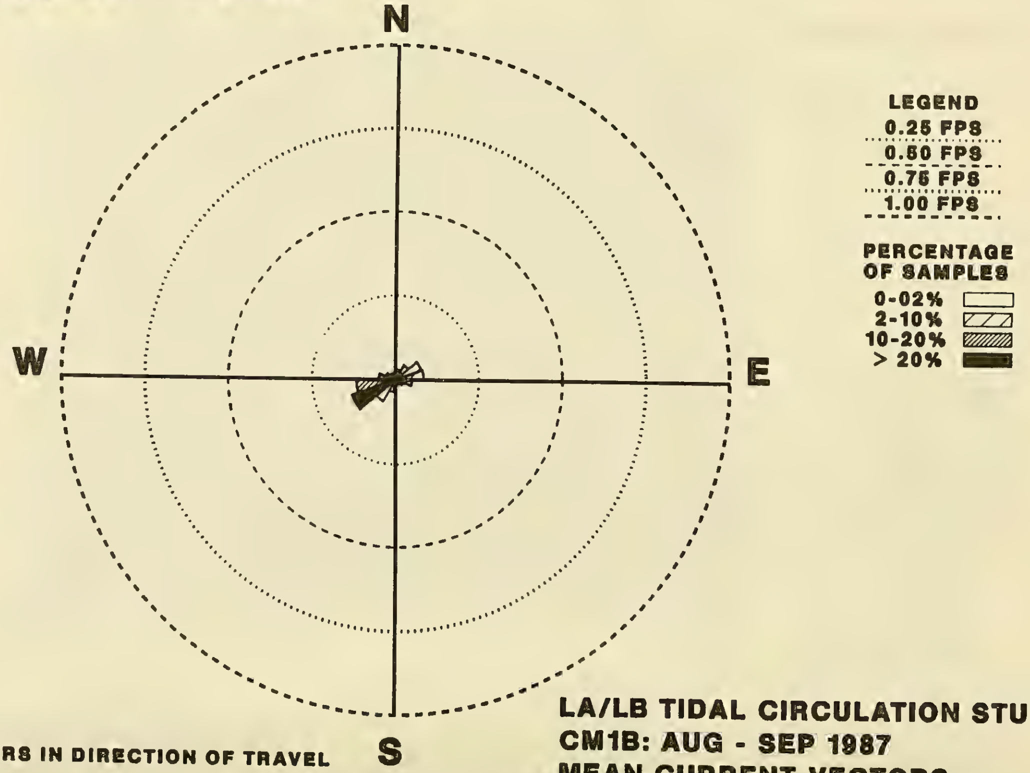


CURRENT VECTOR ROSE

VECTORS IN DIRECTION OF TRAVEL

LA/LB TIDAL CIRCULATION STUDY
CM1S: AUG 1987
MEAN CURRENT VECTORS

CURRENT VECTOR ROSE

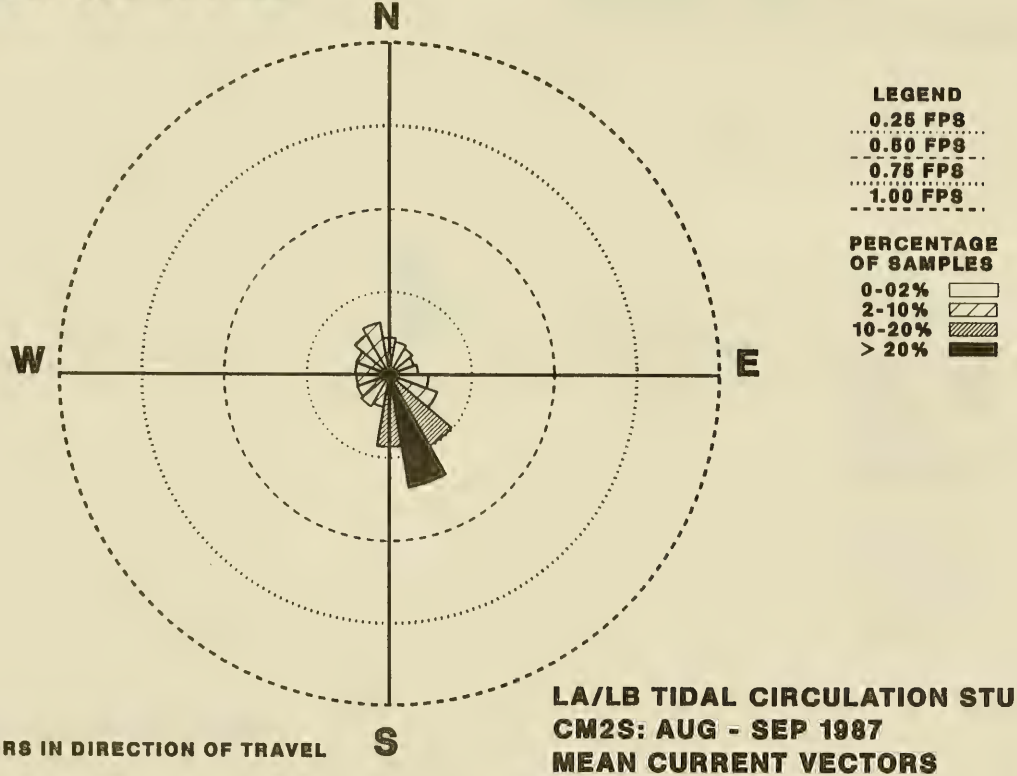


VECTORS IN DIRECTION OF TRAVEL

LA/LB TIDAL CIRCULATION STUDY
CM1B: AUG - SEP 1987
MEAN CURRENT VECTORS

PLATE 17B

CURRENT VECTOR ROSE



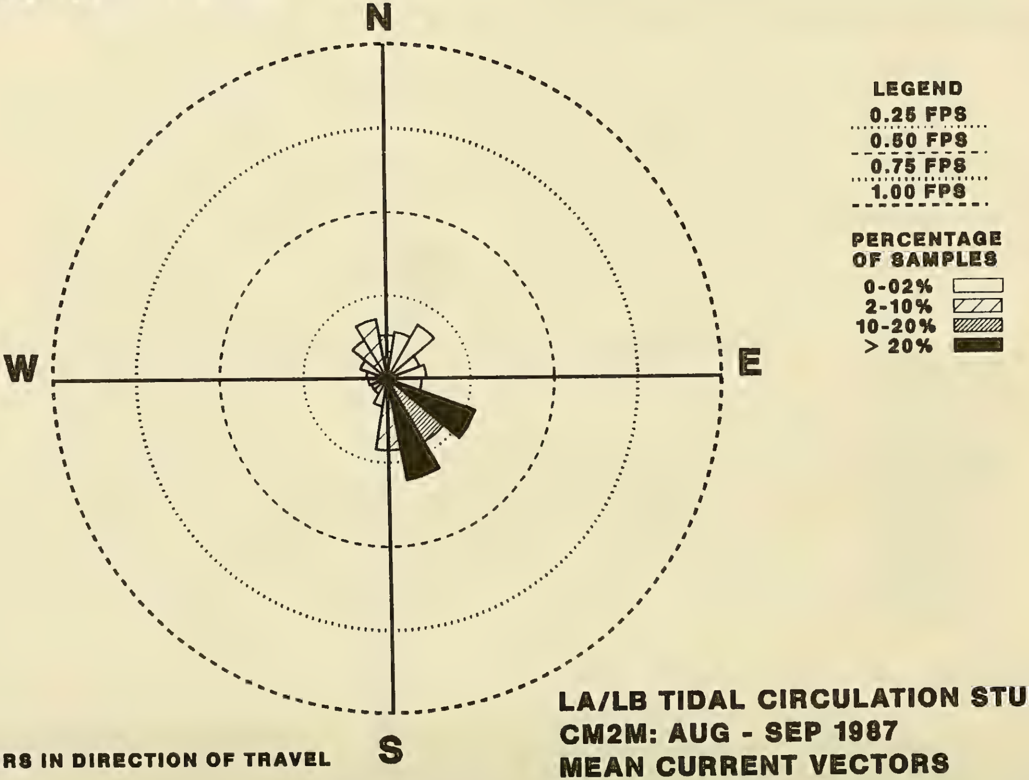
VECTORS IN DIRECTION OF TRAVEL

LA/LB TIDAL CIRCULATION STUDY
CM2S: AUG - SEP 1987
MEAN CURRENT VECTORS

PLATE 18A

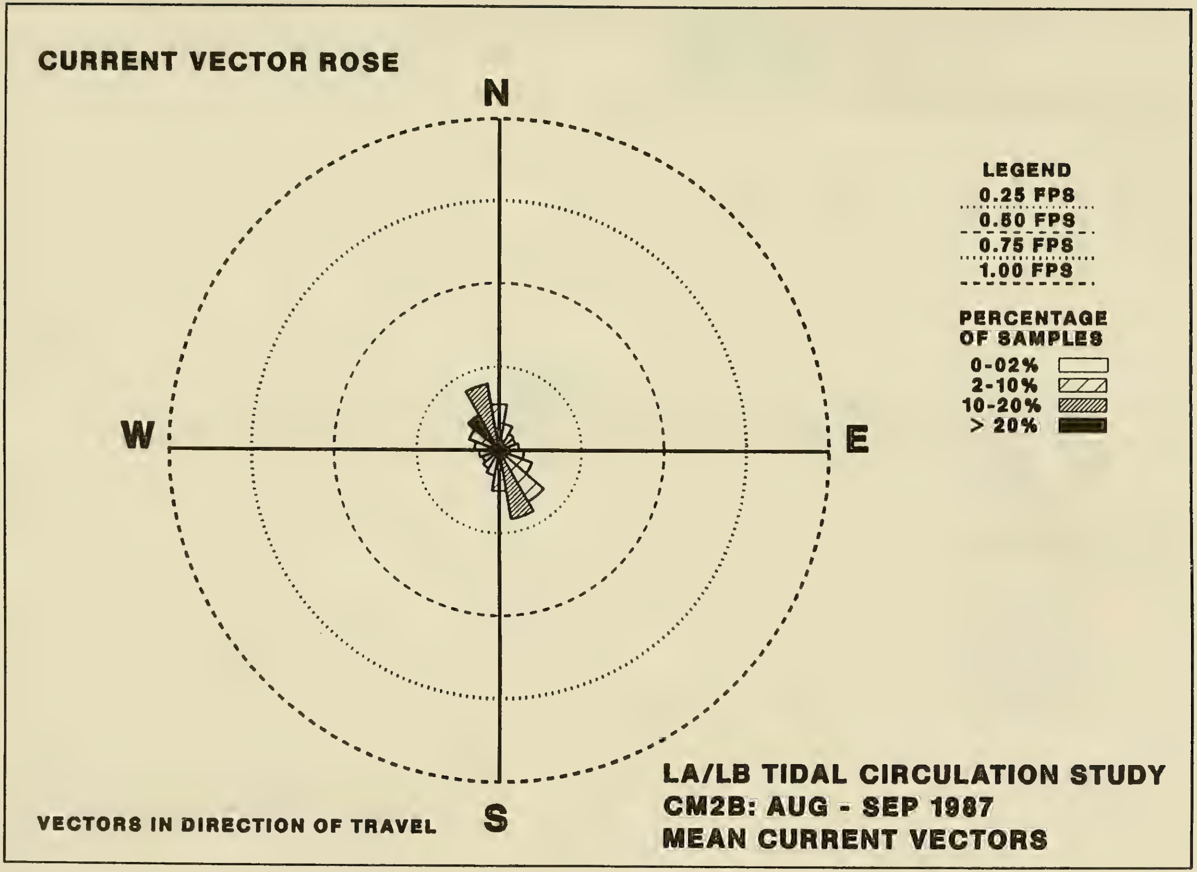
PLATE 18B

CURRENT VECTOR ROSE



VECTORS IN DIRECTION OF TRAVEL

LA/LB TIDAL CIRCULATION STUDY
CM2M: AUG - SEP 1987
MEAN CURRENT VECTORS

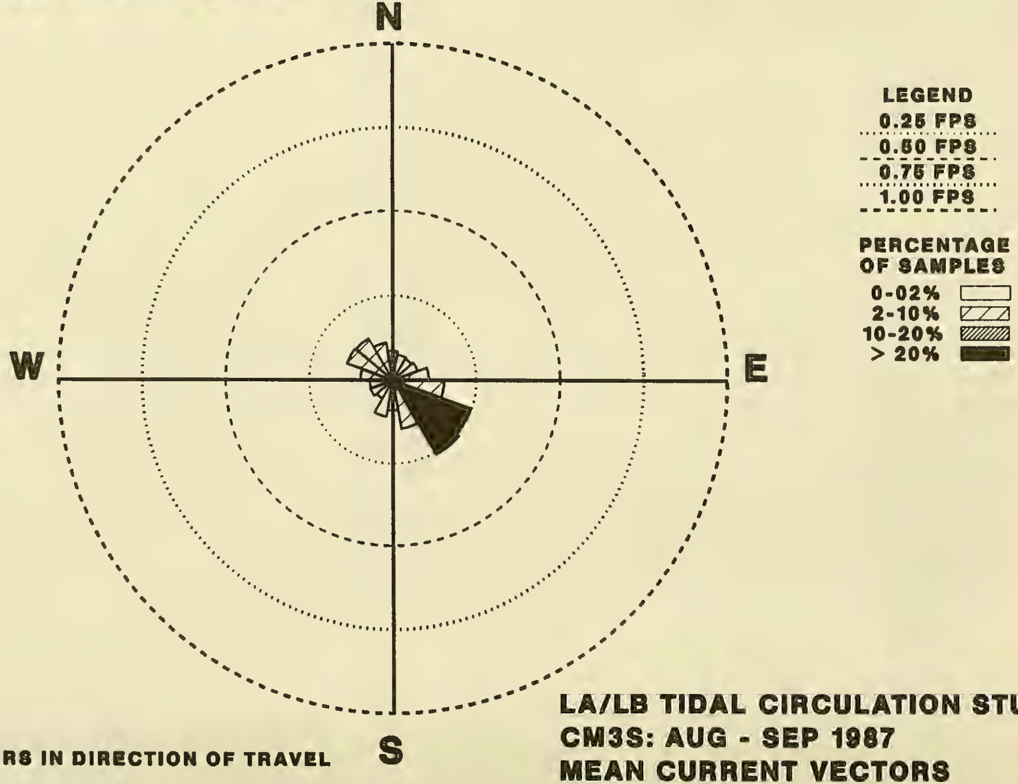


LA/LB TIDAL CIRCULATION STUDY
CM2B: AUG - SEP 1987
MEAN CURRENT VECTORS

PLATE 18C

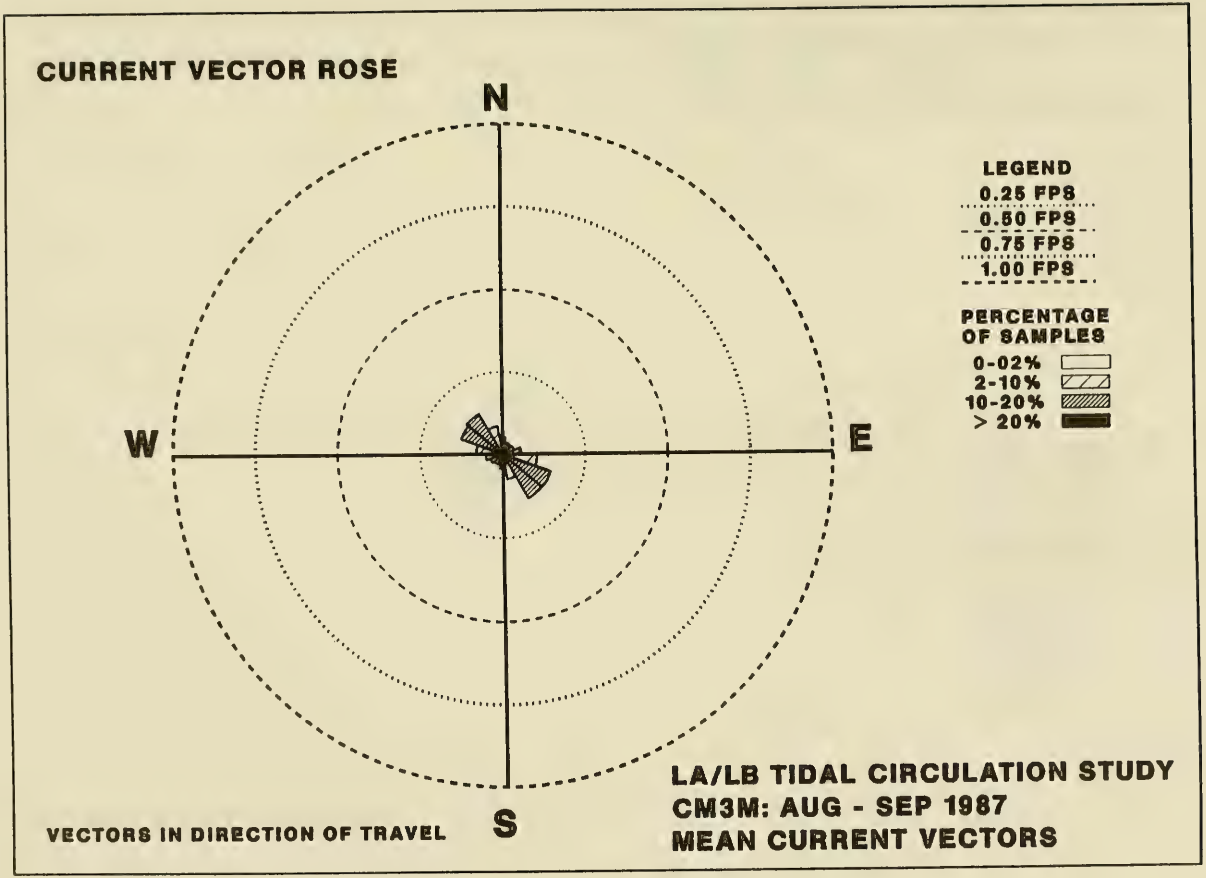
PLATE 19A

CURRENT VECTOR ROSE



VECTORS IN DIRECTION OF TRAVEL

LA/LB TIDAL CIRCULATION STUDY
CM3S: AUG - SEP 1987
MEAN CURRENT VECTORS



CURRENT VECTOR ROSE

VECTORS IN DIRECTION OF TRAVEL

LA/LB TIDAL CIRCULATION STUDY
CM3M: AUG - SEP 1987
MEAN CURRENT VECTORS

PLATE 19B

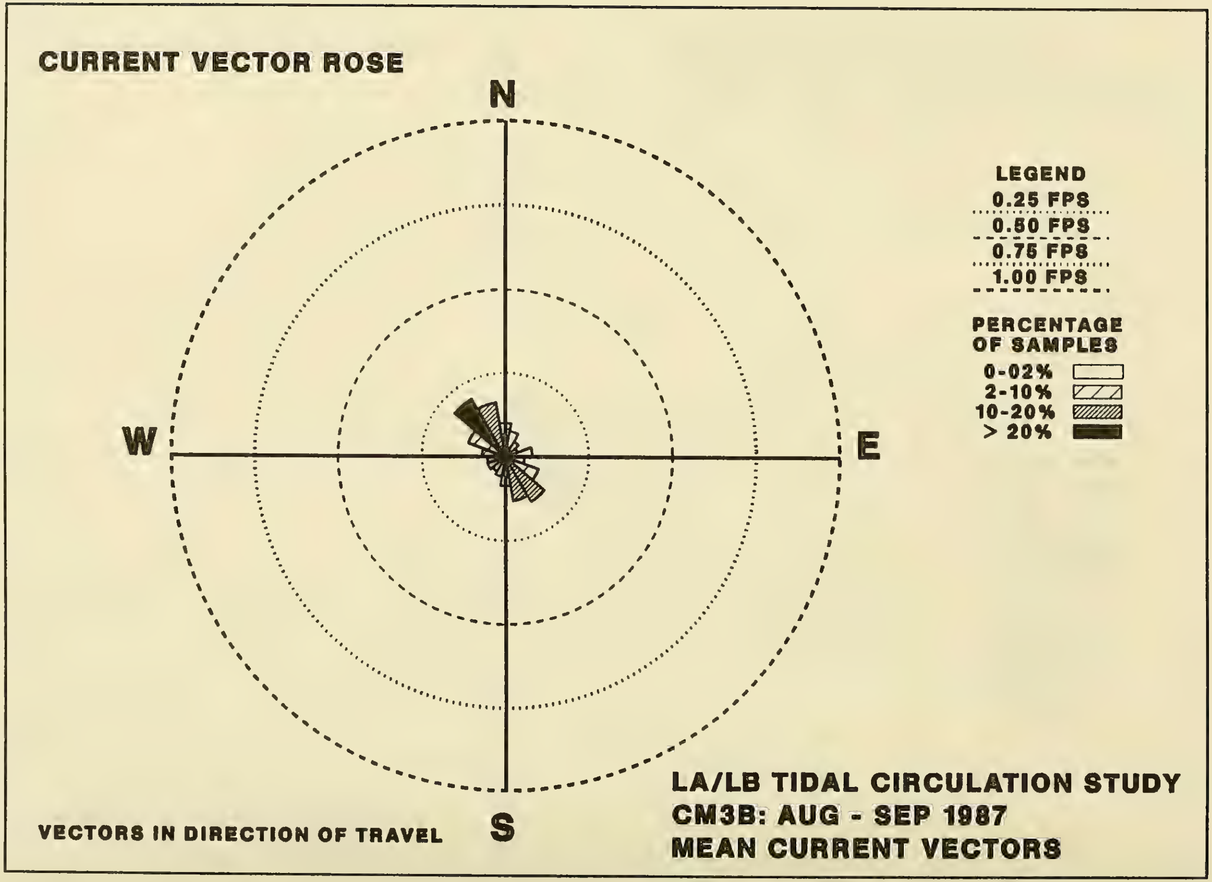
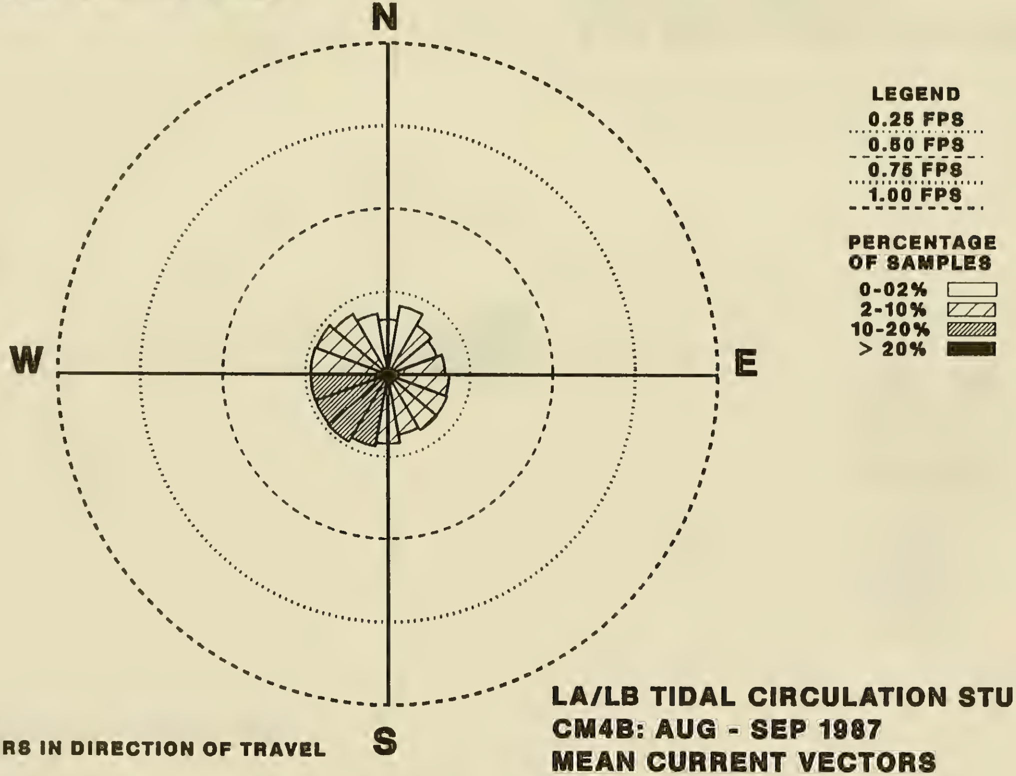

CURRENT VECTOR ROSE
N
W
E
S
LEGEND
0.25 FPS
0.50 FPS
0.75 FPS
1.00 FPS
PERCENTAGE OF SAMPLES
0-02% ☐
2-10% ▨
10-20% ▨
> 20% ■
VECTORS IN DIRECTION OF TRAVEL
LA/LB TIDAL CIRCULATION STUDY
CM3B: AUG - SEP 1987
MEAN CURRENT VECTORS

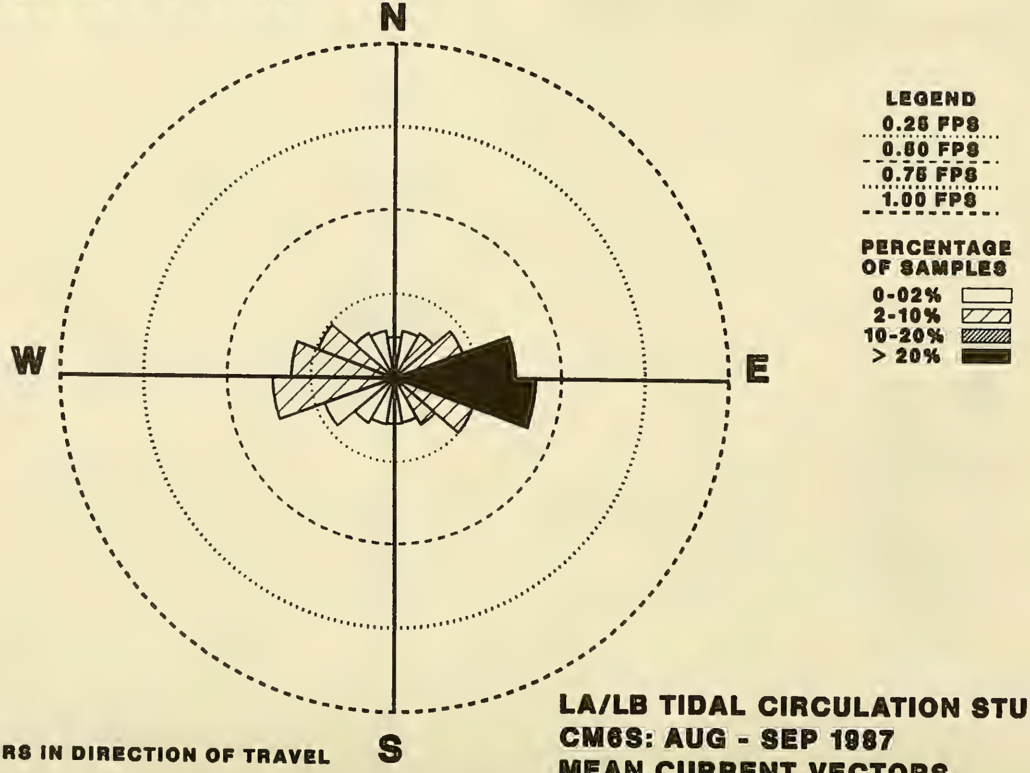
PLATE 19C

CURRENT VECTOR ROSE



VECTORS IN DIRECTION OF TRAVEL

LA/LB TIDAL CIRCULATION STUDY
CM4B: AUG - SEP 1987
MEAN CURRENT VECTORS

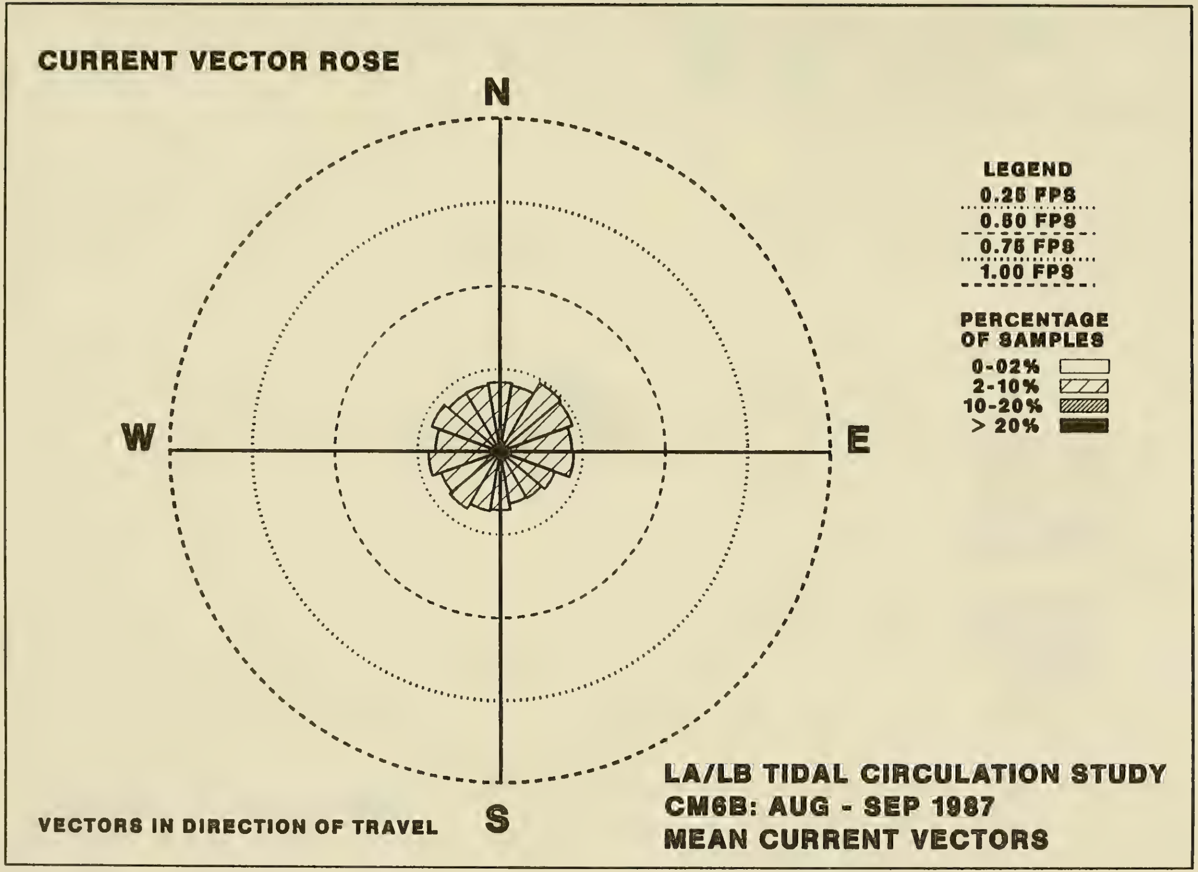


CURRENT VECTOR ROSE

VECTORS IN DIRECTION OF TRAVEL

LA/LB TIDAL CIRCULATION STUDY
CM6S: AUG - SEP 1987
MEAN CURRENT VECTORS

PLATE 21A



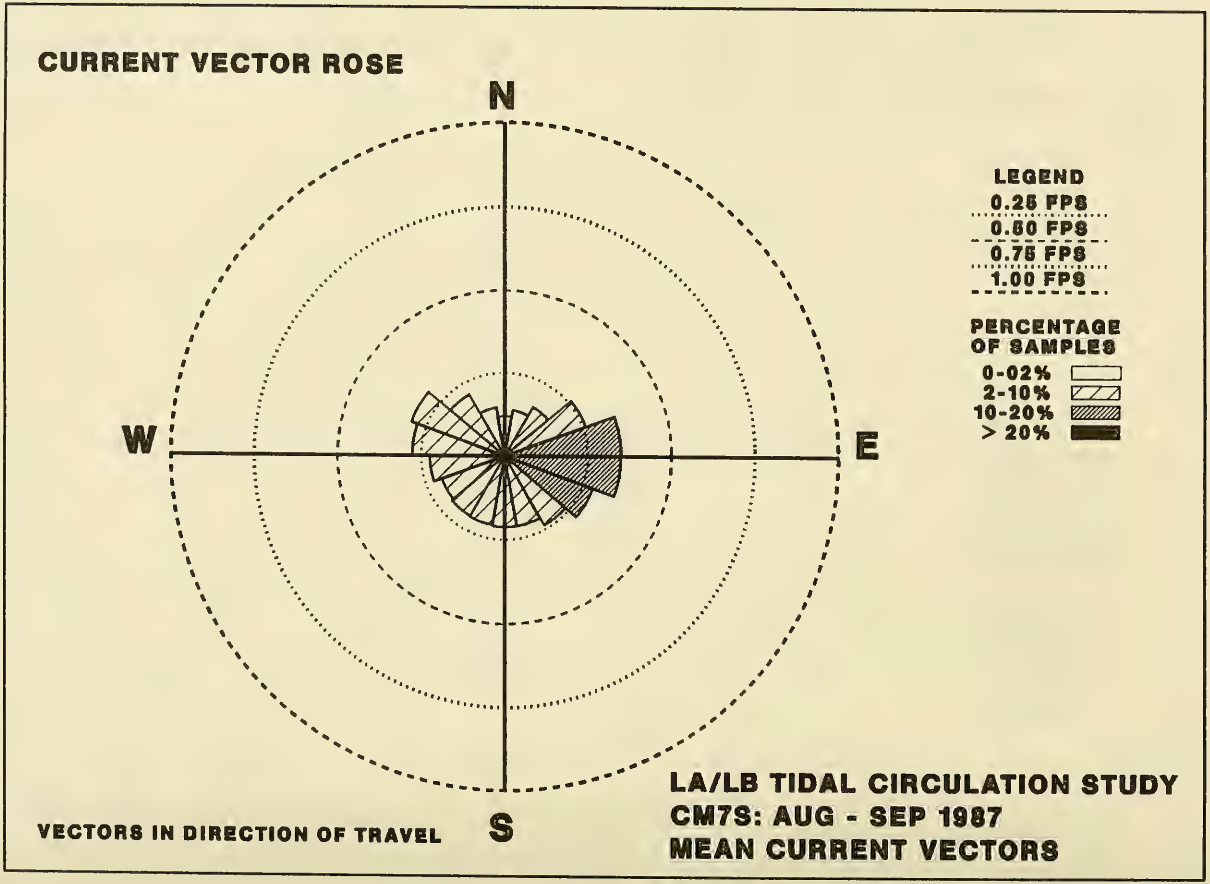
CURRENT VECTOR ROSE

LA/LB TIDAL CIRCULATION STUDY
CM6B: AUG - SEP 1987
MEAN CURRENT VECTORS

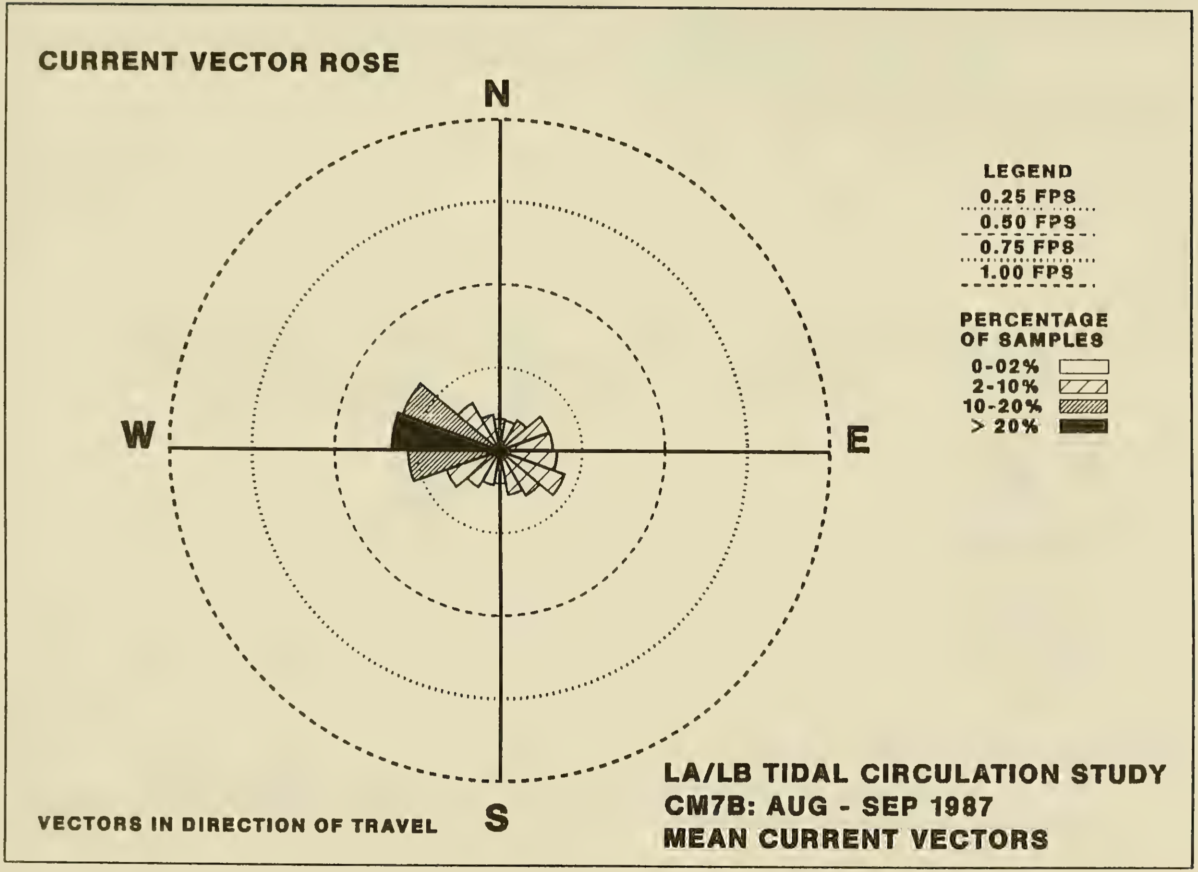
VECTORS IN DIRECTION OF TRAVEL

PLATE 21B

PLATE 22A



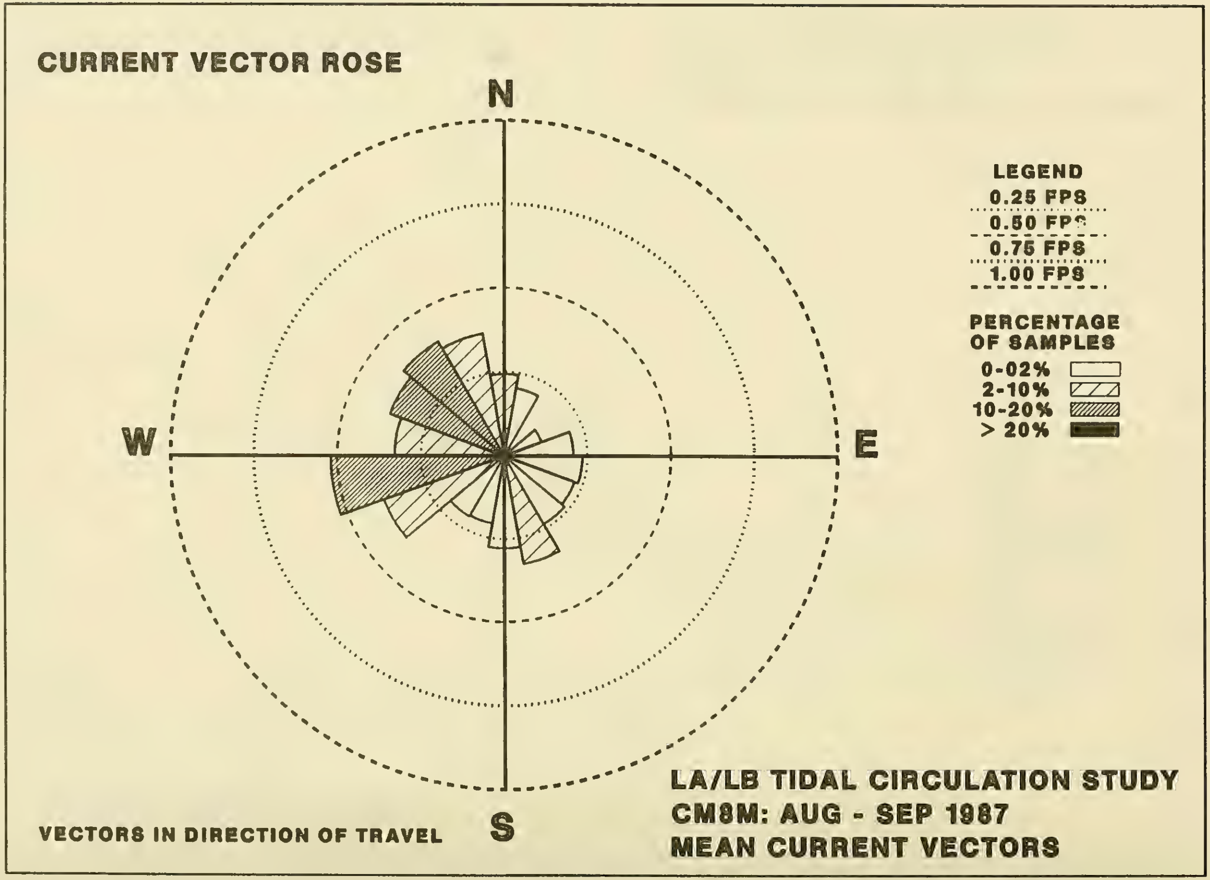
LA/LB TIDAL CIRCULATION STUDY
CM7S: AUG - SEP 1987
MEAN CURRENT VECTORS



LA/LB TIDAL CIRCULATION STUDY
CM7B: AUG - SEP 1987
MEAN CURRENT VECTORS

PLATE 22B

PLATE 23

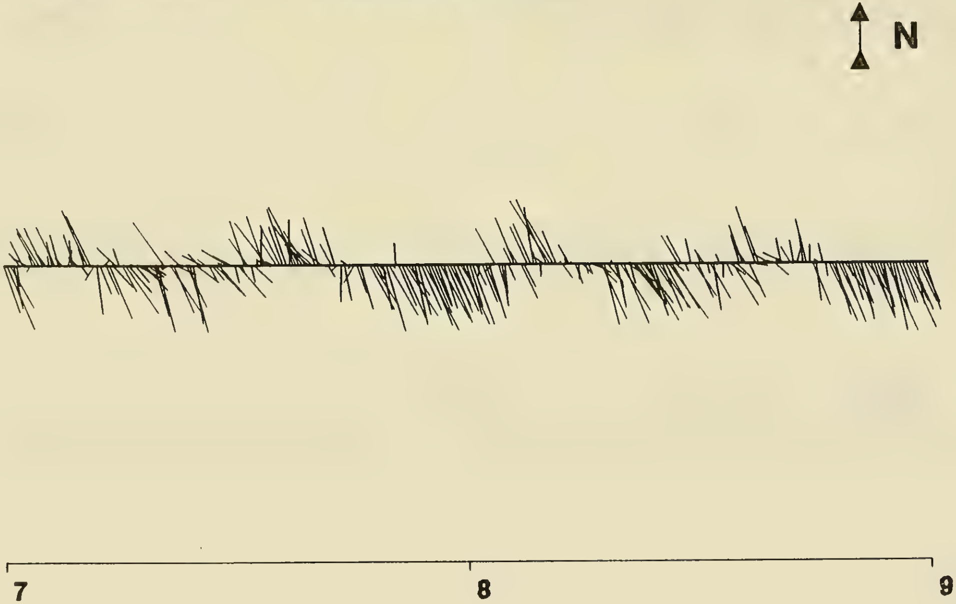


CURRENT VECTOR ROSE

VECTORS IN DIRECTION OF TRAVEL

LA/LB TIDAL CIRCULATION STUDY
CM8M: AUG - SEP 1987
MEAN CURRENT VECTORS

CURRENT VELOCITY AND DIRECTION



SCALE: 1.0 FPS

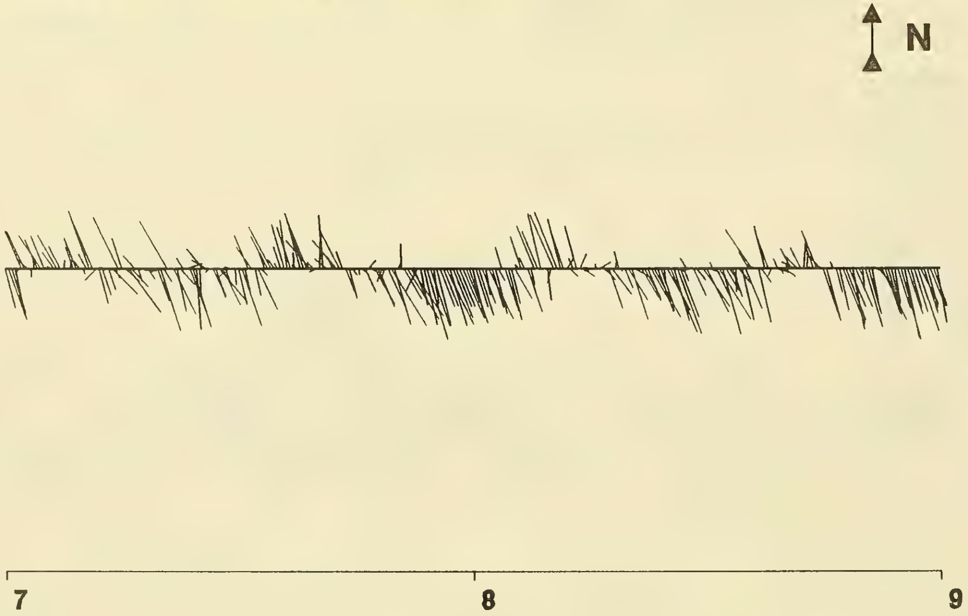
VECTOR POINTS IN DIRECTION OF TRAVEL

LA/LB TIDAL CIRCULATION STUDY
CM2S: 7 - 8 AUG 1987
10 MINUTE AVERAGE VECTORS

PLATE 24

PLATE 25

CURRENT VELOCITY AND DIRECTION

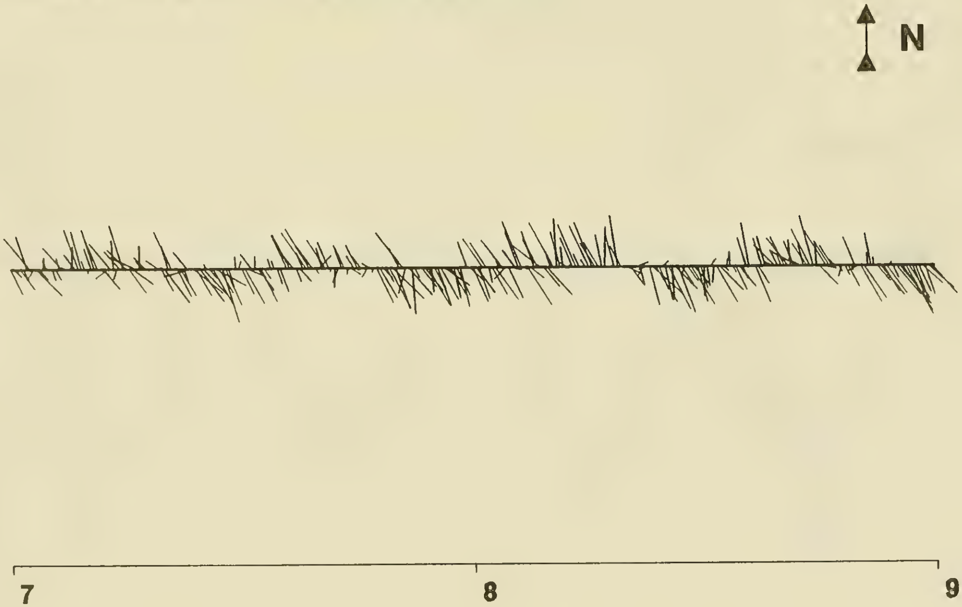


SCALE: 1.0 FPS

VECTOR POINTS IN DIRECTION OF TRAVEL

LA/LB TIDAL CIRCULATION STUDY
CM2M: 7 - 8 AUG 1987
10 MINUTE AVERAGE VECTORS

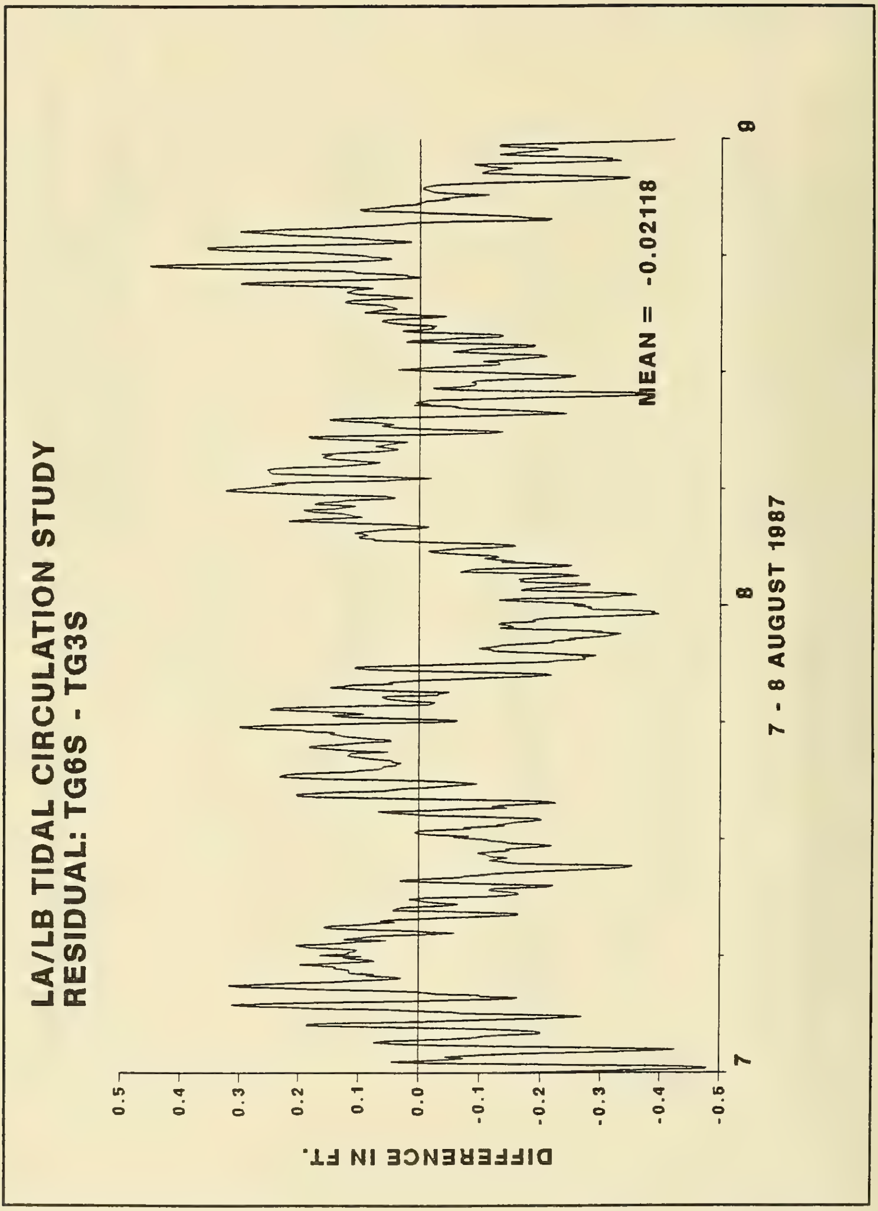
CURRENT VELOCITY AND DIRECTION



SCALE: 1.0 FPS

VECTOR POINTS IN DIRECTION OF TRAVEL

LA/LB TIDAL CIRCULATION STUDY
CM2B: 7 - 8 AUG 1987
10 MINUTE AVERAGE VECTORS



LA/LB TIDAL CIRCULATION STUDY
RESIDUAL: TG6S - TG3S

PLATE 27

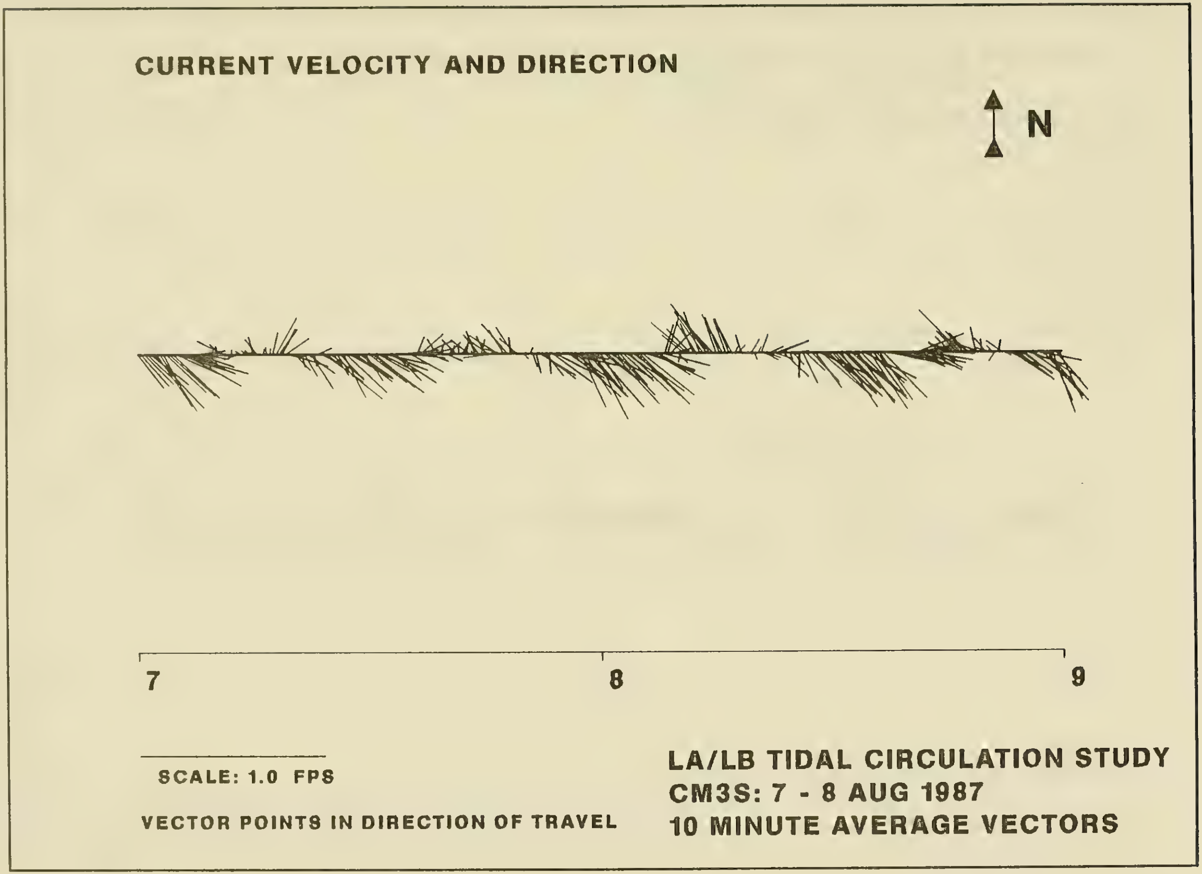
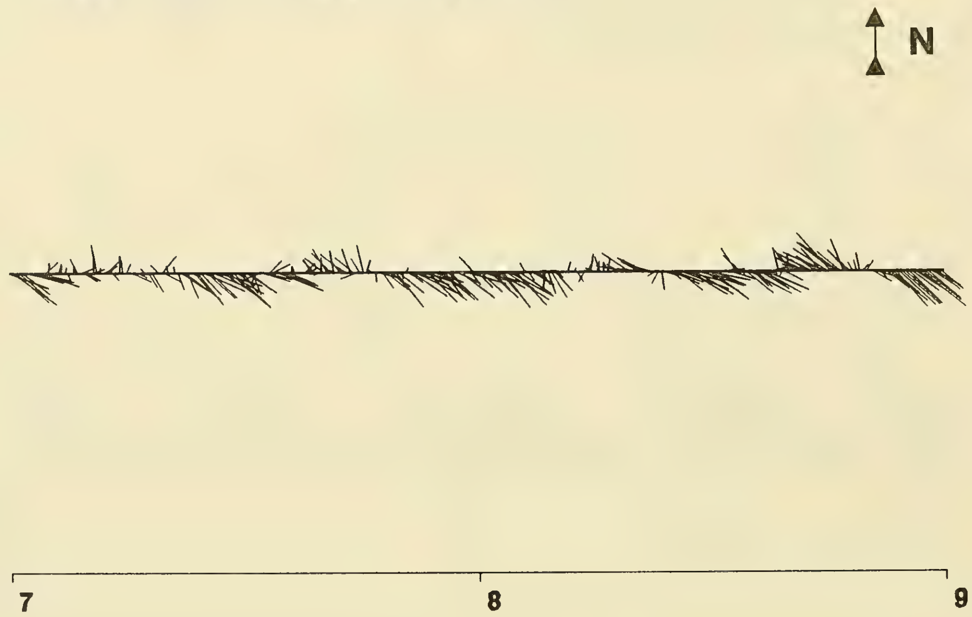

CURRENT VELOCITY AND DIRECTION
N
7
8
9
SCALE: 1.0 FPS
VECTOR POINTS IN DIRECTION OF TRAVEL
LA/LB TIDAL CIRCULATION STUDY
CM3S: 7 - 8 AUG 1987
10 MINUTE AVERAGE VECTORS

PLATE 28

CURRENT VELOCITY AND DIRECTION



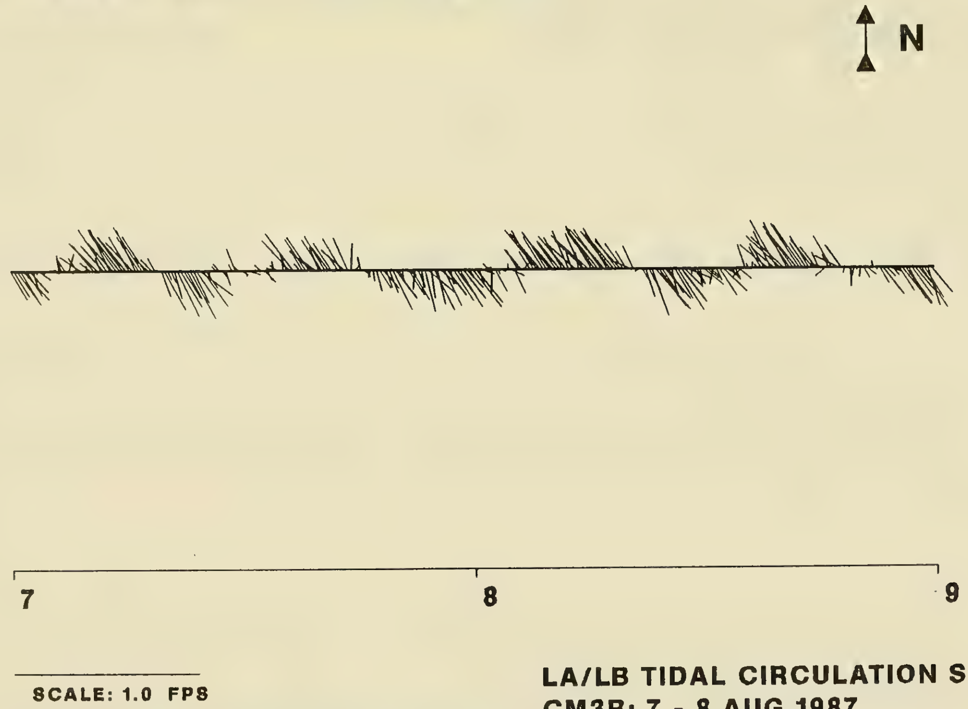
SCALE: 1.0 FPS

VECTOR POINTS IN DIRECTION OF TRAVEL

LA/LB TIDAL CIRCULATION STUDY
CM3M: 7 - 8 AUG 1987
10 MINUTE AVERAGE VECTORS

PLATE 29

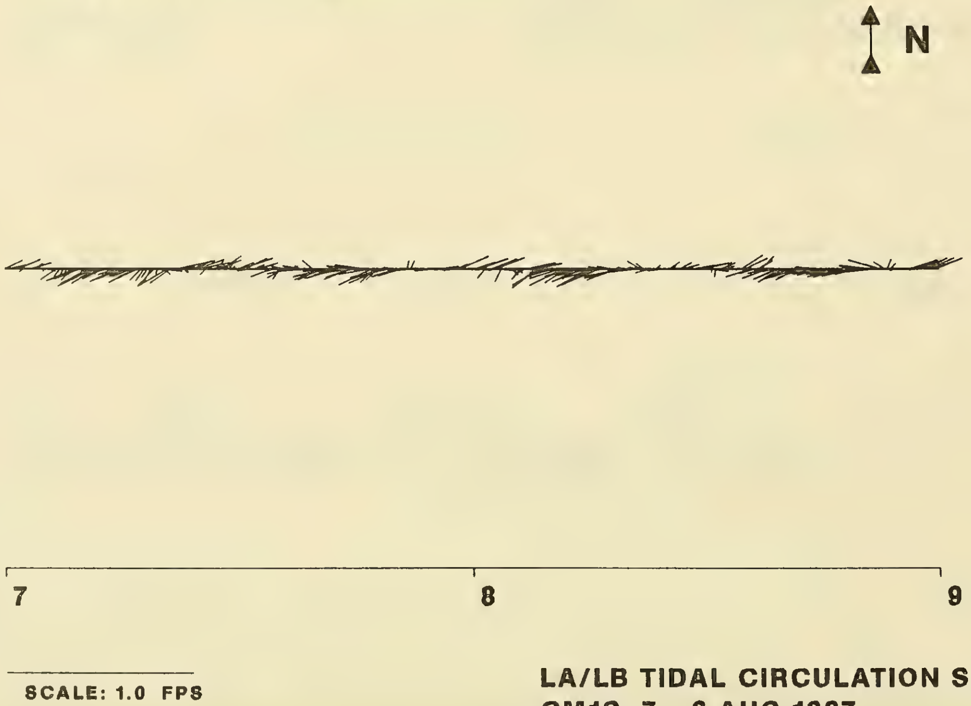
CURRENT VELOCITY AND DIRECTION



VECTOR POINTS IN DIRECTION OF TRAVEL

LA/LB TIDAL CIRCULATION STUDY
CM3B: 7 - 8 AUG 1987
10 MINUTE AVERAGE VECTORS

CURRENT VELOCITY AND DIRECTION

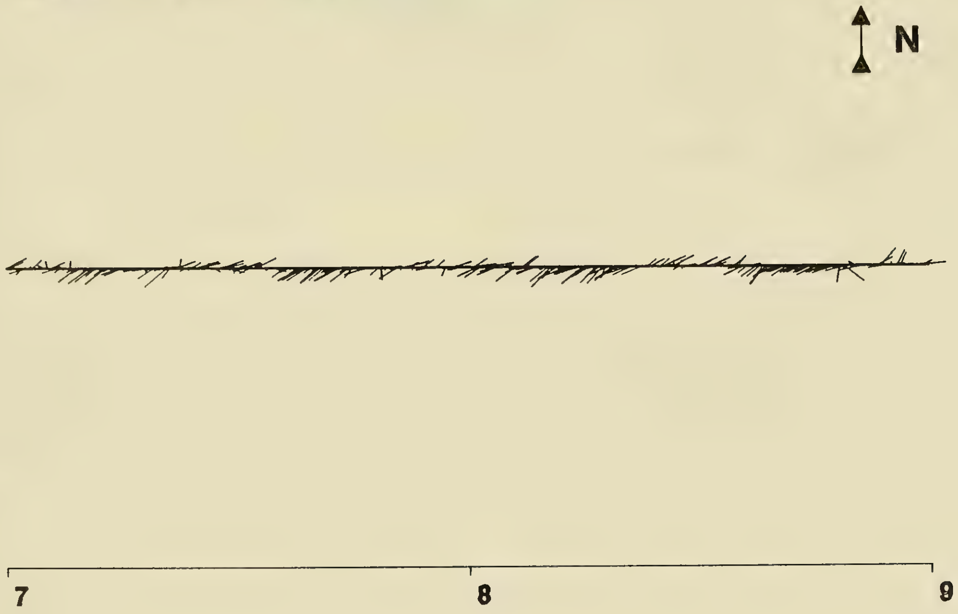


VECTOR POINTS IN DIRECTION OF TRAVEL

LA/LB TIDAL CIRCULATION STUDY
CM1S: 7 - 8 AUG 1987
10 MINUTE AVERAGE VECTORS

PLATE 31

CURRENT VELOCITY AND DIRECTION



SCALE: 1.0 FPS

VECTOR POINTS IN DIRECTION OF TRAVEL

LA/LB TIDAL CIRCULATION STUDY
CM1B: 7 - 8 AUG 1987
10 MINUTE AVERAGE VECTORS

PLATE 32

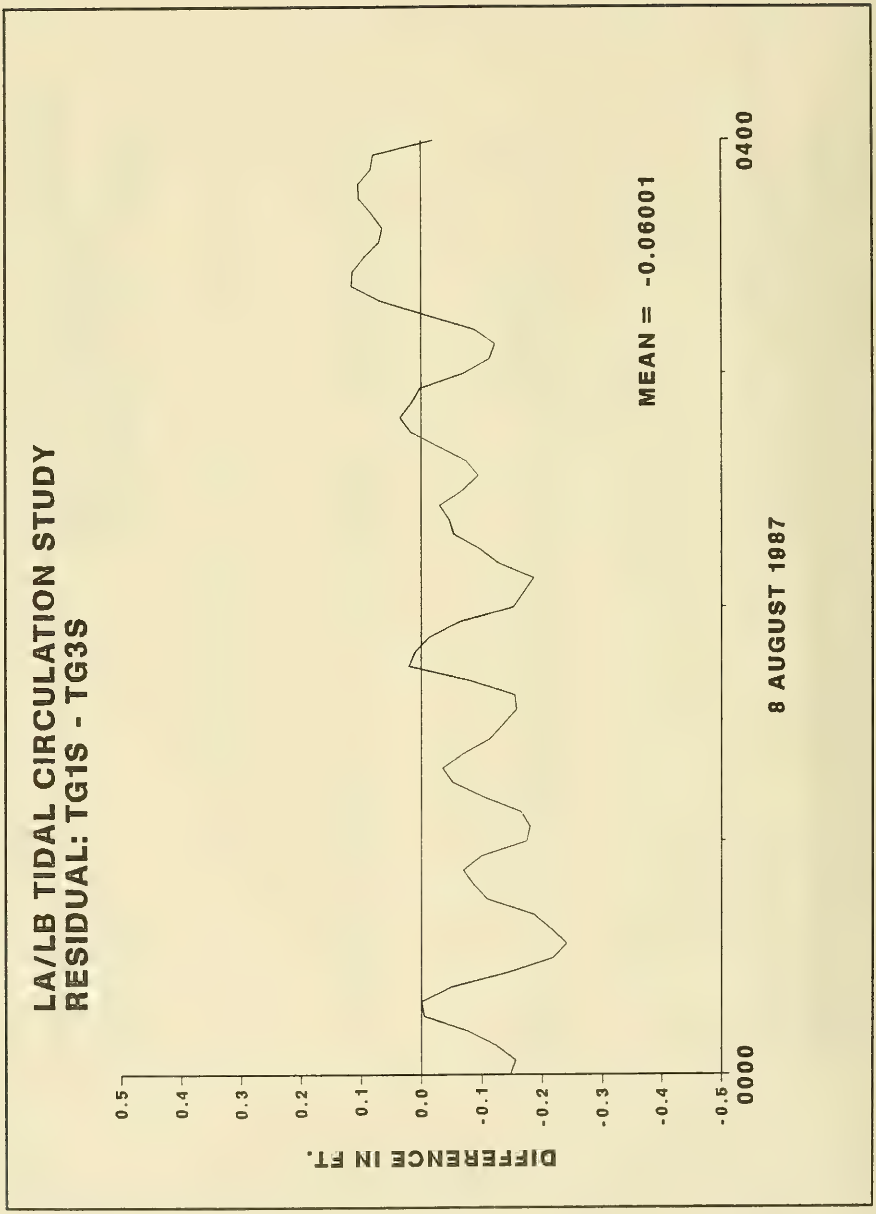

LA/LB TIDAL CIRCULATION STUDY
RESIDUAL: TG1S - TG3S

PLATE 33

LA/LB TIDAL CIRCULATION STUDY
RESIDUAL: TG6S - TG3S

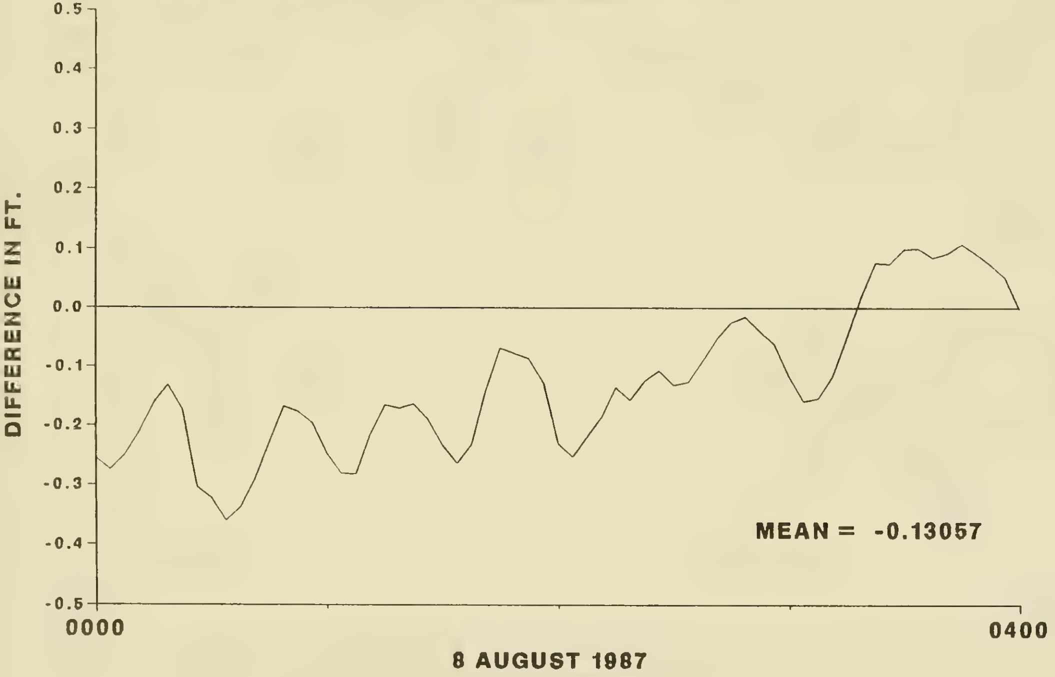
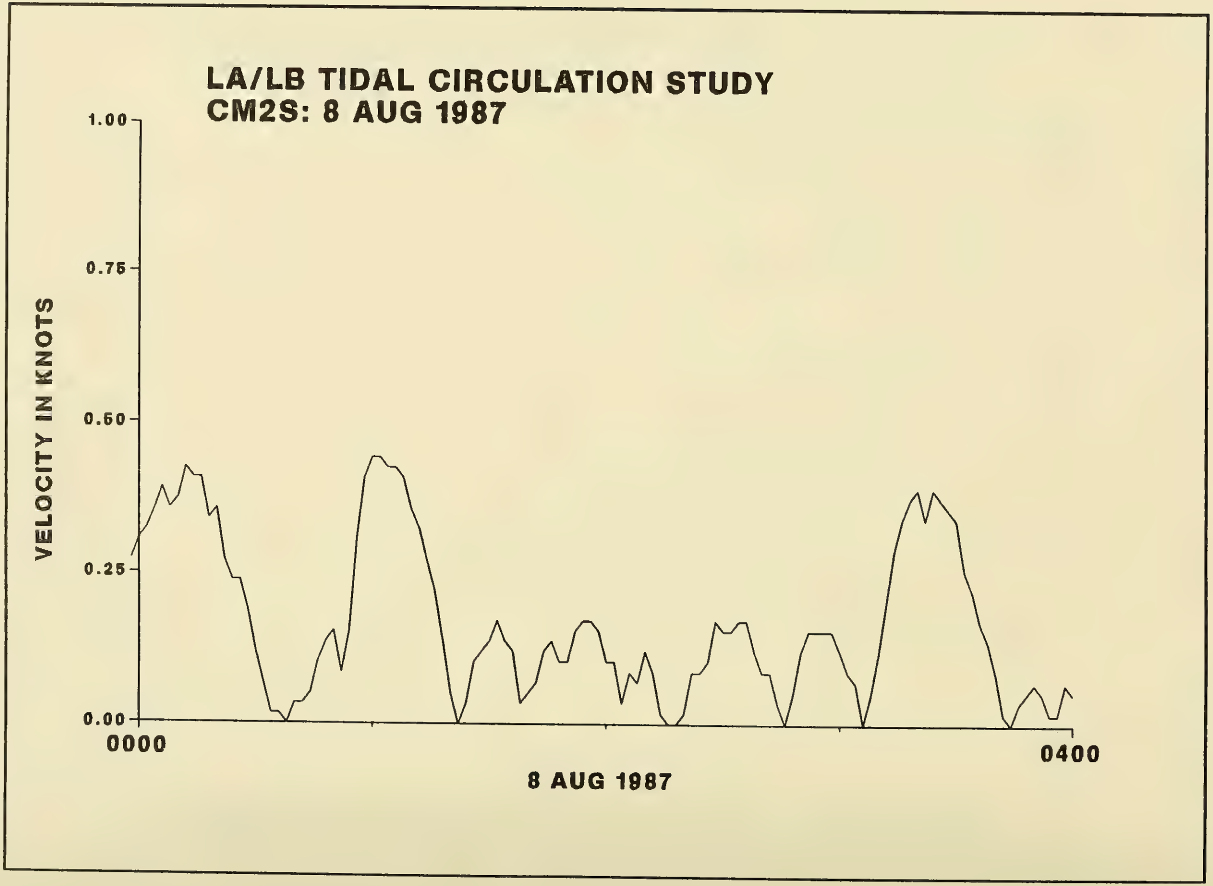
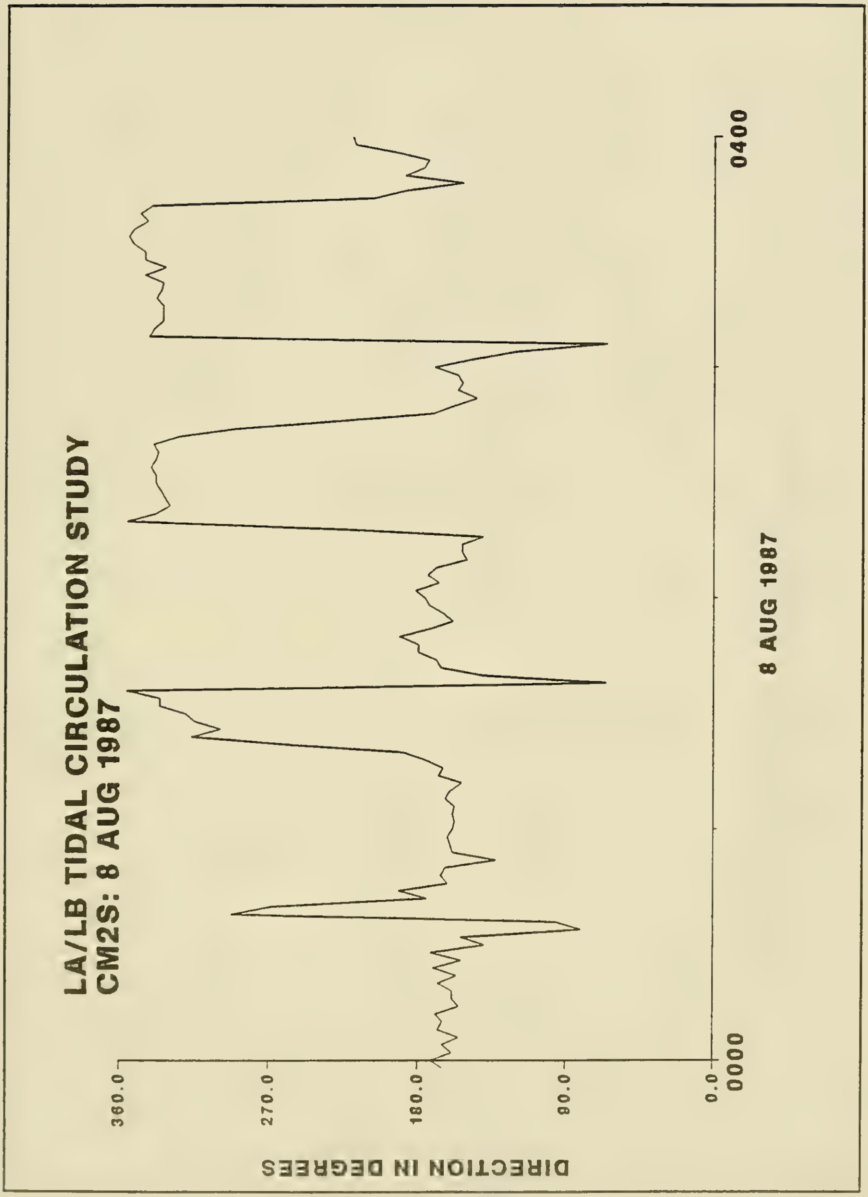


PLATE 34



LA/LB TIDAL CIRCULATION STUDY
CM2S: 8 AUG 1987

PLATE 35


LA/LB TIDAL CIRCULATION STUDY
CM2S: 8 AUG 1987
DIRECTION IN DEGREES
360.0
270.0
180.0
90.0
0.0
0000
8 AUG 1987
0400

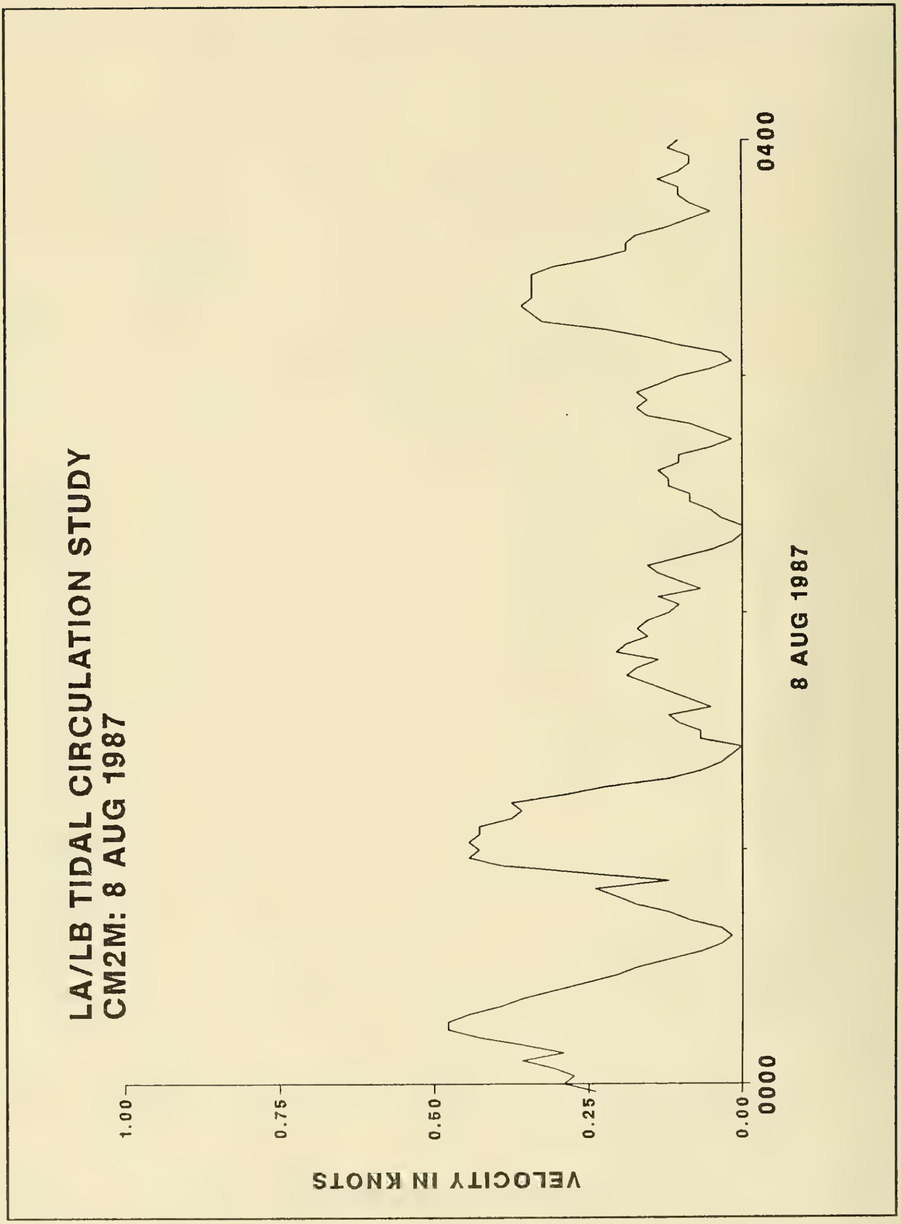

LA/LB TIDAL CIRCULATION STUDY
CM2M: 8 AUG 1987
VELOCITY IN KNOTS
1.00
0.75
0.50
0.25
0.00
0000
0400
8 AUG 1987

PLATE 37

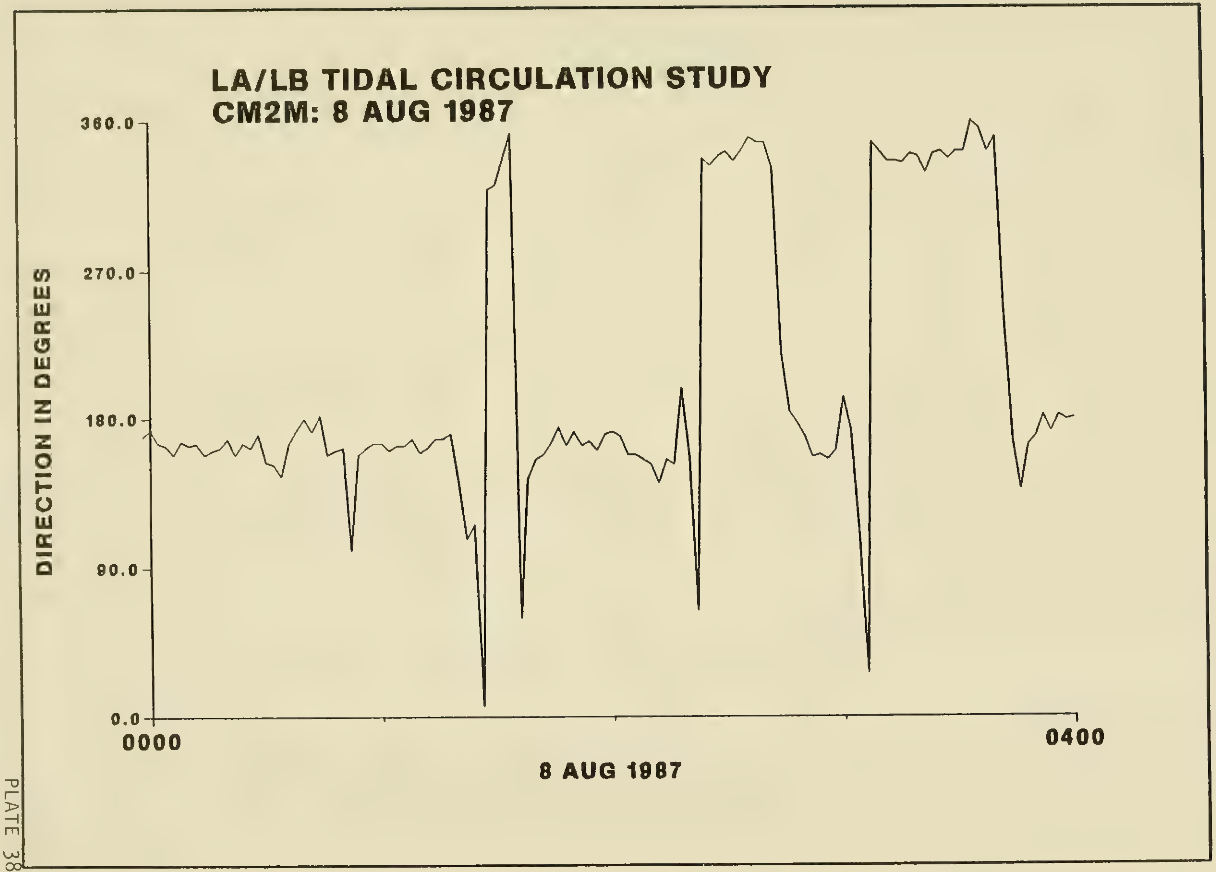
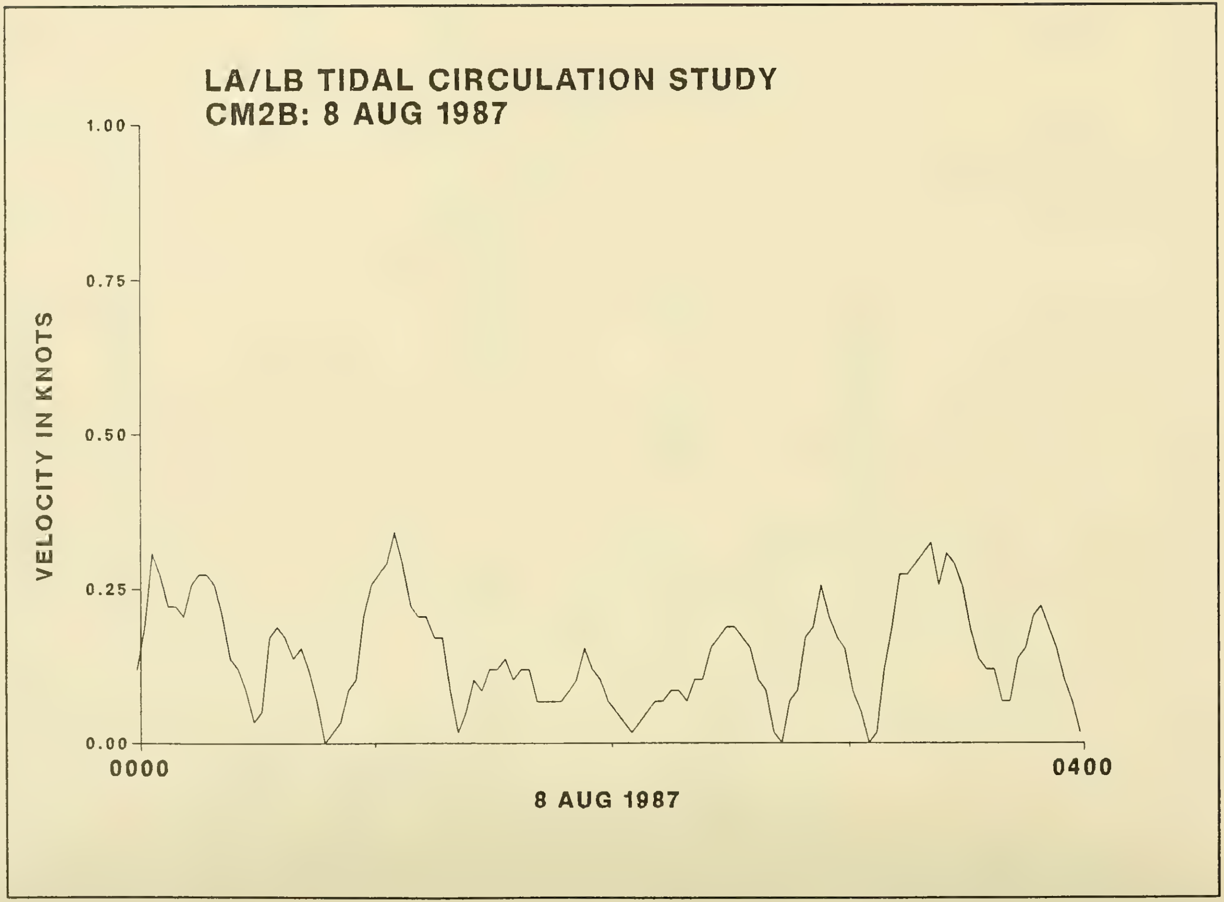

LA/LB TIDAL CIRCULATION STUDY
CM2M: 8 AUG 1987
DIRECTION IN DEGREES
360.0
270.0
180.0
90.0
0.0
0000
0400
8 AUG 1987

PLATE 38

PLATE 39



LA/LB TIDAL CIRCULATION STUDY
CM2B: 8 AUG 1987

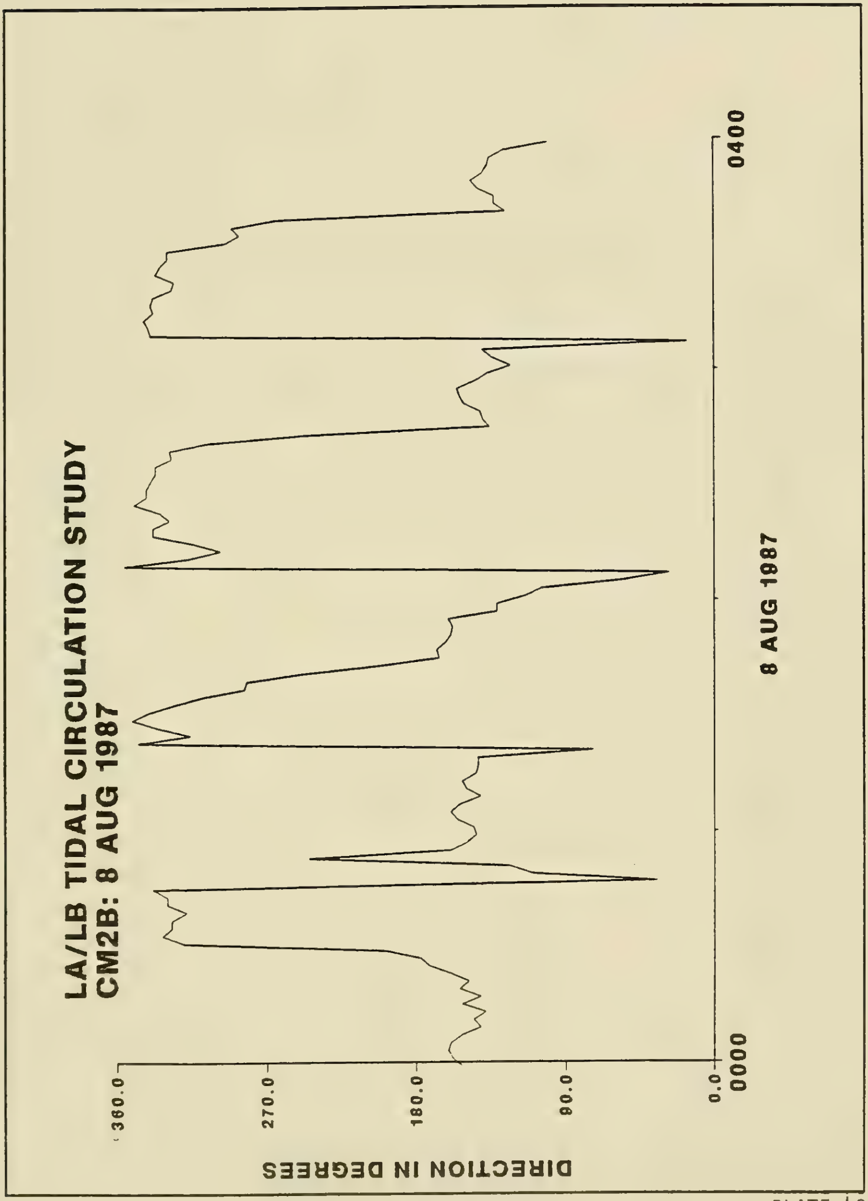
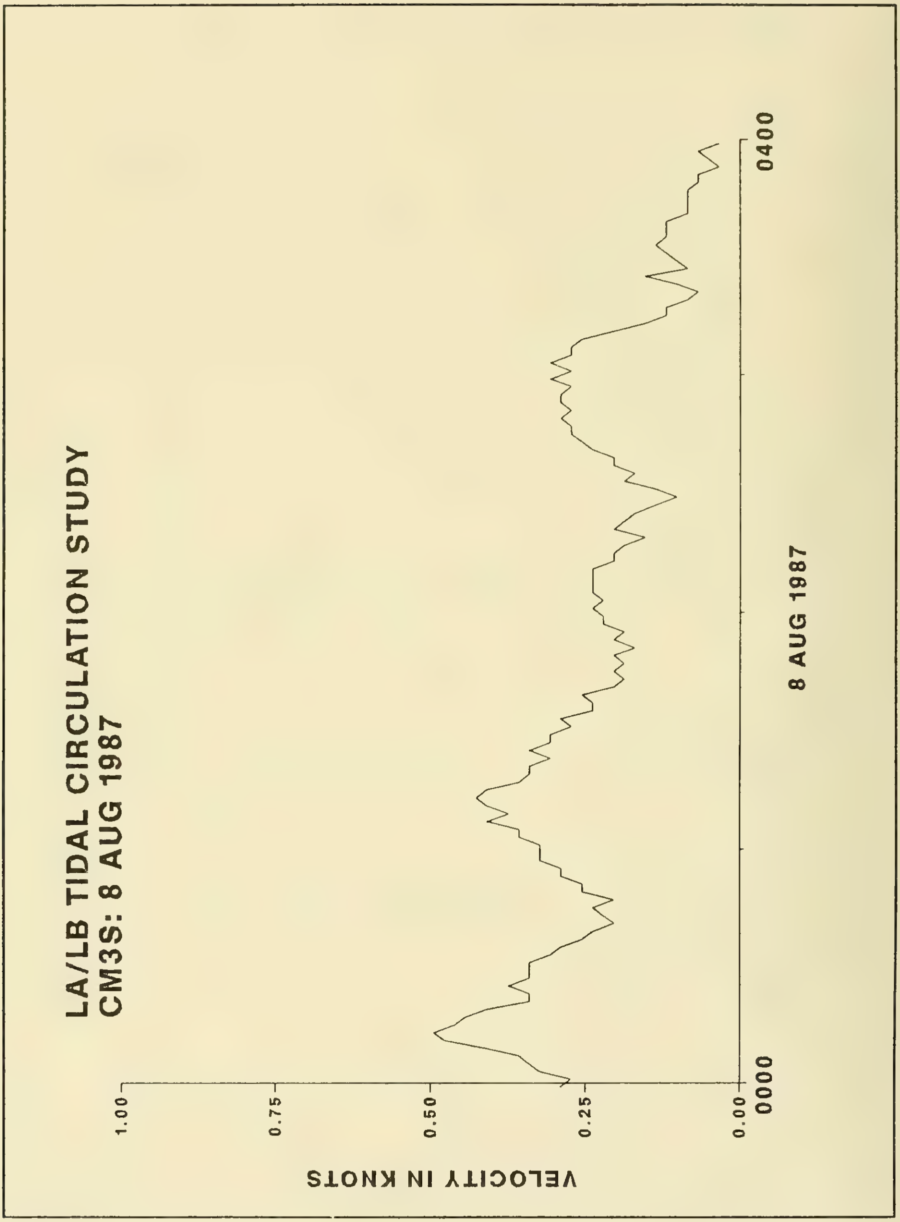

LA/LB TIDAL CIRCULATION STUDY
CM2B: 8 AUG 1987
DIRECTION IN DEGREES
360.0
270.0
180.0
90.0
0.0
0000
0400
8 AUG 1987

PLATE 40



LA/LB TIDAL CIRCULATION STUDY
CM3S: 8 AUG 1987

PLATE 41

LA/LB TIDAL CIRCULATION STUDY
CM3S: 8 AUG 1987

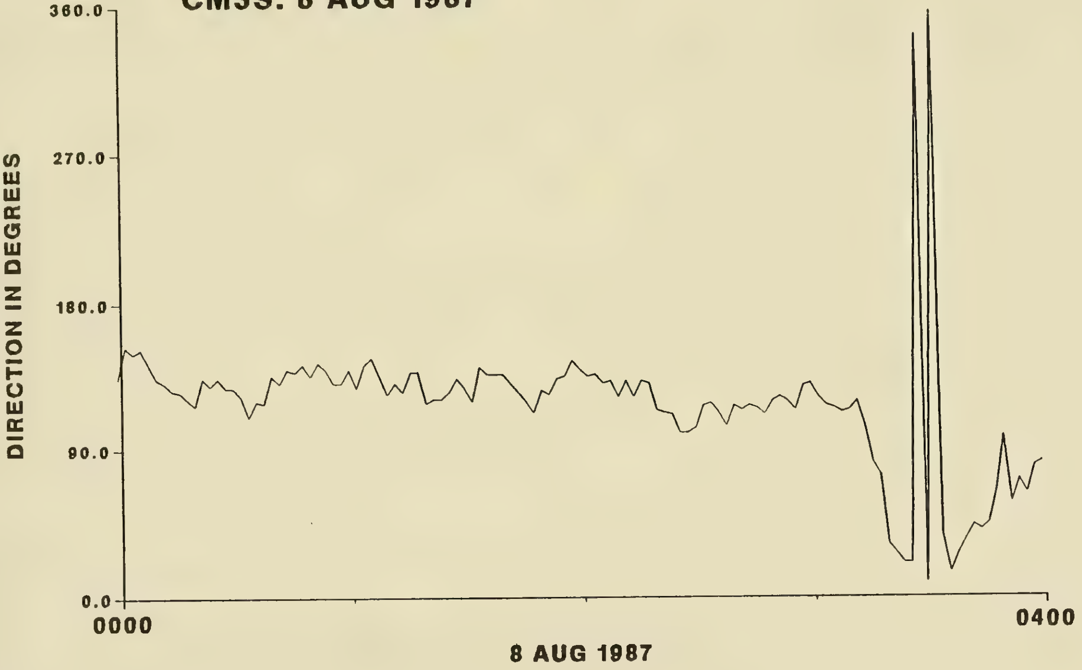
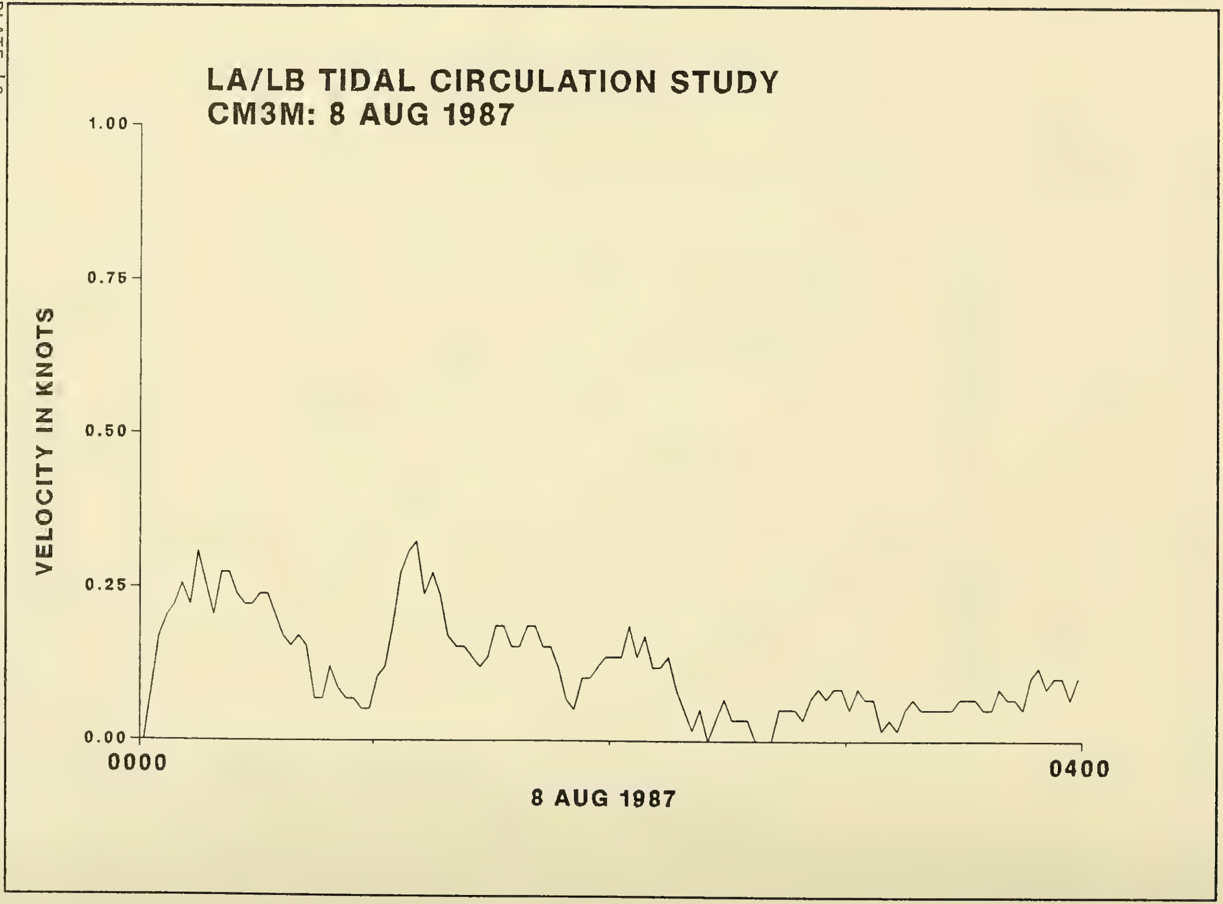


PLATE 42

PLATE 43



LA/LB TIDAL CIRCULATION STUDY
CM3M: 8 AUG 1987

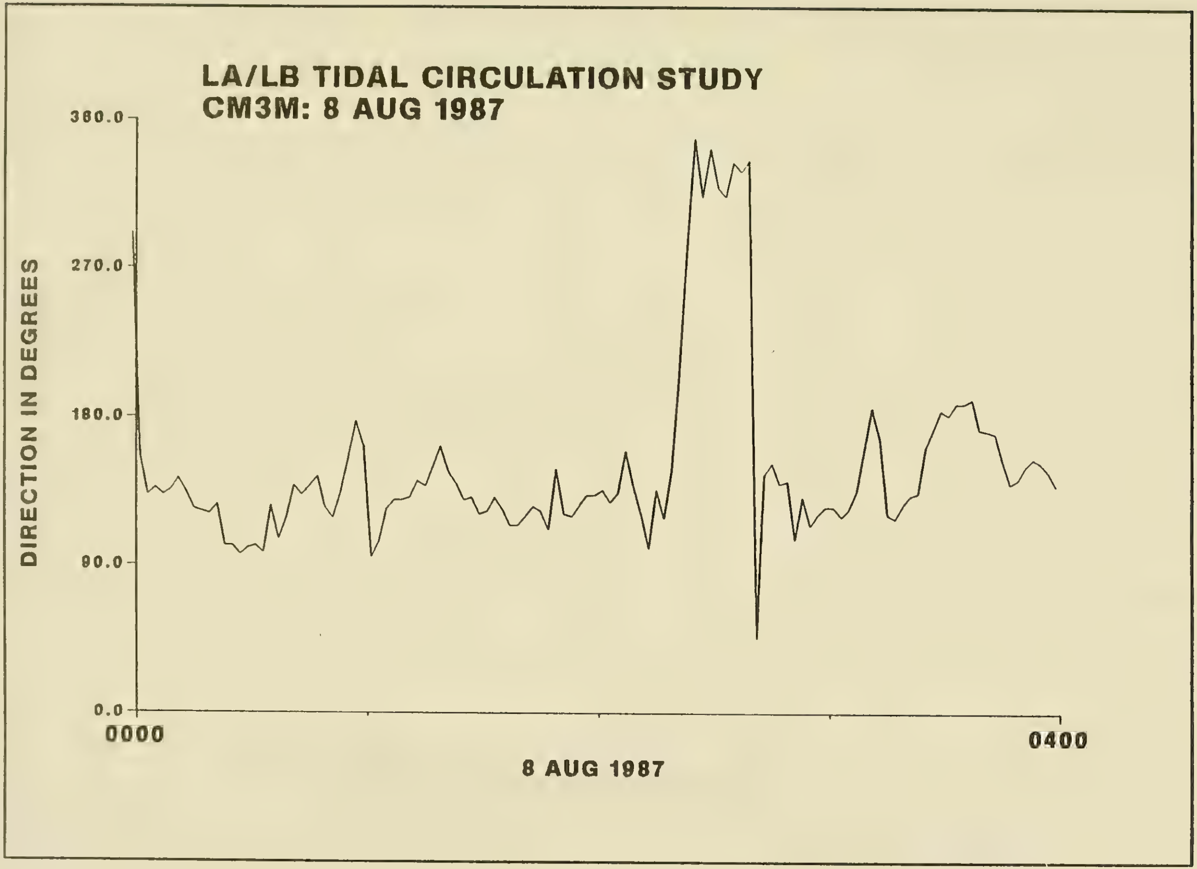

LA/LB TIDAL CIRCULATION STUDY
CM3M: 8 AUG 1987
DIRECTION IN DEGREES
360.0
270.0
180.0
90.0
0.0
0000
0400
8 AUG 1987

PLATE 44

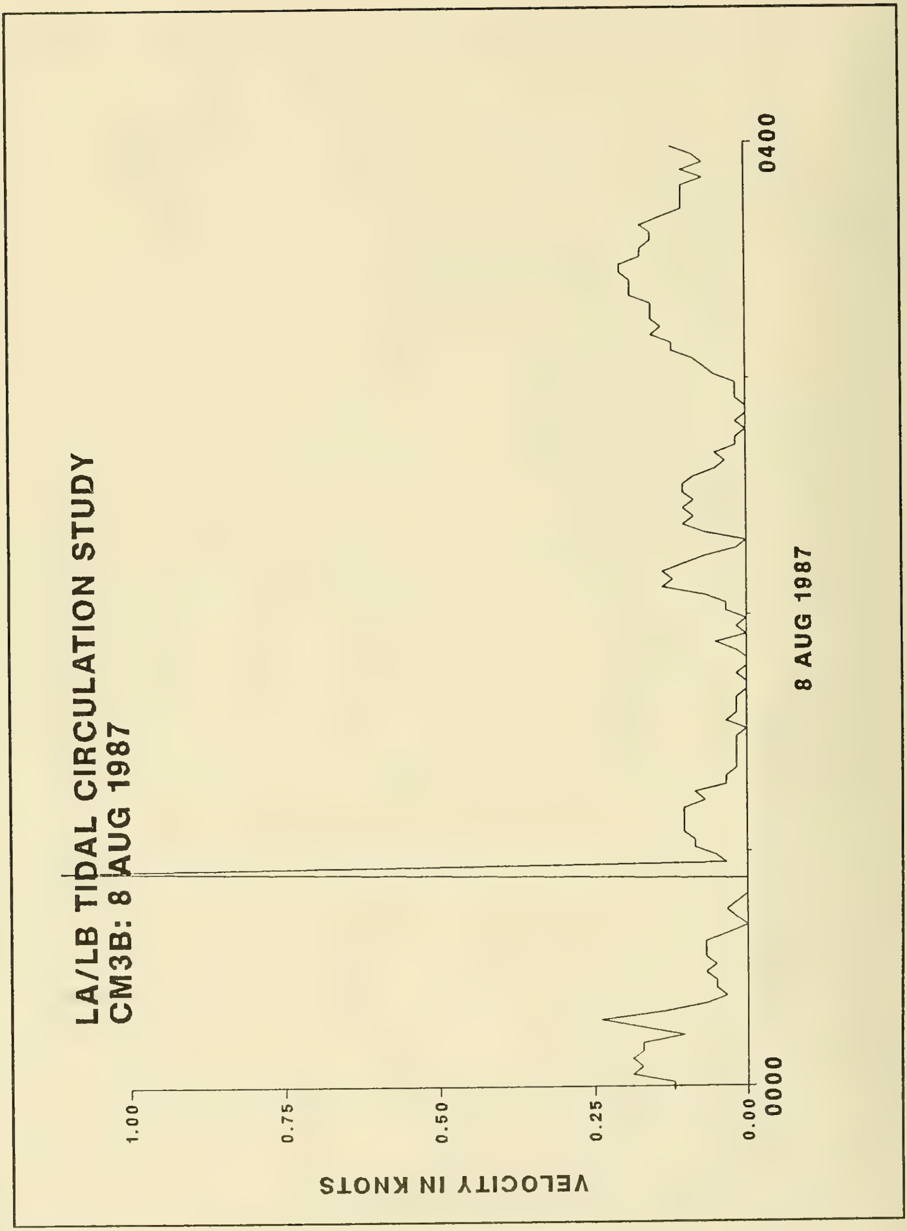

LA/LB TIDAL CIRCULATION STUDY
CM3B: 8 AUG 1987
VELOCITY IN KNOTS
1.00
0.75
0.50
0.25
0.00
0000
0400
8 AUG 1987

PLATE 45

LA/LB TIDAL CIRCULATION STUDY
CM3B: 8 AUG 1987

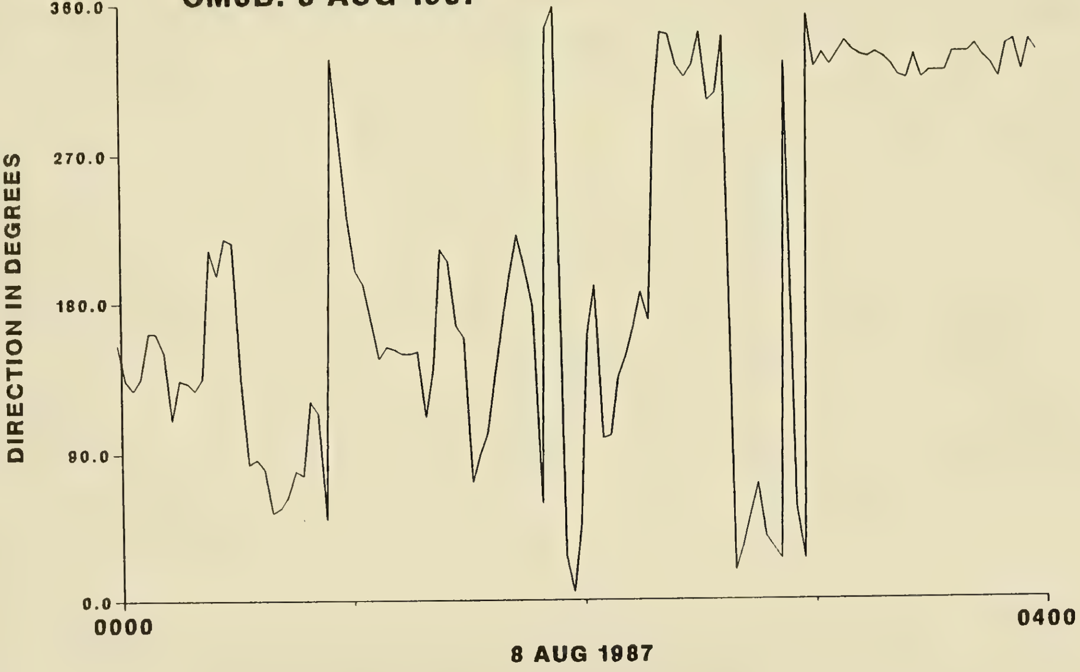
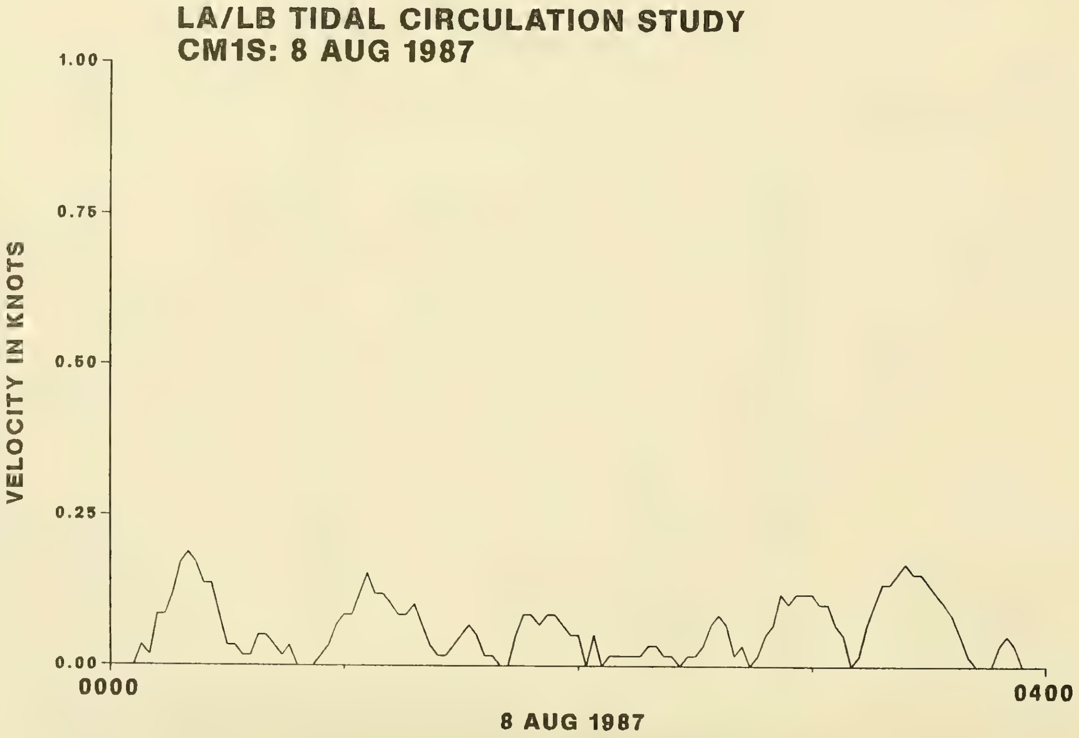


PLATE 46

PLATE 47


LA/LB TIDAL CIRCULATION STUDY
CM1S: 8 AUG 1987
VELOCITY IN KNOTS
1.00
0.75
0.50
0.25
0.00
0000
0400
8 AUG 1987

LA/LB TIDAL CIRCULATION STUDY
CM1S: 8 AUG 1987

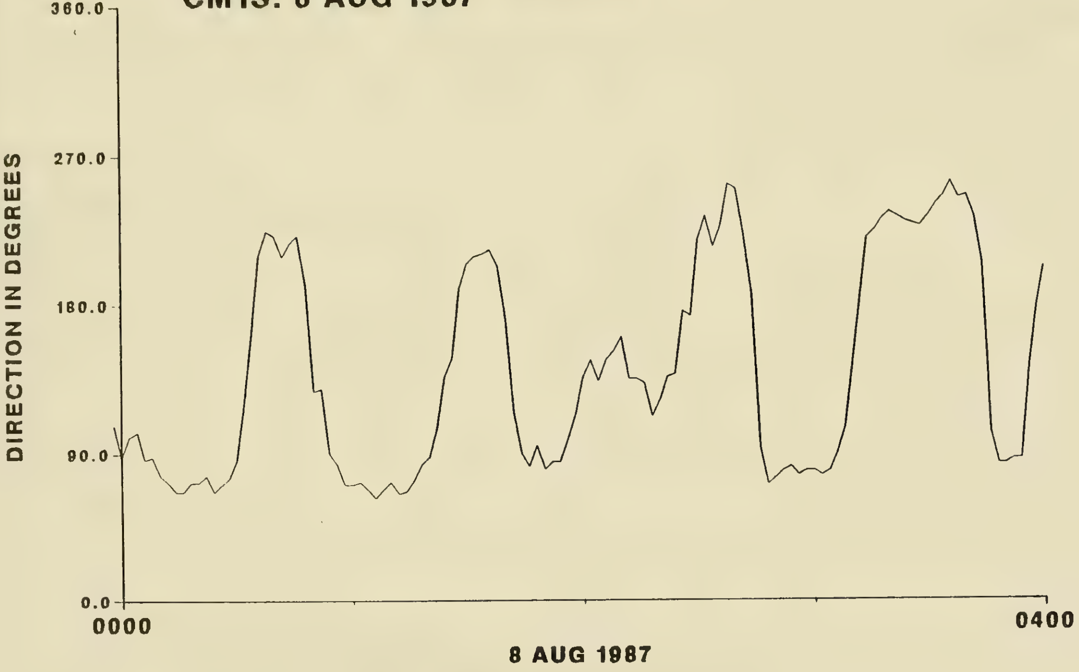


PLATE 48

PLATE 49

LA/LB TIDAL CIRCULATION STUDY
CM1B: 8 AUG 1987

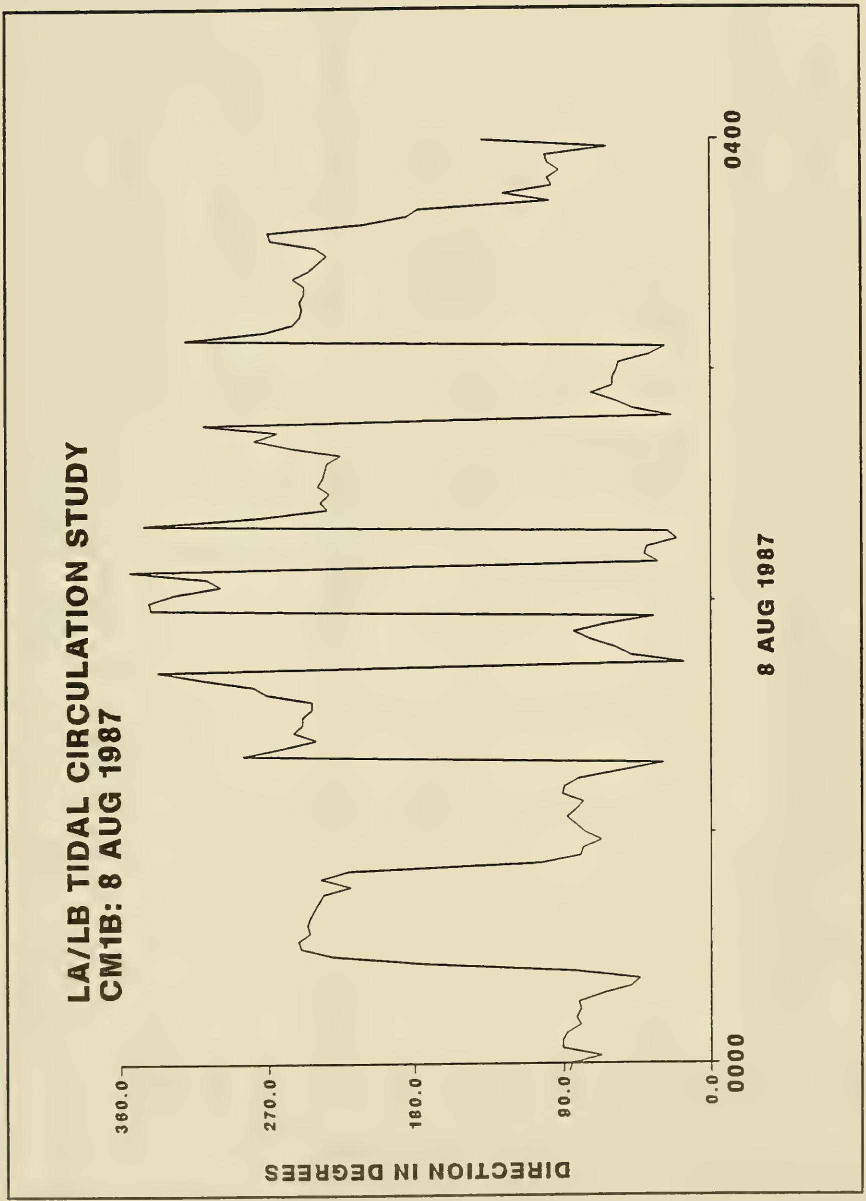
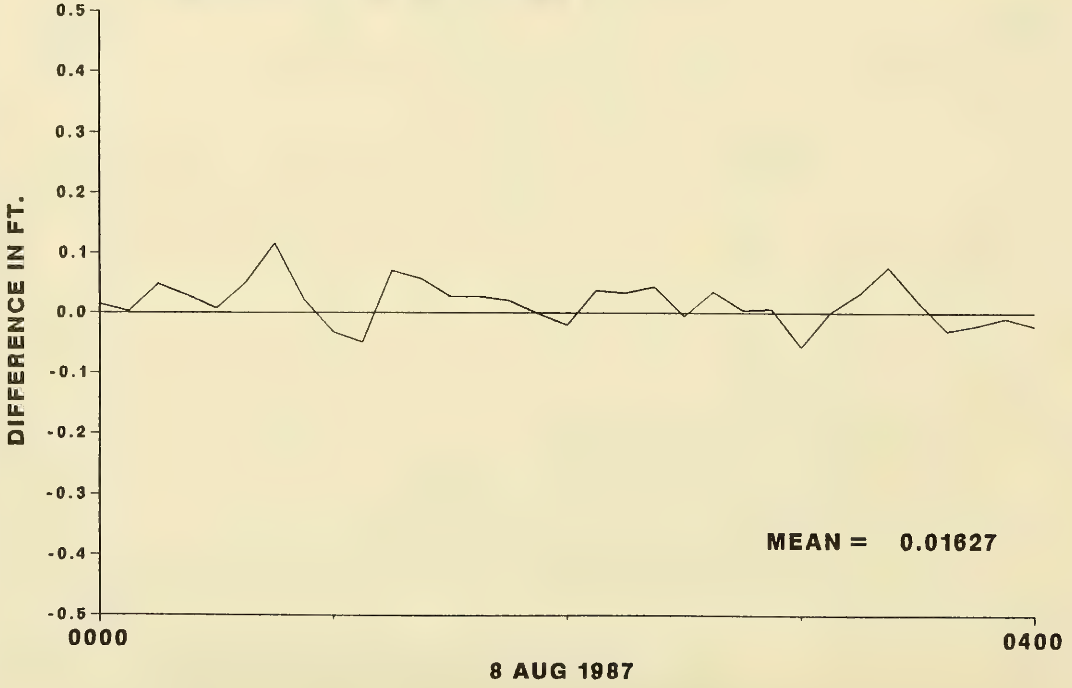

LA/LB TIDAL CIRCULATION STUDY
CM1B: 8 AUG 1987
DIRECTION IN DEGREES
360.0
270.0
180.0
90.0
0.0
0000
0400
8 AUG 1987

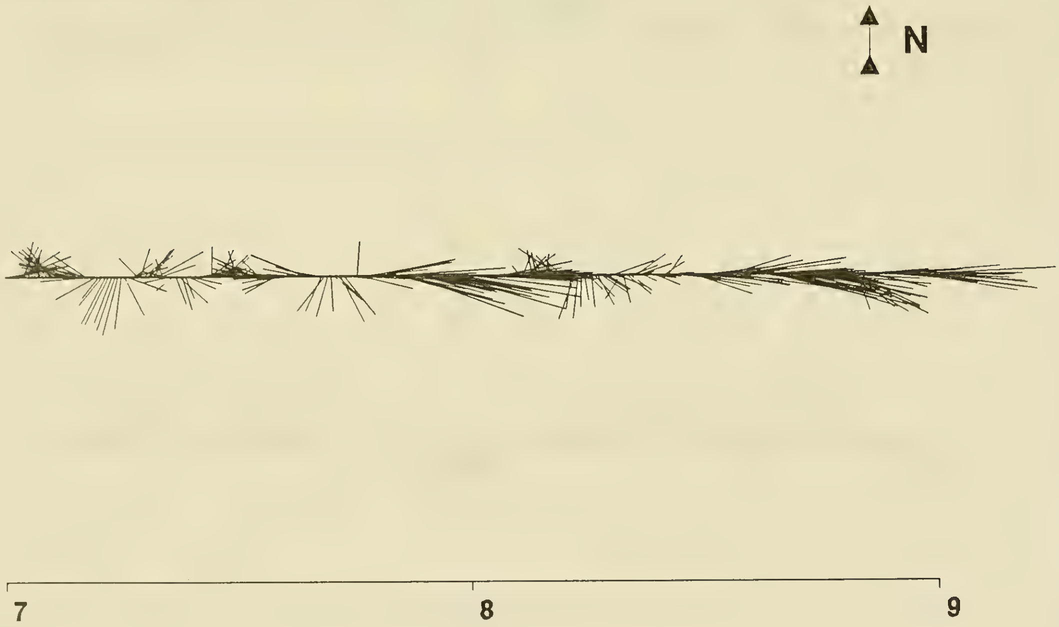
PLATE 50

PLATE 51

LA/LB HARBOR STUDY
RESIDUAL: LA4A - LB4A



CURRENT VELOCITY AND DIRECTION



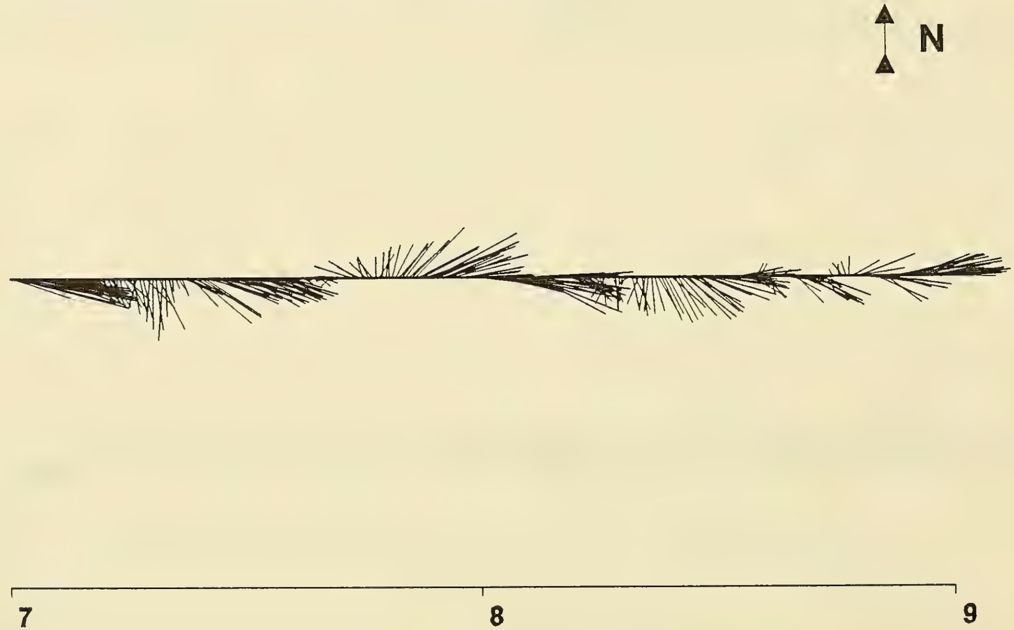
SCALE: 1.0 FPS

VECTOR POINTS IN DIRECTION OF TRAVEL

LA/LB TIDAL CIRCULATION STUDY
CM6S: 7 - 8 AUG 1987
10 MINUTE AVERAGE VECTORS

PLATE 53

CURRENT VELOCITY AND DIRECTION



SCALE: 1.0 FPS

VECTOR POINTS IN DIRECTION OF TRAVEL

LA/LB TIDAL CIRCULATION STUDY
CM7S: 7 - 8 AUG 1987
10 MINUTE AVERAGE VECTORS

LA/LB TIDAL CIRCULATION STUDY
LA WINDS : 7 - 8 AUG 1987

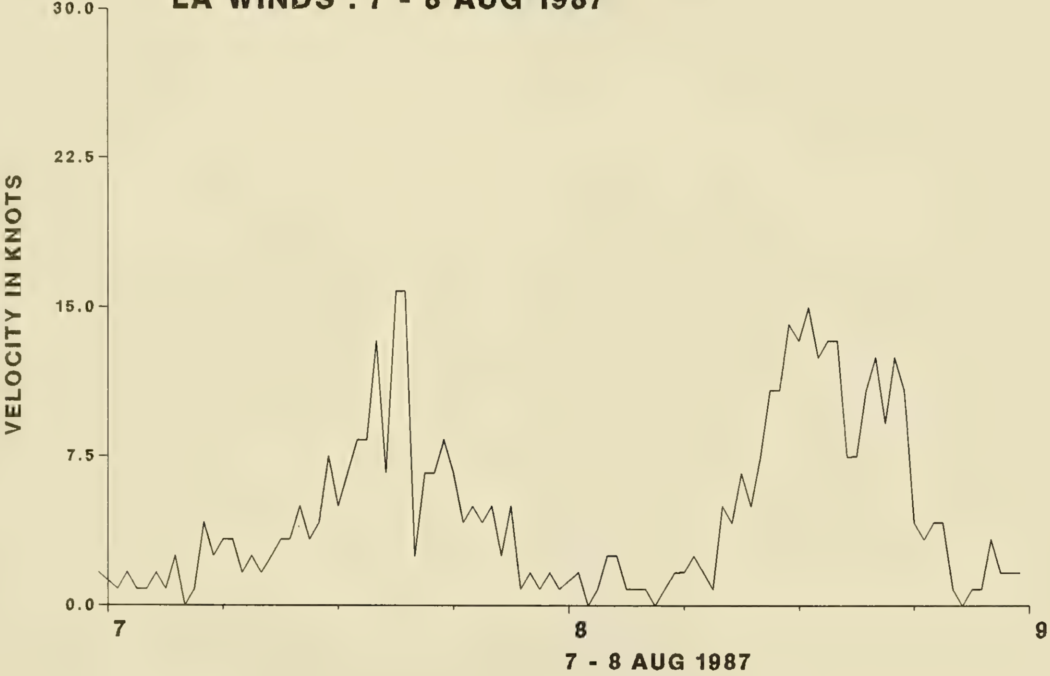
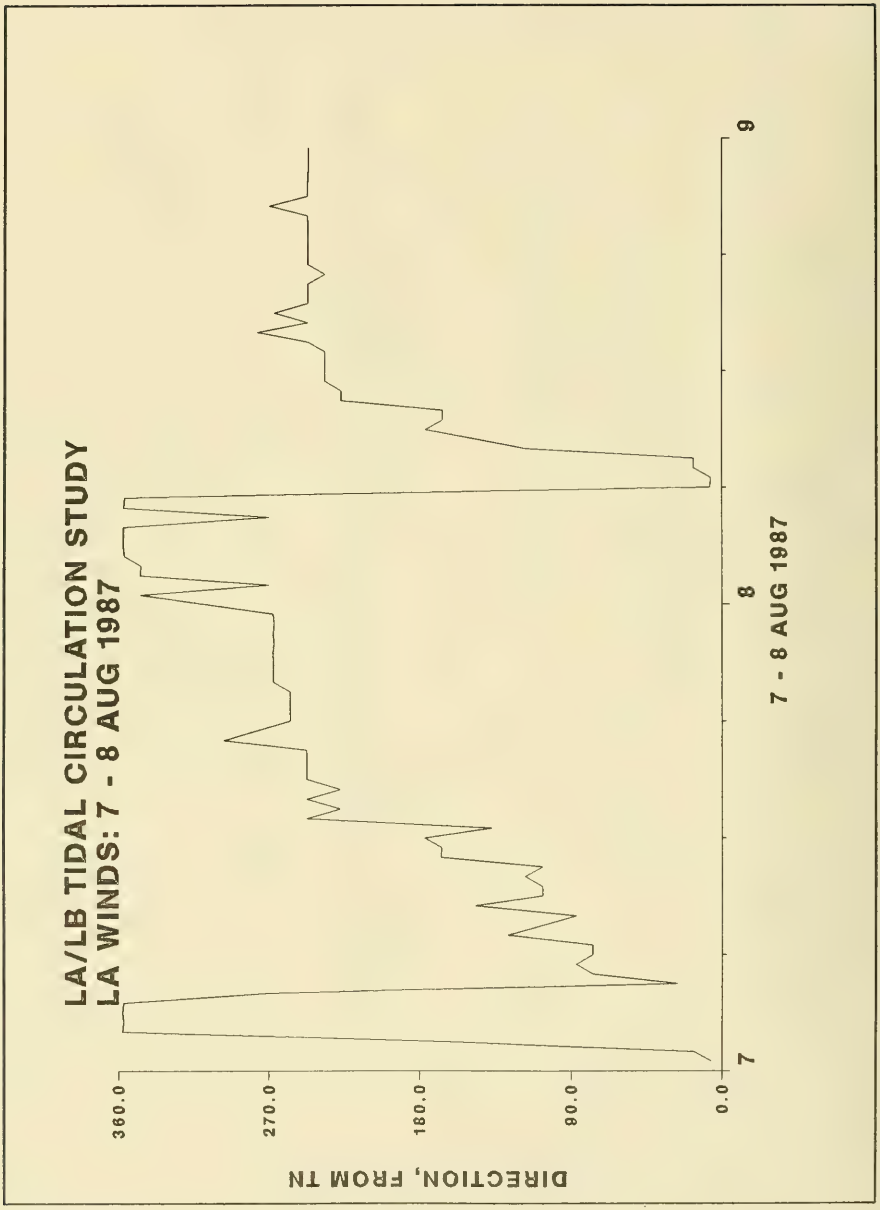


PLATE 54A



LA/LB TIDAL CIRCULATION STUDY
LA WINDS: 7 - 8 AUG 1987

PLATE 54B

APPENDIX A: INSTRUMENT DESCRIPTIONS AND SPECIFICATIONS

This appendix provides brief descriptions and detailed specifications of the instruments used during this experiment.

1. Three types of instrumentation were used: during the tidal data, in situ current velocity, and current velocity profile phases of the experiment. This appendix provides a brief description of the instruments, followed by detailed specifications provided by the manufacturer.

2. Tidal data were collected using Sea Data, Inc., Model 635-11 Wave and Tide Recorders. The 635-11 is a self-contained digital-recording instrument, capable of accurately measuring and recording water pressure. Accuracy of the instrument is attained by use of the Paroscientific, Inc., quartz crystal oscillating pressure transducer, which exhibits a 0.005-percent maximum worst-case hysteresis error, over a full range pressure excursion. The instrument electronics employs all C-MOS circuitry to minimize power drain. An ultra-accurate quartz clock allows precise measurement of the sensor's frequency. Data are recorded on a highly precise digital tape recorder, which writes on four tracks at an 800 bits-per-inch density, allowing 15-megabit data capacity on a 450-min cassette tape.

3. The Datasonics, Inc., "AQUARANGE: Acoustic Command System is a multipurpose ranging, position, and relocation system. Applications of the system include long baseline acoustic navigation, ranging and subsea instrumentation. It may be deployed as a recoverable position marker or data telemetry transponder or as a pop-up buoy marker. Operating in the 30-kHz band, a selection of 5 reply frequencies and 27 unique command codes may be set by internal switches. Transmit, receive, and release functions are powered by separate batteries to reduce the possibility of a total system failure and assure recovery. Power is applied to the transponding release, upon either fresh or saltwater immersion, by external electrodes. The transponder housing pressure rated to a depth of 1,000 m, and the release mechanixm has a load capability of 2,000 lb.

4. In situ current velocity data were collected using an ENDECO, Inc., Type 174 Digital Recording Tethered Current Meter. The 174 is an axial flow, ducted impeller current meter, which is self-contained and records sampled data on a 1/4-in. magnetic tape. The instrument samples and records current velocity and direction, as well as water temperature and conductivity, at preselected intervals. It is normally deployed attached to a vertically buoyed 3/16- to 1/4-in. stainless steel wire rope, held taut by a subsurface buoy. The instrument is attached to the wire rope by a braided line terminated by a unique clampling device, known as a "Cook Cable Clamp

Assembly." The tether assembly allows the instrument to freely rotate around the mooring, with changes in current direction.

5. Current velocity profile data were collected using an ENDECO, Inc., Type 174 Solid State Memory (SSM) Tethered Current Meter. The 174SSM is similar in design to the 174, but incorporates a solid state data logger for instrument and data storage. It may be used as a self-contained current meter or as a profiling current meter, with real-time data telemetered via a 3-conductor cable to a surface-operated terminal. The cable assembly is sleeved with a Dacron rope braid, enabling it to be used as a suspension tether as well as a signal cable. Sampling parameters may be set by an external terminal, or the instrument may be initialized by simply applying power, using default settings.

Sea Data, Inc. Mdl. 635-11 Wave and Tide Recorder

Pressure Sensor: Paroscientific, Inc., "Digi-Quartz"

100 psia*

	feet	meters
Standard Ranges:	190	58
Maximum Depth:	235	70
Resolution - Waves:	0.0035	0.10 cm
Tides:	0.0040	0.12 cm
Accuracy		
(more than 80 ft)	0.03	
(less than 80 ft)	0.05	
vs temp @ 30 ft	0.004 ft/°C (max)	

Frequency Response: DC to 1.0 Hz (Nyquist limit for 0.5-sec sampling)

Stability:
vs time: 0.0002 percent FS/month at (almost constant) ocean depths
vs temp: zero 0.0007 percent FS/°C
span 0.005 percent FS/°C (at 2/3 FS, 0.004 percent/°C)

Timebase: 4.194304 MHz special quartz crystal
Stability: 0.1 ppm/°C, 1 ppm/year; unmeasurable (0.001 percent) pressure data error at ocean depths

Physical Specifications:

Size:
Case: 7-in. diam. by 24 in. long
Mounts: two 0.5-in. bolt holes on 13-in. centers, 1.0-in. clearance

Weight: 41 lb in air, with battery; 12.5 lb in water

Pressure Case:
Material: 6061-T6 aluminum
Hardware: 316 stainless and Delrin insulators
Finish: Hard-coat anodize with electrostatic epoxy overcoat
Depth: 1,100-m operating depth

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* psia = pounds per square inch, absolute.

ENDECO, Inc., Type 110/923 Remote Reading and Recording Current Meter

Current Speed Sensor: Ducted impeller and reed switch

Range:	0 to 5 knots (0 to 257 cm/sec)
Accuracy:	±3 percent of full scale
Threshold:	>0.05 knot (2.57 cm/sec)

Current Direction Sensor: Magnetic compass with potentiometer

Range:	0 to 360° (0 to 357° electrical)
Accuracy:	±3 percent of full scale
Threshold:	0.05 knot (2.57 cm/sec)

Depth Sensor: Pressure-operated potentiometer

Range:	0 to 30 m (0 to 100 ft)
Accuracy:	±2 percent of full scale
Overpressure:	1.5 × full scale
Sensor Isolation:	Oil-filled isolator with neoprene diaphragm for corrosion protection of sensor

Physical Size:

Weight:	18 kg (40 lb) in air
Weight in sea water:	Approximately neutrally buoyant
Dimensions:	76.2 cm long by 40.6 cm diam (30 in 16 in.)

ENDECO, Inc., Type 174 Digital Recording Tethered Current Meter

Current Velocity:

Sensor Type: Ducted impeller
Sensitivity: 58.0 rpm knot (51.4 cm/sec)
Speed Range: Dependent on sampling interval (user selectable-

2,3,4,5,6,10 min); 0 to 221.2 cm/sec (0 to 4.3 knots) at standard 2-min interval

Impeller Threshold: <2.57 cm/sec (0.05 knot)
Resolution: 0.4 percent of speed range
Speed Accuracy: ±3.0 percent of full scale

Current Direction:

Magnetic Direction: 0 to 360°
Resolution: 1.4°
Accuracy: ±7.2° above 2.57 cm/sec (0.05 knot) when referenced to computer calibration

Phsical Size:

Weight: 14 kg (31 lb) in air
Buoyancy: Approximately neutral; adjustable for salt, fresh, or polluted water
Dimensions: 85.1 cm (33.5 in.) long by 40.6 cm (16 in.) diam
Shipping Weight: 25.7 kg (57 lb)

ENDECO, In., Type 174 (S.S.M.) Solid State Memory Tethered Current Meter

Current Velocity:

Sensor Type:	Ducted impeller
Sensitivity:	111.9 rpm/m/sec (57.58 rmp/knot)
Speed Range:	0 to 2.57 m/sec (0 to 5 knots), programmable to 10 knots
Impeller:	Threshold 1.54 cm/sec (0.03 knots)
Accuracy:	1.6 percent of full scale (99-percent confidence limit)
Resolution:	0.1 percent of speed range

Current Direction:

Sensor Type:	Gimballed, two-axis, flux gate compass
Magnetic Direction:	0 to 360°
Gimballed Range:	±30° (two axis)
Accuracy:	±5.0° above speed threshold
Resolution:	1.4°
Internal Heading Correction:	32 point EPROM stored correction curve
Vector Averaging:	Fixed displacement, sine/cosine summation

Pressure Sensor:

Sensor Type:	Potentiometric transducer
Range:	0 to 152 m (500 ft)
Accuracy:	±1 percent
Resolution:	0.39 percent
Optional Resolution:	Up to 12 bits binary (0.02 percent)

Physical Size:

Weight:	14 kg (31 lb) in air
Buoyancy:	Neutrally buoyant, adjustable for fluid medium
Dimensions:	88.9 cm (35.0 in.) long by 40.6 cm (16 in.) in diameter
Shipping Weight:	25.7 kg (57 lb)

Datasonics, Inc., AQUARANGE/Acoustic Command System

Range Interrogate:

Frequency: 26 kHz
Reply Frequencies: Internally selectable; 28, 29, 30, 31, or 32 kHz
Pulse Length: 5 msec
Turn Around Time: 20 msec
Stability: ±0.1 msec
Inhibit Time: 0.8 sec
Source Level: +188 db ref. 1 μPa @ 1 m
Operating Life: 12 months, 50,000 replies

APPENDIX B: CURRENT PROFILE DATA

This appendix contains locations of current profile stations and a tabular listing of the profile data. Station locations are suffixed with T, M, and B, which stand for top, mid-depth, and bottom respectively. When velocities were too low to allow direct readout in knots, a velocity was calculated using a formula relating the velocity to the number of pulses (P) or revolutions of the impeller, observed in a 30-sec interval.

STATION#	POSITION	
	N. LAT	W LONG
P1 A	33° 42.55'	118° 15.05
B	33° 42.6'	118° 14.8
C	33° 42.65'	118° 14.7
P2 A	33° 43.4'	118° 11.1
B	33° 43.4'	118° 11.0'
C	33° 43.4'	118° 10.9'
P3 A	33° 44.6	118° 07.4'
B	33° 44.3'	118° 07.6'
C	33° 44.0'	118° 07.8'
D	33° 43.8'	118° 07.9'
E	33° 43.5'	118° 08.1'
P4 A	33° 43.3	118° 16.2
B	33° 43.3	118° 16.1
C	33° 43.35	118° 16.0
P6 A	33° 44.34	118° 13.75
B	33° 44.14	118° 13.64
C	33° 43.76	118° 13.48
D	33° 43.47	118° 13.37
E	33° 43.25	118° 13.26
P7 A	33° 44.08	118° 11.11
B	33° 43.90	118° 10.99
C	33° 43.73	118° 10.89
D	33° 43.61	118° 10.84
E	33° 43.48	118° 10.80
P8 A	33° 44.7	118° 13.0
B	33° 44.7	118° 13.05
C	33° 44.75	118° 13.1
P9	33° 45.56	118° 13.10
	33° 45.58	118° 13.08
	33° 45.60	118° 13.05
P10	33° 43.90'	118° 16.37'
P11	33° 44.97'	118° 16.23'
P12	33° 45.47'	118° 15.62'
P13	33° 45.88	118° 14.65

LA/LB CURRENT PROFILE DATA

RANGE 3 08/06/87-08/07/87 EASTERN OPENING

TEAM	METER S/N	TIME (PDT)	STATION	DEPTH (FEET)	DIRECTION (MAGNETIC)	VELOCITY (KNOTS)	PULSES (p)	VELOCITY (KNOTS) $K=\frac{p}{30 X 3.56}$
PMAB	0031	2047	3A-B	09	167	0.16		
PMAB	0031	2048	3A-M	07	194	0.10		
PMAB	0031	2050	3A-T	05	214	0.08		
PMAB	0273	2110	3A-B	09	180		15	0.14
PMAB	0273	2112	3A-M	07	180		10	0.09
PMAB	0273	2115	3A-T	05	220		06	0.06
PMAB	0273	2137	3B-B	17	015		06	0.06
PMAB	0273	2140	3B-M	11	160		06	0.06
PMAB	0273	2145	3B-T	05	180		14	0.13
PMAB	0273	2158	3C-B	30	135		19	0.18
PMAB	0273	2205	3C-M	19	060		27	0.25
PMAB	0273	2208	3C-T	05	135		13	0.12
PMAB	0273	2220	3D-B	36	080		18	0.17
PMAB	0273	2222	3D-M	20	090	0.40		
PMAB	0273	2227	3D-T	05	115		15	0.14
PMAB	0273	2240	3E-B	41	105	0.40		
PMAB	0273	2243	3E-M	23	100	0.40		
PMAB	0273	2247	3E-T	05	110		23	0.22
PMAB	0273	2302	3A-B	06	120		12	0.11
PMAB	0273	2304	3A-M	05	085		13	0.12
PMAB	0273	2306	3A-T	03	030		12	0.11
PMAB	0273	2320	3B-B	14	065		11	0.10
PMAB	0273	2323	3B-M	10	170		20	0.19
PMAB	0273	2326	3B-T	05	200		14	0.13
PMAB	0273	2337	3C-B	28	120		20	0.19
PMAB	0273	2339	3C-M	16	090	0.40		
PMAB	0273	2341	3C-T	05	150		18	0.17
PMAB	0273	2352	3D-B	33	115	0.30		
PMAB	0273	2354	3D-M	19	090	0.60		
PMAB	0273	2359	3D-T	05	125	0.40		
PMAB	0273	2400	3E-B	38	110	0.40		
PMAB	0273	0007	3E-M	22	095	0.50		
PMAB	0273	0008	3E-T	05	085	0.30		
FRF	0273	0051	3A-T	05	210		17	0.16
FRF	0273	0117	3B-B	11	160		22	0.21
FRF	0273	0128	3B-M	08	130		25	0.23
FRF	0273	0130	3B-T	03	040		20	0.19
FRF	0273	0146	3C-B	25	130		18	0.17
FRF	0273	0154	3C-M	15	095		30	0.28
FRF	0273	0200	3C-T	03	105		20	0.19
FRF	0273	0209	3D-B	31	070		22	0.21
FRF	0273	0213	3D-M	18	090		31	0.30
FRF	0273	0216	3D-T	03	095		31	0.30
FRF	0273	0229	3E-B	37	070		16	0.15
FRF	0273	0233	3E-M	21	075		32	0.30
FRF	0273	0237	3E-T	03	090		28	0.26
FRF	0273	0309	3B-B	10	260		16	0.15
FRF	0273	0312	3B-M	07	050		08	0.08
FRF	0273	0324	3C-B	25	320		09	0.08
FRF	0273	0328	3C-M	15	050		10	0.09

FRF	0273	0330	3C-T	03	295		07	0.07
FRF	0273	0340	3D-B	30	020		15	0.14
FRF	0273	0343	3D-M	18	085		19	0.18
FRF	0273	0346	3D-T	03	120		18	0.17
FRF	0273	0358	3E-B	37	340		17	0.16
FRF	0273	0404	3E-M	21	000		26	0.24
FRF	0273	0408	3E-T	03	100		11	0.10
FRF	0273	0426	3A-T	03	180		12	0.11
FRF	0273	0438	3B-B	11	235		22	0.21
FRF	0273	0441	3B-M	08	330		07	0.07
FRF	0273	0444	3B-T	03	020		06	0.06
FRF	0273	0454	3C-B	26	345		19	0.18
FRF	0273	0456	3C-M	15	320		08	0.08
FRF	0273	0459	3C-T	03	285		16	0.15
FRF	0273	0509	3D-B	32	330	0.40		
FRF	0273	0514	3D-M	18	330		32	0.30
FRF	0273	0516	3D-T	03	265		25	0.23
FRF	0273	0526	3E-B	38	350	0.60		
FRF	0273	0529	3E-M	22	340	0.50		
FRF	0273	0531	3E-T	03	250	0.35		

RANGE 6 08/07/87-08/08/87 GYRE

PMAB	0030	1530	6A-B	42	104	0.12
PMAB	0030	1535	6A-M	24	191	0.07
PMAB	0030	1543	6A-T	05	253	0.17
PMAB	0030	1555	6B-B	34	224	0.09
PMAB	0030	1559	6B-M	19	257	0.08
PMAB	0030	1602	6B-T	05	131	0.16
PMAB	0030	1830	6C-B	65	219	0.00
PMAB	0030	1832	6C-M	35	248	0.15
PMAB	0030	1835	6C-T	05	083	0.25
PMAB	0030	1858	6D-B	60	215	0.10
PMAB	0030	1901	6D-M	34	281	0.04
PMAB	0030	1903	6D-T	08	094	0.23
PMAB	0030	1920	6E-B	45	236	0.17
PMAB	0030	1923	6E-M	23	090	0.06
PMAB	0030	1925	6E-T	04	058	0.26
PMAB	0030	1938	6A-B	46	214	0.08
PMAB	0030	1942	6A-M	25	218	0.10
PMAB	0030	1945	6A-T	06	205	0.13
PMAB	0030	1952	6B-B	36	298	0.00
PMAB	0030	1953	6B-M	19	281	0.17
PMAB	0030	1955	6B-T	06	160	0.13
PMAB	0030	2010	6C-B	67	260	0.01
PMAB	0030	2014	6C-M	35	260	0.12
PMAB	0030	2015	6C-T	06	101	0.24
PMAB	0030	2025	6D-B	61	181	0.10
PMAB	0030	2026	6D-M	32	219	0.10
PMAB	0030	2028	6D-T	06	186	0.05
PMAB	0030	2037	6E-B	44	222	0.01
PMAB	0030	2045	6E-M	23	107	0.13
PMAB	0030	2046	6E-T	06	042	0.19
PMAB	0030	2100	6A-B	45	211	0.06
PMAB	0030	2105	6A-M	25	263	0.14
PMAB	0030	2108	6A-T	05	226	0.12
PMAB	0030	2120	6B-B	35	291	0.03
PMAB	0030	2122	6B-M	20	284	0.08
PMAB	0030	2125	6B-T	08	232	0.06
PMAB	0030	2150	6C-B	65	294	0.03
PMAB	0030	2153	6C-M	35	239	0.19
PMAB	0030	2155	6C-T	05	108	0.24
PMAB	0030	2214	6D-B	59	132	0.04
PMAB	0030	2218	6D-M	30	018	0.17

PMAB	0030	2219	6D-T	05	121	0.13
PMAB	0030	2235	6E-B	46	253	0.08
PMAB	0030	2237	6E-M	27	025	0.17
PMAB	0030	2240	6E-T	05	060	0.21
FRF	0030	2340	6A-B	42	262	0.00
FRF	0030	2345	6A-M	24	350	0.00
FRF	0030	2352	6A-T	05	210	0.00
FRF	0030	0016	6B-B	36	030	0.01
FRF	0030	0019	6B-M	19	190	0.00
FRF	0030	0023	6B-T	05	218	0.05
FRF	0030	0032	6C-B	66	024	0.04
FRF	0030	0036	6C-M	33	190	0.14
FRF	0030	0041	6C-T	05	130	0.13
FRF	0030	0055	6D-B	61	120	0.00
FRF	0030	0059	6D-M	33	203	0.08
FRF	0030	0101	6D-T	05	075	0.07
FRF	0030	0113	6E-B	44	045	0.01
FRF	0030	0117	6E-M	22	075	0.05
FRF	0030	0120	6E-T	05	031	0.12
FRF	0030	0140	6A-B	42	068	0.08
FRF	0030	0143	6A-M	22	039	0.11
FRF	0030	0145	6A-T	05	045	0.10
FRF	0030	0155	6B-B	39	007	0.00
FRF	0030	0200	6B-M	20	038	0.03
FRF	0030	0203	6B-T	05	049	0.01
FRF	0030	0215	6C-B	63	159	0.01
FRF	0030	0220	6C-M	34	205	0.04
FRF	0030	0222	6C-T	05	013	0.13
FRF	0030	0234	6D-B	58	108	0.00
FRF	0030	0237	6D-M	30	211	0.06
FRF	0030	0241	6D-T	05	055	0.14
FRF	0030	0259	6E-B	42	006	0.06
FRF	0030	0304	6E-B	21	104	0.05
FRF	0030	0306	6E-T	05	040	0.07
FRF	0030	0326	6A-B	43	356	0.01
FRF	0030	0330	6A-M	21	100	0.04
FRF	0030	0333	6A-T	05	039	0.01
FRF	0030	0344	6B-B	33	230	0.00
FRF	0030	0348	6B-M	17	090	0.03
FRF	0030	0351	6B-T	05	025	0.01
FRF	0030	0404	6C-B	63	220	0.03
FRF	0030	0406	6C-M	33	267	0.00
FRF	0030	0410	6C-T	05	055	0.15
FRF	0030	0421	6D-B	58	108	0.00
FRF	0030	0424	6D-M	30	208	0.07
FRF	0030	0429	6D-T	05	016	0.12
FRF	0030	0440	6E-B	42	077	0.08
FRF	0030	0443	6E-M	22	230	0.02
FRF	0030	0448	6E-T	05	123	0.03
FRF	0030	0508	6A-B	43	115	0.00
FRF	0030	0511	6A-M	22	059	0.06
FRF	0030	0513	6A-T	05	225	0.04
FRF	0030	0522	6B-B	34	320	0.04
FRF	0030	0524	6B-M	18	120	0.01
FRF	0030	0528	6B-T	05	331	0.05
FRF	0030	0540	6C-B	64	070	0.02
FRF	0030	0542	6C-M	32	262	0.05
FRF	0030	0545	6C-T	05	035	0.06
FRF	0030	0555	6D-B	59	315	0.00
FRF	0030	0559	6D-M	30	210	0.06
FRF	0030	0601	6D-T	05	330	0.06
FRF	0030	0612	6E-B	44	075	0.01
FRF	0030	0614	6E-M	22	223	0.03
FRF	0030	0617	6E-T	05	228	0.03

RANGE 10-13 08/08/87 - 08/09/87 CERRITOS CHANNEL

PMAB	0030	1648	12-B	44	114	0.00
PMAB	0030	1654	12-M	26	001	0.10
PMAB	0030	1658	12-T	05	121	0.12
PMAB	0030	1726	13-B	45	108	0.04
PMAB	0030	1733	13-M	28	243	0.19
PMAB	0030	1741	13-T	09	252	0.33
PMAB	0030	1757	12-B	47	250	0.05
PMAB	0030	1759	12-M	29	056	0.14
PMAB	0030	1806	12-T	09	073	0.19
PMAB	0030	1823	11-B	45	357	0.14
PMAB	0030	1828	11-M	31	356	0.13
PMAB	0030	1830	11-T	05	325	0.05
PMAB	0030	1902	10-B	44	346	0.18
PMAB	0030	1904	10-M	26	224	0.15
PMAB	0030	1910	10-T	07	318	0.04
PMAB	0030	1949	12-B	45	217	0.15
PMAB	0030	1951	12-M	26	090	0.00
PMAB	0030	1953	12-T	07	230	0.05
PMAB	0030	2018	13-B	45	212	0.18
PMAB	0030	2019	13-M	23	262	0.25
PMAB	0030	2021	13-T	06	236	0.20
PMAB	0030	2036	12-B	45	230	0.15
PMAB	0030	2039	12-M	25		0.00
PMAB	0030	2043	12-T	08	220	0.05
PMAB	0030	2148	11-B	50	018	0.18
PMAB	0030	2149	11-M	27	051	0.21
PMAB	0030	2150	11-T	05	120	0.10
PMAB	0030	2210	10-B	46	138	0.23
PMAB	0030	2212	10-M	24	132	0.31
PMAB	0030	2214	10-T	03	129	0.31
PMAB	0030	2232	11-B	49	156	0.05
PMAB	0030	2234	11-M	26	163	0.10
PMAB	0030	2236	11-T	05	316	0.13
PMAB	0030	2305	12-B	45	225	0.10
PMAB	0030	2306	12-M	26	200	0.10
PMAB	0030	2308	12-T	06	190	0.10
FRF	0030	2359	10-B	48	006	0.07
FRF	0030	0002	10-M	24	141	0.15
FRF	0030	0004	10-T	05	128	0.36
FRF	0030	0039	11-B	45	190	0.15
FRF	0030	0042	11-M	17	191	0.15
FRF	0030	0044	11-T	05	186	0.05
FRF	0030	0059	12-B	35	170	0.10
FRF	0030	0101	12-M	19	225	0.21
FRF	0030	0102	12-T	05	176	0.15
FRF	0030	0118	13-B	38	076	0.05
FRF	0030	0120	13-M	18	170	0.00
FRF	0030	0124	13-T	05	038	0.18
FRF	0030	0209	10-B	35	141	0.15
FRF	0030	0211	10-M	21	128	0.31
FRF	0030	0213	10-T	05	145	0.36
FRF	0030	0234	11-B	46	350	0.00
FRF	0030	0237	11-M	19	174	0.10
FRF	0030	0238	11-T	05	158	0.12
FRF	0030	0251	12-B	40	143	0.00
FRF	0030	0255	12-M	19	166	0.04
FRF	0030	0259	12-T	05	180	0.05
FRF	0030	0316	13-B	35	255	0.05
FRF	0030	0322	13-M	17	050	0.00
FRF	0030	0326	13-T	05	200	0.10
FRF	0030	0407	10-B	35	063	0.07
FRF	0030	0409	10-M	18	224	0.15

FRF	0030	0416	10-T	05	050	0.05
FRF	0030	0440	11-B	36	285	0.05
FRF	0030	0456	12-B	35	323	0.10
FRF	0030	0459	12-M	18	010	0.00
FRF	0030	0501	12-T	05	205	0.15
FRF	0030	0516	13-B	36	229	0.20
FRF	0030	0518	13-M	18	235	0.15
FRF	0030	0519	13-T	05	230	0.15

RANGE 8-9 08/09/87-08/10/87 ENTRANCE TO NAVY BASIN

FRF	0030	2349	8A-B	35	110	0.23
FRF	0030	2351	8A-M	17	100	0.22
FRF	0030	2353	8A-T	04	085	0.20
FRF	0030	0014	8B-B	61	136	0.30
FRF	0030	0017	8B-M	32	112	0.27
FRF	0030	0019	8B-T	05	097	0.21
FRF	0030	0031	8C-B	41	163	0.36
FRF	0030	0033	8C-M	22	159	0.41
FRF	0030	0034	8C-T	04	163	0.42
FRF	0030	0051	9A-B	52	154	0.21
FRF	0030	0053	9A-M	24	140	0.31
FRF	0030	0055	9A-T	03	163	0.28
FRF	0030	0106	9B-B	57	190	0.15
FRF	0030	0107	9B-M	36	145	0.26
FRF	0030	0109	9B-T	03	140	0.31
FRF	0030	0116	9C-B	45	260	0.05
FRF	0030	0120	9C-M	24	330	0.02
FRF	0030	0122	9C-T	05	105	0.25
FRF	0030	0137	8A-B	53	127	0.48
FRF	0030	0139	8A-M	25	113	0.46
FRF	0030	0140	8A-T	03	113	0.46
FRF	0030	0153	8B-B	56	138	0.41
FRF	0030	0156	8B-M	31	111	0.42
FRF	0030	0157	8B-T	07	138	0.36
FRF	0030	0223	8C-B	33	191	0.11
FRF	0030	0225	8C-M	16	173	0.31
FRF	0030	0227	8C-T	04	174	0.32
FRF	0030	0241	9A-B	42	144	0.17
FRF	0030	0245	9A-M	21	159	0.40
FRF	0030	0247	9A-T	07	136	0.48
FRF	0030	0256	9B-B	55	230	0.21
FRF	0030	0259	9B-M	24	135	0.25
FRF	0030	0301	9B-T	05	179	0.10
FRF	0030	0308	9C-B	53	285	0.17
FRF	0030	0310	9C-M	30	300	0.05
FRF	0030	0313	9C-T	07	089	0.05
FRF	0030	0329	8A-B	39	111	0.24
FRF	0030	0331	8A-M	22	127	0.36
FRF	0030	0332	8A-T	06	103	0.20
FRF	0030	0349	8B-B	55	124	0.03
FRF	0030	0351	8B-M	29	120	0.23
FRF	0030	0354	8B-T	06	084	0.21
FRF	0030	0402	8C-B	24	312	0.10
FRF	0030	0403	8C-M	13	029	0.10
FRF	0030	0405	8C-T	07	041	0.07
FRF	0030	0421	9A-B	47	117	0.18
FRF	0030	0423	9A-M	28	152	0.21
FRF	0030	0426	9A-T	07		0.00
FRF	0030	0433	9B-B	52	154	0.14
FRF	0030	0436	9B-M	32	160	0.10
FRF	0030	0438	9B-T	06	116	0.15
FRF	0030	0446	9C-B	55	235	0.02
FRF	0030	0501	9C-M	27	285	0.25

FRF	0030	0503	9C-T	07	180	0.05
FRF	0030	0533	8A-B	38	307	0.10
FRF	0030	0535	8A-M	24	255	0.20
FRF	0030	0537	8A-T	06	330	0.07
FRF	0030	0547	8B-B	57	318	0.10
FRF	0030	0553	8B-M	31	305	0.25
FRF	0030	0555	8B-T	08	186	0.10
FRF	0030	0711	8C-B	25	340	0.05
FRF	0030	0713	8C-M	12	140	0.09
FRF	0030	0717	8C-T	07	160	0.17
FRF	0030	0733	9A-B	48	265	0.17
FRF	0030	0734	9A-M	22	315	0.12
FRF	0030	0737	9A-T	03	335	0.24
FRF	0030	0747	9B-B	54	320	0.23
FRF	0030	0749	9B-M	26	305	0.13
FRF	0030	0751	9B-T	06	330	0.19
FRF	0030	0758	9C-B	53	315	0.13
FRF	0030	0759	9C-M	26	340	0.08
FRF	0030	0801	9C-T	02	350	0.13
FRF	0015	0822	8A-B	41	150	0.20
FRF	0015	0825	8A-M	20	135	0.23
FRF	0015	0826	8A-T	06	105	0.33
PMAB	0030	0954	8B-B	59	132	0.10
PMAB	0030	1002	8B-M	34	283	0.05
PMAB	0030	1004	8B-T	05	011	0.25
PMAB	0031	1016	8C-B	61	068	0.10
PMAB	0031	1018	8C-M	33	249	0.05
PMAB	0031	1020	8C-T	05	308	0.15
PMAB	0031	1036	9A-B	34	006	0.30
PMAB	0031	1039	9A-M	17	037	0.20
PMAB	0031	1041	9A-T	05	293	0.21
PMAB	0031	1049	9B-B	53	187	0.05
PMAB	0031	1051	9B-M	28	250	0.10
PMAB	0031	1053	9B-T	06	118	0.05
PMAB	0031	1058	9C-B	52	180	0.05
PMAB	0031	1101	9C-M	28	160	0.10
PMAB	0031	1103	9C-T	05	162	0.10
PMAB	0031	1120	8A-B	58	312	0.15
PMAB	0031	1121	8A-M	34	330	0.00
PMAB	0031	1123	8A-T	07	136	0.21
PMAB	0031	1125	8B-B	58	300	0.36
PMAB	0031	1127	8B-M	31	294	0.15
PMAB	0031	1141	8B-T	06	105	0.18
PMAB	0031	1150	8C-B	58	173	0.15
PMAB	0031	1152	8C-M	30	166	0.28
PMAB	0031	1155	8C-T	04	153	0.25

RANGE 4 08/11/87 LA ENTRANCE TO CERRITOS CHANNEL

PMAB	0031	0031	4A-B	42	210	0.18
PMAB	0031	0033	4A-M	25	118	0.10
PMAB	0031	0036	4A-T	05	146	0.51
PMAB	0031	0043	4B-B	46	142	0.05
PMAB	0031	0047	4B-M	22	149	0.21
PMAB	0031	0049	4B-T	05	150	0.46
PMAB	0031	0103	4C-B	45	135	0.07
PMAB	0031	0106	4C-M	25	142	0.36
PMAB	0031	0108	4C-T	05	143	0.49
PMAB	0031	0116	4A-B	42	145	0.10
PMAB	0031	0119	4A-M	23	148	0.41
PMAB	0031	0121	4A-T	05	150	0.57
PMAB	0031	0130	4B-B	45	342	0.02
PMAB	0031	0131	4B-M	26	153	0.15
PMAB	0031	0133	4B-T	05	145	0.52

PMAB	0031	0140	4C-B	40	307	0.10
PMAB	0031	0142	4C-M	22	146	0.30
PMAB	0031	0143	4C-T	05	146	0.57
PMAB	0031	0151	4A-B	42	121	0.05
PMAB	0031	0153	4A-M	24	145	0.31
PMAB	0031	0155	4A-T	05	149	0.52
PMAB	0031	0200	4B-B	42	143	0.10
PMAB	0031	0214	4B-M	23	135	0.25
PMAB	0031	0215	4B-T	06	148	0.67
PMAB	0031	0220	4C-B	40	148	0.10
PMAB	0031	0222	4C-M	25	146	0.31
PMAB	0031	0224	4C-T	05	146	0.72
PMAB	0031	0228	4A-B	42	176	0.05
PMAB	0031	0233	4A-M	24	148	0.41
PMAB	0031	0235	4A-T	05	148	0.52
PMAB	0031	0244	4B-B	40	070	0.05
PMAB	0031	0245	4B-M	25	122	0.26
PMAB	0031	0248	4B-T	05	152	0.44
PMAB	0031	0256	4C-B	40	318	0.10
PMAB	0031	0259	4C-M	26	167	0.04
PMAB	0031	0300	4C-T	06	150	0.41
PMAB	0031	0307	4A-B	41	238	0.18
PMAB	0031	0309	4A-M	25	145	0.25
PMAB	0031	0311	4A-T	05	134	0.36
PMAB	0031	0318	4B-B	41	120	0.05
PMAB	0031	0320	4B-M	25	142	0.25
PMAB	0031	0321	4B-T	05	148	0.57
PMAB	0031	0328	4C-B	39	028	0.05
PMAB	0031	0330	4C-M	25	143	0.21
PMAB	0031	0333	4C-T	05	143	0.42
PMAB	0031	0345	4A-B	40	097	0.05
PMAB	0031	0347	4A-M	21	149	0.36
PMAB	0031	0349	4A-T	05	156	0.51
PMAB	0031	0359	4B-B	40	296	0.05
PMAB	0031	0401	4B-M	23	149	0.10
PMAB	0031	0402	4B-T	04	149	0.36
PMAB	0031	0413	4C-B	38	295	0.05
PMAB	0031	0416	4C-M	22	153	0.25
PMAB	0031	0417	4C-T	05	146	0.41
PMAB	0015	0742	4A-B	35		0.15
PMAB	0015	0744	4A-M	18		0.06
PMAB	0015	0746	4A-T	05		0.30
PMAB	0015	0754	4B-B	43	310	0.39
PMAB	0015	0757	4B-M	25	310	0.30
PMAB	0015	0759	4B-T	09	335	0.13
PMAB	0015	0809	4C-B	25	340	0.33
PMAB	0015	0811	4C-M	15	120	0.10
PMAB	0015	0814	4C-T	05	140	0.18
PMAB	0015	0823	4A-B	40	215	0.15
PMAB	0015	0825	4A-M	20	275	0.08
PMAB	0015	0827	4A-T	09	175	0.06
PMAB	0015	0834	4B-B	35	310	0.04
PMAB	0015	0835	4B-M	15	345	0.01
PMAB	0015	0836	4B-T	05	350	0.02
PMAB	0015	0844	4C-B	40	320	0.27
PMAB	0015	0845	4C-M	20	130	0.05
PMAB	0015	0847	4C-T	09	150	0.07
PMAB	0015	0910	4A-B	41	325	0.25
PMAB	0015	0912	4A-M	20	330	0.26
PMAB	0015	0913	4A-T	05	340	0.23
PMAB	0015	0923	4B-B	45	350	0.12
PMAB	0015	0925	4B-M	23	350	0.08
PMAB	0015	0927	4B-T	09	260	0.10
PMAB	0015	0934	4C-B	29	315	0.25
PMAB	0015	0936	4C-M	24	230	0.10

PMAB	0015	0938	4C-T	05	125	0.10
PMAB	0015	0947	4A-B	42	300	0.33
PMAB	0015	0949	4A-M	21	340	0.30
PMAB	0015	0953	4A-T	09	340	0.30
PMAB	0015	1003	4B-B	45	325	0.15
PMAB	0015	1005	4B-M	20	315	0.10
PMAB	0015	1008	4B-T	05	300	0.05
PMAB	0015	1020	4C-B	37	290	0.02
PMAB	0015	1022	4C-M	18	135	0.19
PMAB	0015	1023	4C-T	09	145	0.31
PMAB	0015	1031	4A-B	41	355	0.20
PMAB	0015	1035	4A-M	20	275	0.23
PMAB	0015	1036	4A-T	06	005	0.10
PMAB	0015	1045	4B-B	45	310	0.27
PMAB	0015	1046	4B-M	22	320	0.29
PMAB	0015	1048	4B-T	09	300	0.10
PMAB	0015	1055	4C-B	31	305	0.04
PMAB	0015	1057	4C-M	15	130	0.25
PMAB	0015	1058	4C-T	05	145	0.23

RANGE 1 08/12/87 ANGELS GATE

PMAB	0015	0842	1A-B	44	280	0.38
PMAB	0015	0845	1A-M	24	315	0.33
PMAB	0015	0848	1A-T	04	080	0.40
PMAB	0015	0856	1B-B	46	300	0.60
PMAB	0015	0857	1B-M	27	315	0.45
PMAB	0015	0902	1B-T	04	295	0.05
PMAB	0015	0913	1C-B	45	265	0.60
PMAB	0015	0914	1C-M	25	255	0.45
PMAB	0015	0916	1C-T	04	215	0.40
PMAB	0015	0945	1A-B	51	320	0.16
PMAB	0015	0948	1A-M	28	285	0.39
PMAB	0015	0952	1A-T	04	285	0.10
PMAB	0015	1000	1B-B	50	320	0.28
PMAB	0015	1004	1B-M	27	280	0.44
PMAB	0015	1006	1B-T	05	270	0.44
PMAB	0015	1013	1C-B	53	210	0.44
PMAB	0015	1016	1C-M	29	210	0.44
PMAB	0015	1019	1C-T	06	200	0.42
PMAB	0015	1114	1A-B	52	205	0.30
PMAB	0015	1120	1A-M	27	190	0.32
PMAB	0015	1124	1A-T	05	070	0.40
PMAB	0015	1137	1B-B	54	225	0.35
PMAB	0015	1142	1B-M	28	185	0.32
PMAB	0015	1145	1B-T	05	180	0.45
PMAB	0015	1149	1C-B	53	225	0.40
PMAB	0015	1150	1C-M	27	210	0.40
PMAB	0015	1153	1C-T	06	150	0.40
PMAB	0015	1200	1A-B	50	170	0.30
PMAB	0015	1202	1A-M	28	215	0.35
PMAB	0015	1204	1A-T	06	090	0.30
PMAB	0015	1212	1B-B	50	245	0.35
PMAB	0015	1215	1B-M	27	220	0.40
PMAB	0015	1216	1B-T	05	090	0.25
PMAB	0015	1225	1C-B	52	225	0.60
PMAB	0015	1227	1C-M	29	215	0.55
PMAB	0015	1230	1C-T	06	165	0.55
PMAB	0015	1238	1A-B	53	135	0.40
PMAB	0015	1239	1A-M	30	180	0.35
PMAB	0015	1241	1A-T	06	055	0.70
PMAB	0015	1250	1B-B	50	185	0.25
PMAB	0015	1253	1B-M	28	170	0.25
PMAB	0015	1256	1B-T	06	080	0.35

PMAB	0015	1336	1C-B	52	205	0.35
PMAB	0015	1339	1C-M	28	180	0.40
PMAB	0015	1341	1C-T	06	085	0.45
FRF	0015	1518	1A-B	49	250	0.10
FRF	0015	1520	1A-M	22	350	0.35
FRF	0015	1521	1A-T	05	060	0.35
FRF	0015	1536	1B-B	46	225	1.00
FRF	0015	1539	1B-M	24	275	0.65
FRF	0015	1540	1B-T	03	260	0.80
FRF	0015	1509	1A-B	50	265	0.13
FRF	0015	1511	1A-M	24	010	0.38
FRF	0015	1513	1A-T	05	015	0.30
FRF	0015	1622	1B-B	46	225	0.47
FRF	0015	1623	1B-M	22	010	0.47
FRF	0015	1624	1B-T	05	020	0.45
FRF	0015	1638	1C-B	39	020	0.25
FRF	0015	1640	1C-M	18	010	0.47
FRF	0015	1642	1C-T	06	015	0.47
FRF	0015	1653	1A-B	46	335	0.42
FRF	0015	1655	1A-M	24	020	0.18
FRF	0015	1656	1A-T	03	100	0.38
FRF	0015	1749	1B-B	46	005	0.48
FRF	0015	1751	1B-M	22	020	0.60
FRF	0015	1753	1B-T	05	025	0.45
FRF	0015	1821	1C-B	39	340	0.90
FRF	0015	1823	1C-M	21	015	1.00
FRF	0015	1825	1C-T	03	025	1.00
FRF	0015	1834	1A-B	49	005	0.45
FRF	0015	1836	1A-M	22	350	0.48
FRF	0015	1838	1A-T	05	235	0.60
FRF	0015	1846	1B-B	49	325	0.70
FRF	0015	1847	1B-M	23	015	0.80
FRF	0015	1849	1B-T	06	030	0.80
FRF	0015	1858	1C-B	49	315	0.90
FRF	0015	1900	1C-M	23	345	0.90
FRF	0015	1902	1C-T	06	020	1.00

RANGE 2 08/13/87 QUEENS GATE

PMAB	0015	0821	2A-B	56	330	0.35
PMAB	0015	0823	2A-M	30	105	0.30
PMAB	0015	0830	2A-T	05	085	0.35
PMAB	0015	0850	2B-B	54	345	0.50
PMAB	0015	0852	2B-M	30	010	0.50
PMAB	0015	0854	2B-T	05	320	0.51
PMAB	0015	0904	2C-B	54	235	0.20
PMAB	0015	0912	2C-M	30	240	0.25
PMAB	0015	0915	2C-T	05	255	0.34
PMAB	0015	0926	2A-B	56	340	0.52
PMAB	0015	0930	2A-M	30	005	0.50
PMAB	0015	0932	2A-T	05	085	0.40
PMAB	0015	0957	2B-B	58	330	0.45
PMAB	0015	0959	2B-M	30	345	0.50
PMAB	0015	1000	2B-T	05	000	1.00
PMAB	0015	1010	2C-B	55	335	0.50
PMAB	0015	1012	2C-M	30	320	0.35
PMAB	0015	1014	2C-T	05	045	0.40
PMAB	0015	1021	2A-B	57	320	0.60
PMAB	0015	1023	2A-M	30	290	0.60
PMAB	0015	1025	2A-T	05	295	0.60
PMAB	0015	1037	2B-B	56	345	0.50
PMAB	0015	1038	2B-M	30	330	0.60
PMAB	0015	1040	2B-T	05	310	0.60
PMAB	0015	1055	2C-B	55	345	0.40

PMAB	0015	1057	2C-M	30	275	0.35		
PMAB	0015	1100	2C-T	05	295	0.20		
PMAB	0015	1107	2A-B	59	315	0.60		
PMAB	0015	1109	2A-M	30	305	0.40		
PMAB	0015	1111	2A-T	05	310	0.45		
PMAB	0015	1118	2B-B	54	325	0.60		
PMAB	0015	1120	2B-M	30	315	0.50		
PMAB	0015	1122	2B-T	05	320	0.40		
PMAB	0015	1133	2C-B	56	300		21	0.20
PMAB	0015	1135	2C-M	30	270	0.40		
PMAB	0015	1138	2C-T	05	255	0.25		
PMAB	0015	1146	2A-B	59	310	0.50		
PMAB	0015	1148	2A-M	30	315	0.45		
PMAB	0015	1150	2A-T	05	345	0.30		
PMAB	0015	1202	2B-B	54	005	0.50		
PMAB	0015	1205	2B-M	30	290	0.60		
PMAB	0015	1207	2B-T	05	315	0.50		
PMAB	0015	1215	2C-B	55	020		21	0.20
PMAB	0015	1217	2C-M	30	240		25	0.23
PMAB	0015	1220	2C-T	05	225	0.30		
PMAB	0015	1228	2A-B	66	300	0.35		
PMAB	0015	1230	2A-M	30	300	0.35		
PMAB	0015	1232	2A-T	05	335	0.20		
PMAB	0015	1237	2B-B	55	330	0.40		
PMAB	0015	1240	2B-M	30	260	0.35		
PMAB	0015	1242	2B-T	05	290	0.30		
PMAB	0015	1250	2C-B	57	140		13	0.12
PMAB	0015	1252	2C-M	30	210	0.30		
PMAB	0015	1254	2C-T	05		0.25		
FRF	0015	1404	2C-B	54	220	0.35		
FRF	0015	1406	2C-M	26	175	0.25		
FRF	0015	1408	2C-T	06	140	0.42		
FRF	0015	1448	2A-B	57	170	0.20		
FRF	0015	1450	2A-M	27	105	0.40		
FRF	0015	1452	2A-T	03	095	0.44		
FRF	0015	1502	2B-B	53	185	0.38		
FRF	0015	1504	2B-M	27	145	0.37		
FRF	0015	1505	2B-T	07	115	0.70		
FRF	0015	1618	2A-B	56	125	0.42		
FRF	0015	1620	2A-M	28	110	0.33		
FRF	0015	1622	2A-T	06	100	0.44		
FRF	0015	1634	2B-B	53	155	0.30		
FRF	0015	1635	2B-M	24	140	0.42		
FRF	0015	1637	2B-T	06	105	0.70		
FRF	0015	1649	2C-B	54	240	0.34		
FRF	0015	1651	2C-M	26	200	0.35		
FRF	0015	1654	2C-T	06	120	0.43		
FRF	0015	1703	2A-B	58	075	0.25		
FRF	0015	1706	2A-M	30	095	0.36		
FRF	0015	1710	2A-T	06	080	0.25		
FRF	0015	1718	2B-B	53	105	0.20		
FRF	0015	1720	2B-M	26	105	0.27		
FRF	0015	1722	2B-T	05	090	0.43		
FRF	0015	1735	2C-B	52	090	0.20		
FRF	0015	1738	2C-M	25	070	0.18		
FRF	0015	1740	2C-T	05	080	0.39		
FRF	0015	1749	2A-B	58	135	0.25		
FRF	0015	1751	2A-M	28	120	0.38		
FRF	0015	1753	2A-T	06	095	0.44		
FRF	0015	1801	2B-B	52	110	0.32		
FRF	0015	1803	2B-M	26	100	0.25		
FRF	0015	1805	2B-T	06	080	0.43		
FRF	0015	1815	2C-B	52	065	0.15		
FRF	0015	1817	2C-M	24	080	0.20		
FRF	0015	1820	2C-T	06	060	0.44		

RANGE 7 08/14/87 NAVY MOLE TO ANGELS GATE

PMAB	0015	0837	7A-B	38	225		08	0.08
PMAB	0015	0841	7A-M	18	070		08	0.08
PMAB	0015	0845	7A-T	05	355		12	0.11
PMAB	0015	0856	7B-B	42	310		14	0.13
PMAB	0015	0859	7B-M	25	340		25	0.23
PMAB	0015	0901	7B-T	05	015		15	0.14
PMAB	0015	0914	7C-B	46	355		25	0.23
PMAB	0015	0916	7C-M	26	035		26	0.24
PMAB	0015	0919	7C-T	05	030		16	0.15
PMAB	0015	0930	7D-B	48	020	0.40		
PMAB	0015	0932	7D-M	28	035	0.35		
PMAB	0015	0934	7D-T	05	045		16	0.15
PMAB	0015	0955	7E-B	49	330		21	0.20
PMAB	0015	0957	7E-M	28	010	0.55		
PMAB	0015	1000	7E-T	05	075	0.40		
PMAB	0015	1016	7A-B	40	220		17	0.16
PMAB	0015	1019	7A-M	23	255		21	0.20
PMAB	0015	1021	7A-T	05	350		08	0.08
PMAB	0015	1033	7B-B	43	345		23	0.22
PMAB	0015	1036	7B-M	25	265		21	0.20
PMAB	0015	1038	7B-T	05	105		16	0.15
PMAB	0015	1049	7C-B	47	315	0.30		
PMAB	0015	1051	7C-M	24	325	0.35		
PMAB	0015	1054	7C-T	05	070		13	0.12
PMAB	0015	1106	7D-B	48	310		16	0.15
PMAB	0015	1108	7D-M	27	355	0.50		
PMAB	0015	1112	7D-T	05	030		16	0.15
PMAB	0015	1123	7E-B	50	315	0.35		
PMAB	0015	1125	7E-M	28	005	0.55		
PMAB	0015	1127	7E-T	05	015	0.60		
PMAB	0015	1147	7A-B	41	260		13	0.12
PMAB	0015	1149	7A-M	24	220		25	0.23
PMAB	0015	1151	7A-T	05	175	0.40		
PMAB	0015	1201	7B-B	43	250		16	0.15
PMAB	0015	1203	7B-M	24	320		28	0.26
PMAB	0015	1206	7B-T	05	170		27	0.25
PMAB	0015	1215	7C-B	48	240		11	0.10
PMAB	0015	1217	7C-M	28	345	0.50		
PMAB	0015	1219	7C-T	05	220		13	0.12
PMAB	0015	1229	7D-B	49	250		17	0.16
PMAB	0015	1231	7D-M	27	350	0.50		
PMAB	0015	1234	7D-T	05	055		29	0.27
PMAB	0015	1242	7E-B	51	320	0.35		
PMAB	0015	1244	7E-M	30	355	0.35		
PMAB	0015	1245	7E-T	05	020	0.30		
PMAB	0015	1433	7A-B	40	340	0.10		
PMAB	0015	1435	7A-M	19	270	0.17		
PMAB	0015	1438	7A-T	06	070	0.16		
PMAB	0015	1451	7B-B	44	290	0.15		
PMAB	0015	1453	7B-M	22	050	0.18		
PMAB	0015	1456	7B-T	06	140	0.17		
PMAB	0015	1509	7C-B	47	210	0.25		
PMAB	0015	1512	7C-M	23	025	0.20		
PMAB	0015	1514	7C-T	06	080	0.22		
PMAB	0015	1524	7D-B	49	195	0.07		
PMAB	0015	1526	7D-M	24	320	0.20		
PMAB	0015	1528	7D-T	07	090	0.34		
PMAB	0015	1536	7E-B	50	040	0.20		
PMAB	0015	1539	7E-M	24	035	0.09		
PMAB	0015	1541	7E-T	06	085	0.44		
FRF	0015	1556	7A-B	40	290	0.09		

FRF	0015	1559	7A-M	18	075	0.15
FRF	0015	1601	7A-T	07	090	0.30
FRF	0015	1614	7B-B	43	250	0.12
FRF	0015	1616	7B-M	21	115	0.12
FRF	0015	1618	7B-T	06	095	0.29
FRF	0015	1629	7C-B	46	285	0.08
FRF	0015	1631	7C-M	22	075	0.28
FRF	0015	1634	7C-T	06	080	0.23
FRF	0015	1643	7D-B	47	240	0.15
FRF	0015	1646	7D-M	23	080	0.17
FRF	0015	1648	7D-T	06	105	0.32
FRF	0015	1700	7E-B	50	190	0.20
FRF	0015	1702	7E-M	23	080	0.16
FRF	0015	1704	7E-T	06	105	0.35
FRF	0015	1721	7A-B	37	020	0.21
FRF	0015	1724	7A-M	17	300	0.14
FRF	0015	1726	7A-T	05	070	0.25
FRF	0015	1738	7B-B	42	245	0.08
FRF	0015	1741	7B-M	19	015	0.10
FRF	0015	1744	7B-T	07	060	0.22
FRF	0015	1755	7C-B	45	235	0.04
FRF	0015	1758	7C-M	21	090	0.23
FRF	0015	1800	7C-T	06	075	0.40
FRF	0015	1813	7D-B	46	040	0.04
FRF	0015	1815	7D-M	23	075	0.30
FRF	0015	1817	7D-T	06	090	0.38
FRF	0015	1827	7E-B	48	360	0.18
FRF	0015	1830	7E-M	24	035	0.20
FRF	0015	1832	7E-T	06	090	0.37
FRF	0015	1843	7A-B	36	040	0.13
FRF	0015	1845	7A-M	17	025	0.09
FRF	0015	1847	7A-T	06	070	0.17
FRF	0015	1856	7B-B	40	290	0.12
FRF	0015	1858	7B-M	20	065	0.23
FRF	0015	1900	7B-T	05	065	0.25
FRF	0015	1909	7C-B	43	265	0.08
FRF	0015	1911	7C-M	21	080	0.20
FRF	0015	1913	7C-T	06	095	0.30
FRF	0015	1921	7D-B	45	025	0.21
FRF	0015	1924	7D-M	26	075	0.17
FRF	0015	1925	7D-T	06	075	0.23
FRF	0015	1934	7E-B	48	045	0.14
FRF	0015	1937	7E-M	23	090	0.17
FRF	0015	1939	7E-T	06	090	0.29

APPENDIX C: DIFFERENTIAL LEVELING SURVEY DESCRIPTION AND LEVEL NOTES

This appendix provides a description of the method used to obtain elevations, referenced to Mean Lower Low Water (MLLW), and the level notes recorded during the surveys.

MEMORANDUM FOR RECORD: 23 October 1987

SUBJECT: 15 October 1987 Survey at LA/LB Stations LA-3 and LB-4

1. As a follow-up to and confirmation of survey work performed, during April in Los Angeles and Long Beach Harbors, additional measurements were made at Stations LA-3 and LB-4. These measurements were made in three stages. The first two were made with diver assistance, measuring from the top edge of the upper pile bracket, down to the harbor bottom and Paros sensor pressure housing diaphragm. The third measurement was made from the top edge of the upper pile bracket, up to a point on the pier, which had been leveled-in previously. Survey bench marks used at LA-3 and LB-4, respectively, were NOAA/NOS bench mark "TIDAL 8" at elevation +13.90′ MLLW and Port of Long Beach Civil Engineering Division bench mark "1935" at elevation +15.98′ MLLW.

2. Using the above mentioned bench marks as backsights, elevations to the control points were measured of 13.28′ and 15.92′ MLLW, for Stations LA-3 and LB-4, respectively. The total distance measured from the control point to the Paros sensor housing diaphragm at LA-3 was 30.70′ and at LB-4 was 34.15′. Subtracting these distances from the pier elevations, yields a sensor elevation of -17.42′ MLLW at LA-3 and -18.23′ MLLW at LB-4. By comparison, sensor elevations obtained in April at Stations LA-3 and LB-4 were -17.50′ and -18.03′ MLLW. The differing elevations from one survey to the next, are due to the inaccuracies of the taped measurements.

3. As was stated above, the taped measurements were made to the Paros sensor pressure housing diaphragm. This is the point of the oil/water interface, between the diaphragm and the surrounding water. The point on the quartz crystal pressure transducer, at which the input force is sensed, is 0.53′ above the diaphragm. Hence if the sensor elevations at each station from both surveys are averaged and then reduced by the transducer offset, the resulting true elevation at Station LA-3 is -16.93′ MLLW and at Station LB-4 is -17.60′ MLLW.

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Los Angeles/Long Beach Differential Leveling Survey

Bench Mark Designations and Elevations:

NOAA/NOS "TIDAL 8" @ Elevation + 13.90′ MLLW
POLB Bollard 1935 @ Elevation + 15.98′ MLLW

April 87 Survey: Survey Date 12 April 1987

STA	BS+	HI	FS-	ELEV.	TAPED DISTANCE	SENSOR ELEVATION
Bollard 1935	5.65′	21.63′		15.98′		
LB-4			5.71′	15.92′	33.95′	- 18.03′
TIDAL 8	5.98′	19.88′		13.90′		
LA-3			6.60′	13.28′	30.78′	- 17.50′

October 87 Survey: Survey Date 15 October 1987

STA	BS+	HI	FS-	ELEV.	TAPED DISTANCE	SENSOR ELEVATION
Bollard 1935	5.72′	21.70′		15.98′		
LB-4			5.78′	15.92′	34.15′	- 18.23′
TIDAL 8	5.15′	19.05′		13.90′		
LA-3			5.77′	13.28′	30.70′	- 17.42′