PRELIMINARY DATA SUMMARY

SEPTEMBER 1985

by

Field Research Facility
Coastal Engineering Research Center
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PRELIMINARY DATA SUMMARY

September 1985

U.S. Army Engineer Waterways Experiment Station
Coastal Engineering Research Center
Field Research Facility
Duck, North Carolina
PRELIMINARY DATA SUMMARY

CERC Field Research Facility
Duck, North Carolina

This report provides a summary of basic oceanographic, meteorological and bottom profile data for the month. The data were obtained as part of the Field Research Facility Measurement and Analysis Work Unit at the U.S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Center's Field Research Facility in Duck, North Carolina. The data were collected and the analyses performed by the FRF staff. These summaries are intended to make the data readily available to all FRF users, and comments on their content and usefulness are invited.
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I. INTRODUCTION

The U.S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Center's (CERC) Field Research Facility (FRF) is located on the Outer Banks of North Carolina, near the village of Duck (Fig. 1).

The FRF research program provides a means for obtaining high-quality field data, particularly during storms, in support of the U.S. Army Corps of Engineers' coastal engineering research missions. The FRF consists of a 561-m (1,840 ft) long concrete research pier supported on 0.91 m (3 ft) diameter steel piles. The pier deck is 6.1 m (20 ft) wide, 7.74 m (25.4 ft) above mean sea level (MSL), and extends from behind the dunes to approximately the 7.6 m (25 ft) depth contour. In addition, a main building contains offices, an instrument repair shop, and a data acquisition room.

One of the responsibilities of the FRF research program is the collection, analysis and dissemination of data on local oceanographic and meteorological conditions. Bottom profiles along both sides of the pier and periodic bathymetric surveys are also performed.

This summary is intended to provide basic data as soon as possible after they are obtained. Most of the data are daily observations or the results of preliminary data analysis. In many instances, continuous analog records and more extensive analyses will be made available later by the CERC Coastal Engineering Information and Analysis Center (CEIAC).

Table 1 is a list of instruments used, their status during the month, and the data collection status. Figure 2 identifies the location of the instruments. The water depth at the wave gages and current meters vary and may best be determined from the information contained in Figure 8. Other installation information is contained in Table 1. All times unless otherwise specified are referenced to Eastern Standard Time (EST).

Section II presents the meteorological data; Sections III through VI, oceanographic data; Section VII, nearshore profiles and bathymetry; and Section VIII, if included, documents special events that occurred at the FRF during the month.

Questions and/or comments concerning the data may be directed to Mr. H. Carl Miller at (919) 261-3511.
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**Instrument Status:** Operational ■ - Daily Observation: YES ■ - Analog Record: ALL ■, PARTIAL ■ - Preliminary Analysis: ALL ■, SOME ■ - Data Collected: ALL ■, SOME ■
Figure 2. Instrument locations at FRF.
II. METEOROLOGICAL DATA

A variety of instruments have been installed at the FRF (Fig. 2) to monitor the meteorological conditions. The data presented in Table 2 are collected and stored on magnetic tape using a Data General NOVA-4 computer. For each instrument identified in Table 1 as having analog outputs, chart records are obtained, a log is maintained and the records are stored for future reference.

The wind measurements are obtained from a Weather Measure Skyvane located on the FRF laboratory building (Fig. 2), 19.1 m above mean sea level (MSL).

The high and low temperatures are obtained from daily readings of NWS maximum and minimum thermometers and represent the extreme temperature values since the last reading.

The following may be useful for converting the data in Table 2 to other frequently used units of measurement:

1. Millimeters (mm) to inches (in) -
   
   \[ \text{mm} \times 0.03937 = \text{in} \]

2. Millibars (mb) to inches of mercury (in Hg) -
   
   \[ \text{mb} \times 0.02953 = \text{in Hg} \]

3. Degrees Celsius (C) to degrees Fahrenheit (F) -
   
   \[ (\text{C} \times \frac{9}{5}) + 32 = \text{F} \]

4. Meters per second (m/s) to knots (kn) -
   
   \[ \text{m/s} \times 1.943 = \text{kn} \]
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## Table 2: Meteorological Data

**Part 2**

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*-=Electronic problems
III. WAVE DATA

Wave data were collected from two Baylor staff gages (CERC gage Nos. 625 and 645) and Waverider buoys (CERC gage Nos. 630 and 640, Table 1 and Figure 2). The data were collected, analyzed, and stored on magnetic tape using a Data General NOVA-4 computer.

The NOVA-4 is programmed to sample the wave gages every 6 hours near 0100, 0700, 1300, and 1900 EST at a sampling rate of four times per second, collecting data in 20-minute records.

Wave height ($H_{mo}$) is an energy-based statistic equal to four times the standard deviation of the sea surface elevations. The wave period is identified from the computation of a variance (energy) spectrum using a Fast Fourier Transform of 4096 data points (1024 sec). The period ($T_p$) is that associated with the maximum energy density in the spectrum. When this analysis is complete, the data are written to magnetic tape and entered into the CERC data base.

Table 3 presents the wave heights and periods for each wave record obtained during the month. The monthly means shown in Table 3 are an average of the values computed for all data records collected. The monthly standard deviations are standard deviations from the monthly mean of values for each record.

Figure 3 is a time history of the $H_{mo}$ and $T_p$ values for the Waverider 6 km from shore (630) and the Baylor gage at pier station 19+00 (625).

Differences in wave periods between wave gages (Table 4 and Figure 3) may be due to wave breaking or reformation, or the presence of multiple wave trains containing nearly equal energy.
| GAGE | 645 Baylor at 7480 | 625 Baylor at 1900 | 640 Neartsh Wvdr | 630 Forshr Wvdr |
|------|------------------|-------------------|-----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
|      | Day (m) | Time (sec) | Day (m) | Time (sec) | Day (m) | Time (sec) | Day (m) | Time (sec) | Day (m) | Time (sec) |
| 1    | 10.68 | 3.95      | 10.64 | 5.05      | 10.66 | 5.09      | 10.67 | 5.09      | 10.71 | 5.09      |
| 2    | 10.52 | 3.95      | 10.53 | 5.05      | 10.54 | 5.09      | 10.55 | 5.09      | 10.56 | 5.09      |
| 3    | 10.43 | 3.95      | 10.43 | 5.05      | 10.44 | 5.09      | 10.45 | 5.09      | 10.46 | 5.09      |
| 4    | 10.29 | 3.95      | 10.29 | 5.05      | 10.30 | 5.09      | 10.31 | 5.09      | 10.32 | 5.09      |
| 5    | 10.17 | 3.95      | 10.17 | 5.05      | 10.18 | 5.09      | 10.19 | 5.09      | 10.20 | 5.09      |
| 6    | 10.06 | 3.95      | 10.06 | 5.05      | 10.07 | 5.09      | 10.08 | 5.09      | 10.09 | 5.09      |
| 7    | 10.01 | 3.95      | 10.01 | 5.05      | 10.02 | 5.09      | 10.03 | 5.09      | 10.04 | 5.09      |
| 8    | 10.00 | 3.95      | 10.00 | 5.05      | 10.01 | 5.09      | 10.02 | 5.09      | 10.03 | 5.09      |
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| 16   | 10.00 | 3.95      | 10.00 | 5.05      | 10.01 | 5.09      | 10.02 | 5.09      | 10.03 | 5.09      |

*=Electronic Problems

**TABLE 3: WAVE DATA**

**SLOTPER: WAVE DATA**

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*=Electronic Problems
CERC Gage Number 630, Waverider 6 km from shore

CERC Gage Number 625, pier station 19+00

FIGURE 3. Time History of Wave Heights and Periods - September 1985

Part I: Heights
CERC Gage Number 630, Waverider 6 km from shore

CERC Gage Number 625, pier station 19+00

FIGURE 3. Time History of Wave Heights and Periods - September 1985

Part II: Periods
IV. CURRENT DATA

Current data (Table 4) are collected from two Marsh McBirney electromagnetic biaxial current meters (Table 1 and Figure 2) and by visually observing the movement of dye on the water surface in the surf and at the seaward end of the pier, as well as 500 m updrift of the pier 12 m offshore.

Since the shoreline orientation is approximately N20W, alongshore currents flow either toward 340 (i.e. northward) or toward 160 (i.e. southward). Similarly, cross-shore currents are either onshore (westward) or offshore (eastward).

All current speeds are given in centimeters per second.
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Note: Depth in meters, MSL is Mean Sea Level.
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<th>CURRENT METER (12M OFFSHORE)</th>
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**KEY:**
- ALL SPEEDS IN CM/SEC
- N = NORTH, S = SOUTH
- ON SHORE, OFF SHORE
### Table 4: Current Data (Speeds in cm/sec)

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<th>CURRENT METER DYE AT 1400 (433m) (surf)</th>
<th>DYE AT MID-SURF Zone (surf)</th>
<th>DYE AT 12M OFFSHORE (DEPTH -4.8 m)</th>
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**KEY**
- ALL SPEEDS IN CM/SEC
- N = NORTHWARD, SHORE PARALLEL
- S = SOUTHWARD, SHORE PARALLEL
- ON = ON SHORE
- OFF = OFF SHORE

**NOTE:**
- Speeds are measured at various depths along the shoreline, ranging from the surf zone to depths of 12m offshore.
- The data includes both dye- and current-meter-based measurements, providing a comprehensive view of water movement along the coast.
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**KEY**
- ALL SPEEDS IN CM/SEC
- N = NORTHWARD, SHORE PARALLEL
- S = SOUTHWARD, SHORE PARALLEL
- ON = OFFSHORE
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**Key:**
- N: North
- S: South
- SHORE PARALLEL: Offshore, Shore Parallel
- CM/SEC: Currents
- N: North
- S: South
- D: Depth
V. SUPPLEMENTAL OBSERVATIONS

Visual wave direction measurements (Table 5) taken at the seaward end of the pier are made of both the primary wave train (i.e. that having the larger wave heights) and the secondary wave train (which must be clearly distinguishable as a wave train separate from the primary waves) but not surface chop or capillary waves. The direction of the primary wave train just north of the seaward end of the pier is also determined using a Raytheon Marine Pathfinder radar and measuring alignment of the wave crests. The pier axis (considered perpendicular to the beach at the FRF) is orientated 70° east of true north; consequently, wave angles greater than 70° imply the waves were coming from the south side of the pier.

The width of the surf zone (seawardmost breaker position to shoreline) is determined from the pier deck.

Measurements of surface water temperature, density, and visibility are made daily at the seaward end of the FRF pier. A jar along with a thermometer is lowered about .3 m (1 ft) into the water and allowed to remain for at least one minute. The jar is removed, the temperature read and a hydrometer is used to determine the density. A secci disc is used to determine the surface visibility.
# Supplemental Observations

September 1985

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VI. WATER LEVELS

The National Ocean Services (NOS) has established a primary tide station (No. 865-1370) at the seaward end of the FRF pier. A Leupold-Stevens digital recording float-type tide gage is used to collect data every 6 minutes throughout the month.

Figure 4 shows the range of each cycle while Figure 5 shows the variation in mean water levels computed over a tidal cycle period (12.42 hours), and contains a list of selected mean and extreme values. This presentation is useful in identifying effects on both meteorological and astronomical forces on the open coast water levels.

Table 6 contains the time of the center of each sampling interval and the range, high, low, and mean water levels during each tidal cycle.
FIGURE 5. Time History of Mean Water Levels, September 1985 (Gage No. 865-1370)

MONTHLY MEAN WATER LEVELS (METERS MSL)

- Extreme Low - -.68 on 28 September at 0100 hrs.
- Extreme High - 1.24 on 27 September at 0230 hrs.
- Monthly Mean - .15
- Mean Low Water - -.34
- Mean High Water - .64
- Mean Range - .98
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VII. NEARSHORE PROFILES

A. Nearshore Profiles. In order to document profile response away from the pier, surveys of four profile lines extending 900 to 1,000 m from shore and located 489 and 581 m north and 517 and 608 m south of the FRF pier are conducted bi-weekly, after storms, and during more complete bathymetric surveys.

These profiles are obtained using the CRAB-Zeiss surveying system; a Zeiss Elta-2 first-order, self-recording electronic theodolite distance meter in combination with the Coastal Research Amphibious Buggy (CRAB), a 10.7 m high, self-powered, mobile tripod on wheels.

Figure 6 shows the last survey in August and the five surveys taken during September on profile line 188, located 517 m south of the pier. The most dramatic changes occurred in the nearshore (120 to 240 m). The last survey in August and the first September survey show the presence of only a small rudimentary nearshore bar (130 m). However, the bar (160 m) reformed following a small storm on the 13th and 14th. The survey obtained on the 25th in anticipation of Hurricane Gloria showed a smaller bar which had migrated 20 m offshore (180 m). The last survey in September immediately following the passage of Hurricane Gloria showed the redevelopment of a well defined nearshore bar (200 m) with a deep inner trough. The bar crest had shifted an additional 20 m offshore. The outer bar also reformed (320 m).

![Figure 6. Monthly CRAB profiles on profile 188 - 517 meters south of pier.](image-url)
The profile envelope (Figure 7) reflects the maximum changes which occurred on the profile between January and September. Hurricane Gloria was responsible for the changes visible on the lower envelope profile (130 m) as well as the seawardmost changes on the upper envelope profile (180 m). The remaining changes to the upper profile reflect the seaward migration of the nearshore bar prior to Hurricane Gloria (27 September).

![Figure 7. CRAB profile envelope - profile 188.](image)

B. Bathymetry. This month's survey was completed on 28 September following the passage of Hurricane Gloria which caused significant bottom changes. Because of this, the data are presented and discussed in Section VIII, Special Events.
VIII. SPECIAL EVENTS

A. Storm Data Collection. The following list identifies times when the wave height at the seaward end of the pier (i.e. as measured by the Baylor gage #625 at pier station 19+00) exceeded 2 m and wave records were obtained every hour:

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B. Hurricane Gloria. On the morning of 27 September, Hurricane Gloria passed over the Field Research Facility. The following discussion of her passage is excerpted from a more-comprehensive report which will be published by CERC. Although predicted to affect the area with 130+ mph winds, the actual path was slightly seaward of the coast resulting in less than hurricane force winds at the FRF. In addition, Gloria's rapid passage coincided with low tide which minimized her impact.

Storm Track. Approaching Wilmington, NC from the southeast, the hurricane veered to the north late on 26 September. Picking up speed, the storm's eye passed over Cape Hatteras, NC at approximately 0130 on 27 September with the western edge of the eye passing over the FRF at approximately 0230. Continuing to gain speed, Gloria made landfall at Long Island, NY early that afternoon.

Meteorological Conditions. Figure 8 shows the time histories of mean wind speed and direction on the land based tower at the FRF. Beginning on 26 September, ENE winds began to steadily increase reaching their NE peak of 21 m/s at 0200 on the 27th. At that time, the wind direction shifted rapidly to the NW and the mean speed dropped dramatically then began to rapidly increase again reaching the storm's peak wind speed of 22 m/s at 0400. These changes occurred only slightly after the time of minimum barometric pressure (966 mb), see Figure 9. These observations indicate that the western edge of the hurricane's eye passed over the FRF at about 0230 on the 27th. Surprisingly, only 30 mm of rainfall was measured during the storm.

Tides. The ocean tide hydrograph (Figure 10), was measured by the National Ocean Service primary tide station at the seaward end of the FRF pier. Predicted values are provided for comparison and indicate that approximately 5 ft of storm surge was produced during Gloria's passage. Note the rapid increase beginning at about midnight, reaching a maximum of 1.2 m (4 ft) above NGVD at 0230 or about 1.5 m (5 ft) above the predicted value at 0230 on the 27th. This was followed by a rapid decrease in water levels between 0230 and 0330. By the next high tide, predicted levels had again been reached. It is fortuitous that the storm passed during low tide, for elevations of more than 8 ft above NGVD would have occurred during high astronomical tides.
Figure 8. Wind Speed and Direction Time History

Figure 9. Barometric Pressure Time History
Waves. Wave heights measured at pier station 14+20 (Baylor gage) and about 6 km (3.7 miles) from shore (Waverider) show similar time histories (Figure 11). Slow but steadily increasing values during the afternoon rose much more rapidly between 2000 and midnight on the 26th. By 0200, maximum wave heights of almost 7 m were recorded at the offshore location. The Baylor gage, being in much shallower water, showed considerably smaller values, indicating that the upper limit on the energy possible at this shallow water depth was reached about midnight, with maximum values over 3 m occurring concurrently with the offshore maxima, slightly after 0200 on the 27th. Wave heights at all locations rapidly diminished with passage of the storm's center and arrival of strong westerly winds. Peak wave periods at the offshore Waverider increased slightly as the storm approached, reaching about 11 seconds, but then diminished to pre-storm values of about 8 seconds (Figure 11). At the Baylor gage, however, maximum values reached about 17 seconds during the eye's passage over the site before diminishing to 8 second values. Wave directional measurements computed from the Sxy directional array indicated that waves approached the pier from slightly south of shore-normal throughout the storm, even though local winds were from the east-northeast during the early stages.

Longshore Currents. Examination of data from the current meters indicates that longshore components of flow were northward throughout the storm, but that their strength varied with time and distance from shore. Figure 12 shows representative time histories of the longshore components of currents from 3 gages; one located near the north property
Figure 11. Wave heights and peak periods

LONGSHORE CURRENTS

Figure 12. Time Histories of Longshore Currents
line about 114 m (375 ft) from shore, another under the pier about 300 m (1100 ft) from shore, and a third on a bottom-mounted tripod about 500 m (1650 ft) south of the pier end. Near shore currents were high throughout the period (up to 1.8 m/second). However, offshore current speeds increased proportionately with wave heights, reaching values equal to those nearshore at about 0400 on the 27th. The longshore components approximate the actual current speeds, since the flow was within 30 degrees of shore parallel. Thus, during these times of rapid longshore flow far from shore, the surf zone apparently extended much farther seaward than normal (probably well beyond the end of the pier), for all the current meters recorded northward flows of over 1.5 m/sec at that time.

Nearshore Profiles and Bathymetric Changes. In order to document the response of the nearshore bottom to Hurricane Gloria, pre and post-storm surveys of two areas were made. One survey area included 25 cross-shore profiles from the toe of the dune to the 9 m water depth, covering a longshore distance of 580 m either side of the pier. This area was surveyed on 21 August (Figure 13) and 28 September (Figure 14). A smaller, more frequently-surveyed area (the mini-grid) covered an area north of the pier extending 400 m longshore and 800 m offshore. A pre-storm survey of this area and two profiles south of the pier were completed on 25 September, with post-storm profiles obtained on 27 and 28 September. Analyses of these data indicate that changes on either side of the pier differed significantly.

On the south side, changes to the nearshore bottom were quite linear (i.e. uniform in the longshore direction). The nearshore bar moved offshore about 40 m, and an offshore bar developed about 200 m from shore. Changes to the shoreline were minimal, with slight landward movement of the mean sea level intercept throughout the area.

On the north side in contrast, changes were much more three-dimensional (Figure 15). The pre-storm crescentic bar configuration was greatly modified, with general offshore movement of the bar and elimination of small rip channels. The post-storm bathymetry was characterized by a relatively large depression and a slightly more-pronounced offshore bar. In this area, a well-developed berm on the upper foreshore was completely eliminated, although shoreline changes showed some accretion.

Near the research pier, the scour trough under the pier enlarged greatly to the north. Just north of this trough extensive deposition occurred (compare the 3 and 4 m contours in Figures 13 and 14).
FIGURE 13.  FRF BATHYMETRY 21 AUG 85
CONTOURS IN METERS
FIGURE 14. FRF BATHYMETRY 28 SEP 85
CONTOURS IN METERS
Summary. Within the vicinity of the Field Research Facility, wave heights and wind speeds during Hurricane Gloria approximated those typical of intense northeasters, although offshore wave heights were considerably greater. Changes to the nearshore bathymetry were essentially mirror-images of those observed during northeasters, apparently due to the fact that Gloria's waves approached from the south. Changes to the beach and dune were minimized by the hurricane's rapid passage, and the timing of maximum surge near the astronomical low water.
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