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CHAPTER 5

REGIONAL NETWORK FOR COASTAL ENGINEERING DATA

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A. Introduction

The California Department of Navigation and Ocean Development (DNOD), responsible for shoreline protection within the state, was particularly aware of the lack of coastal wave statistics to support their beach erosion program. As a direct result of the 1974 ASCE-sponsored New Orleans Conference on Ocean Wave Measurement and Analysis, discussion was initiated within DNOD and then with the Scripps Institution of Oceanography (SIO) at La Jolla, on the feasibility of establishing a regional wave monitoring network for California. The initial specification presented by DNOD was for a 200-station network reporting directional wave spectra twice daily for a period of ten years. SIO ocean engineering personnel responded with a system concept employing low-cost pressure transducers hardwired to shore with a dialup telephone data gathering link to a central station. The initial cost estimates appeared attractive when compared with Corps of Engineers experience as reported in Peacock (1974).

As a result, a small program was funded in February 1975 at Scripps to demonstrate critical hardware items through the breadboard stage. With the successful completion of this work, additional funds were allocated by DNOD as matching funds for a California Sea Grant Project.

The first station in the network began operation on 3 December 1975 at Imperial Beach, California. A second station was added at Ocean Beach (San Diego) on 27 March 1976, a third at SIO (La Jolla) on 18 May 1976 and the fourth at Oceanside, California on 2 June 1976. The locations of these initial stations are shown in Figure 1.

Considerable effort has been directed during the past 10 years toward the development of numerical models to predict deep-water wave conditions from meteorological data. Reasonable results have been obtained and sufficient accuracy achieved to allow routing of both commercial and military ship traffic. There has been some hope by users

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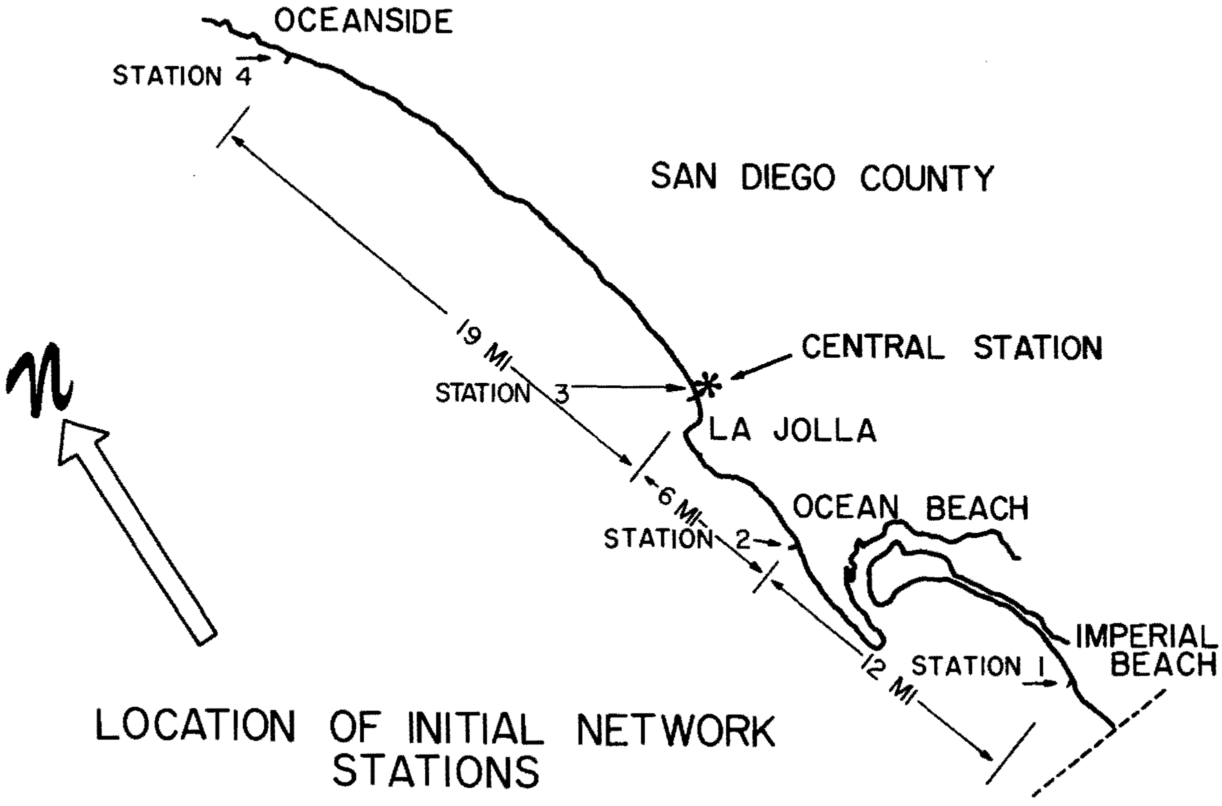


LOCATION OF INITIAL NETWORK STATIONS

FIGURE 1

of nearshore wave data that hindcasting of meteorological records would allow a relatively low-cost method of accumulating long-term coastal wave statistics. However, the realities of the situation indicate that this may never be possible. Because of the irregularities in the continental shelf topography, a very marked difference in the refracted wave intensity at a particular location results from a small change in the deep-water wave approach angle. Accuracies on the order of one-half degree are needed in predicting offshore directional spectra in order to achieve reasonable estimates of local nearshore wave climates. The best obtainable accuracy that may eventually be expected is still at least an order of magnitude poorer than this.

The situation existing in Southern California is even more difficult than in most coastal regimes. The deep-water waves are not only refracted by the very irregular bathymetry of the shelf but are reflected, scattered and diffracted by a chain of large offshore islands.

Since the observed local wave climate is the sum of the deep-water swell that diffracts around the islands, and the locally generated wind waves, these factors combine, in the case of Southern California, to make wave prediction for coastal areas an extremely difficult task. Therefore, in this region of the coastline, it is even more imperative to find an affordable method for acquiring wave statistics through local nearshore measurements at closely spaced sites.

Any effort by man to alter the coastline shape, to prevent the erosion of valuable shoreline property, to manage the sediment budget within a coastal province -- all require the ability to predict the local capacity of the waves to transport sediment onshore, offshore, and longshore. Since man is most often concerned with the long-term cumulative effect of such sediment transport, only long-term statistics on the wave climate will allow meaningful predictions to be made.

Nearshore currents -- tidal, wind-driven or caused by fresh water flows -- can be significant factors in sediment transport and the dispersion of pollutants. Temperature variations with depth and time can provide data on such stable phenomena as thermoclines and such transient events as internal waves and bores. Both features are important in the engineering of the mixing patterns of outfalls. The wind field over the water can be of value in verifying wave generation models and for atmospheric pollution studies. Thus, a variety of additional sensors might be utilized at certain locations in addition to the basic wave gaging.

B. Objectives of the System

1. Coastal Wave Climate Statistics:

The primary objective of the system is to provide an affordable means of gathering directional wave statistics, at least twice each day, from closely placed stations along the coast of California. These stations are to be selected to allow both a characterization of the wave climate along the entire coastline and to highlight areas of specific interest -- such as a coastal reach undergoing critical erosion. These statistics are to be available in a timely manner to the users (reports containing monthly data are mailed no later than the third working day of the following month). Further, the data are to be archived so that raw data tapes and spectra tapes can be used at a future time by investigators.

The data can also be available in nearly realtime for surf reports and boaters' advisories if desired.

It is an objective of the program to collect these data for a minimum of ten years to establish seasonal trends.

2. Sediment Transport Estimates:

The second priority objective is to make estimates of the longshore sediment transport from the wave data in all locations where this would be appropriate. This prediction will utilize the best available model relating the measured wave characteristics and the sediment transport. Since the original wave data are preserved, these estimates can be updated later with improvements in the transport model.

3. Support of Scientific Experiments:

The ability of the network to provide nearly simultaneous observations over a very broad reach of coastline provides a unique data gathering tool to many coastal experiments. It is an objective of the program to support such work whenever possible, either as the primary data source or as an adjunct to the basic data retrieval system.

C. General Description of the System

1. Station Locations:

As of 30 June 1976, four stations have been installed in the network as shown in Figure 1. All are in San Diego County and have been added in a northerly progression. The Imperial Beach location was chosen as the southernmost site in California because a critical beach erosion problem has been experienced here. In addition, a beach renourishment project is now underway and the wave data obtained may be of value in monitoring the effectiveness of the sand placement. The Ocean Beach site is just north of the Sunset Cliffs area, which has suffered damaging erosion. The gaging station is also very close to the entrance to Mission Bay, which will be studied by the Corps of Engineers for possible solution to the dangerous entrance conditions due to breaking waves which are encountered several times each year. The site at SIO is close to the Scripps Submarine Canyon, the terminus for a major littoral cell. The Oceanside location is in an area with chronic problems caused by interrupted littoral drift and localized erosion.

2. Central Station Configuration:

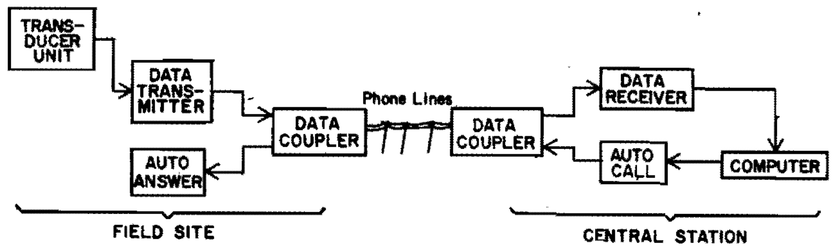
When the multiplexed signal is received at the central station, channel separation is achieved by tuned filters at the carrier frequency. The signal is then demodulated and digitized. The multiplexed data from as many as seven instruments are transmitted over an ordinary voice-grade, dial-up commercial telephone line. The data quality is at least as high as experienced with more costly leased lines over comparable distances.

At the central station, a dedicated minicomputer is interfaced to a receiver and autocall system. Under real-time computer control, a preprogrammed telephone number corresponding to the desired field station is dialed. Each station is called in sequence once every ten hours. This provides a minimum of two reports per day and eliminates the bias possible with fixed polling times. Upon connection to the field site, the digitized words are written to the computer buffer and then to magnetic tape for permanent storage.

The system block diagram is shown in Figure 2.

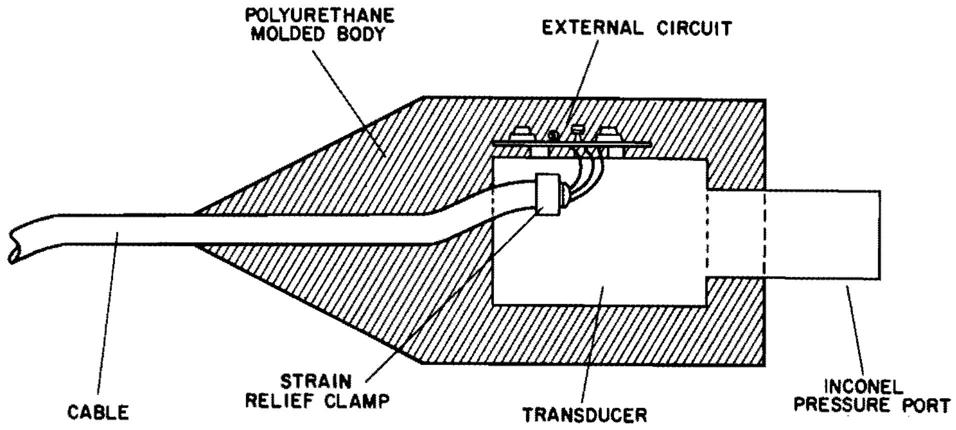
3. Field Station Configuration:

The initial stations utilize existing piers to bridge the surf zone. In the updated configuration, wave measurements are obtained with very stable LVDT (linear variable displacement transformer) pressure transducers which are molded directly on the end of a specially designed high performance armored cable as shown in Figure 3. This construction eliminates the cost and reliability hazards associated with connectors and housings. A single transducer providing one-dimensional wave spectra is the basic station. Three transducers in an array are now being



BLOCK DIAGRAM,
DATA TRANSMISSION SYSTEM

FIGURE 2



GULTON WAVE SENSOR ASSEMBLY

FIGURE 3

installed at each station to provide a directional estimate. The underwater cables are terminated in a data control box on the end of the pier. This unit performs the functions of signal conditioning, multiplexing signals from the various sensors, and responding to telephone requests for data from the central computer. The installed cost of the complete field station with an array of three pressure transducers, the underwater cabling and the data control box is projected to be less than $3,000. Current meters, temperature probes, anemometers and other continuously reporting instruments can be accommodated in addition to the wave measuring devices. The output of each instrument is amplified at the point of measurement and converted to a frequency in the kHz range. At the shore station, this is divided down and used to modulate a carrier tone in the voice range.

4. Reports and Data Analysis:

These data are available for immediate analysis, if required. Normally Fourier transforms of wave data are made once a month and stored on a permanent transform archive tape. From these, a monthly wave climate statistical report is made, including one-dimensional spectra and significant wave height estimates for each data sampling.

D. <u>Data Archiving</u>

It is anticipated that the appropriate federal agency will, at some later time, take over the function of archiving the wave data obtained with this network. Initial discussions with NOAA personnel indicate that they plan a national wave statistics program beginning before the end of this decade. This would meet the needs for a central repository, capable of specifying the format for standard inputs and of meeting the requests of investigators for duplicate tapes or tabulations of data. Until this arrangement is available, the present project organization will attempt to meet the needs of interested investigators for raw data, transforms or tabulations.

Following is a tabulation of data outages which have occurred since the system went into operation in December 1975:

Date	Data Lost	Cause
December 1975	2 runs from 1 site	Power supply failure in central station
April 1976	2 runs from 1 site	Vandalism

Date	Data Lost	Cause
June 1976	2 runs from 1 site	Phone line damaged by construction work
June 1976	1 run from 1 site	Pier power outage

During this time over 1,000 runs have been made, so the data outage rate is 0.7%. Considering only equipment failures, the rate becomes 0.2%.

E. <u>Plans For Expanding Capabilities</u>

1. Additional Stations

As funds become available, other stations will be added to the network. As in the selection of the existing stations, the advice of the Corps of Engineers, the California Department of Navigation and Ocean Development, and other interested agencies will be solicited to aid in selecting future sites.

2. Wave Direction Measurement Capability

During the second half of 1976, the existing stations (and additional stations as they are installed) will have multiple channel capability. This will allow the installation of a minimum of three sensors in an array to estimate wave directional properties.

Two alternate approaches are being evaluated at this time. The first is to calculate a conventional directional spectrum estimate. With the limited array size, this will necessarily result in a poor estimate of actual wave direction. The second approach involves an approximation of the longshore momentum flux, defined by Longuet-Higgins (1970) as the sum over frequency of the products of the energy, the ratio of the phase and group velocities and the sine and cosine of the approach angle. This is expressed symbolically as

$$S_{xy} = \Sigma \, En \sin\theta \cos\theta$$

This parameter, which can be related to the longshore current induced by waves along straight coastlines, may be a more valuable and concise means for describing the overall directionality of the wave field.

Regardless of which method is employed in monthly reporting, the raw data will be preserved for use in other types of analyses.

3. Wind Measurements

Wind will be measured at pier sites utilizing an aerovane-type sensor which has had wide application on ships and oceanographic buoys. Data will be sampled periodically and a number of samples stored in a temporary memory until called by the central station. Upon receipt of a command from the central computer, data will be converted to a frequency proportional to the values stored in the memory and sent as a sequential series. The entire contents of the temporary memory will be sent upon command but the contents will be retained until overflow occurs with the most recent value pushing the oldest data out of the stack. Sample intervals and durations are programmable and can be varied to suit the experiment requirements.

F. Results and Preliminary Conclusions

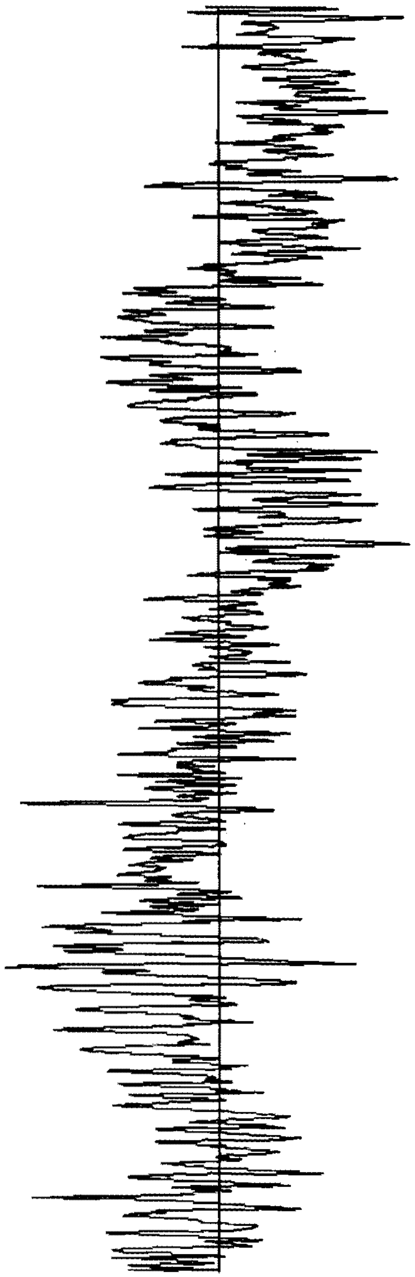
The first seven months of operation of the network have shown gratifying progress. The hardware cost goals have been met or exceeded. The data retrieval reliability has been greater than 99%, including causes beyond the control of the project. Every monthly report has been mailed to users within the first three working days of the following month.

A sufficient data bank has already been acquired to allow some tentative conclusions on the eventual usefulness of these measurements:

.....The ability to discriminate low amplitude, long-period oscillations has been dramatically illustrated by the record of a tsunami reverberation made on 4 December 1975, four days after the earthquake on Hawaii. The uncorrected bottom pressure time history is shown in Figure 4. Although the original tsunami arrival had been detected by the tide gaging station at Scripps Institution of Oceanography, this reverberation was not detectable.

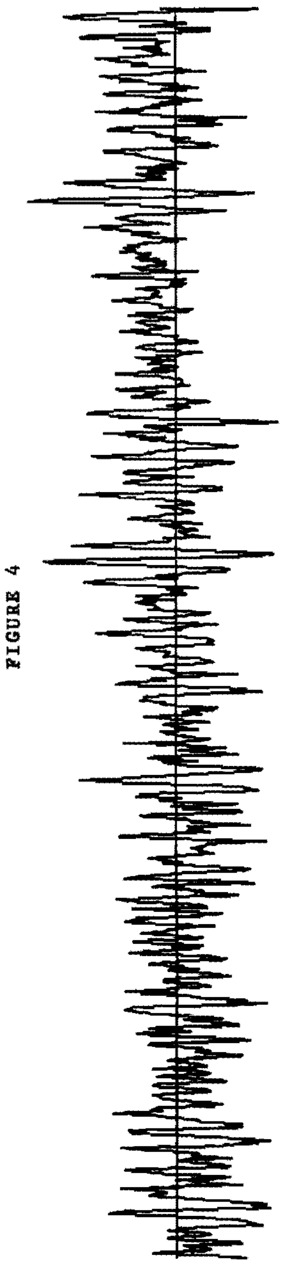
.....The influence of tides on spectral shape is significant when wind waves are small. Figure 5 shows a pressure record in which the mean sea level shift caused by the tide can be easily distinguished.

.....It has long been reasoned that point-to-point variations in nearshore wave climate are large. The present record of the network indicates that these variations may be even larger than anticipated. Figure 6 shows qualitatively the intense spatial variability within an 18-mile stretch of coastline during a single month. The "vertical" dimension suggested by



Pressure-Time Record, Imperial Beach Station, 0600 4 December 1975, Showing Reverberations of 29-30 November Tsunami From Earthquake in Hawaii (Period: Approximately 10 Min., Height: Approximately 1 Foot).

FIGURE 4



Pressure-Time Record Showing Mean Water Level Change Caused By Tide.

FIGURE 5

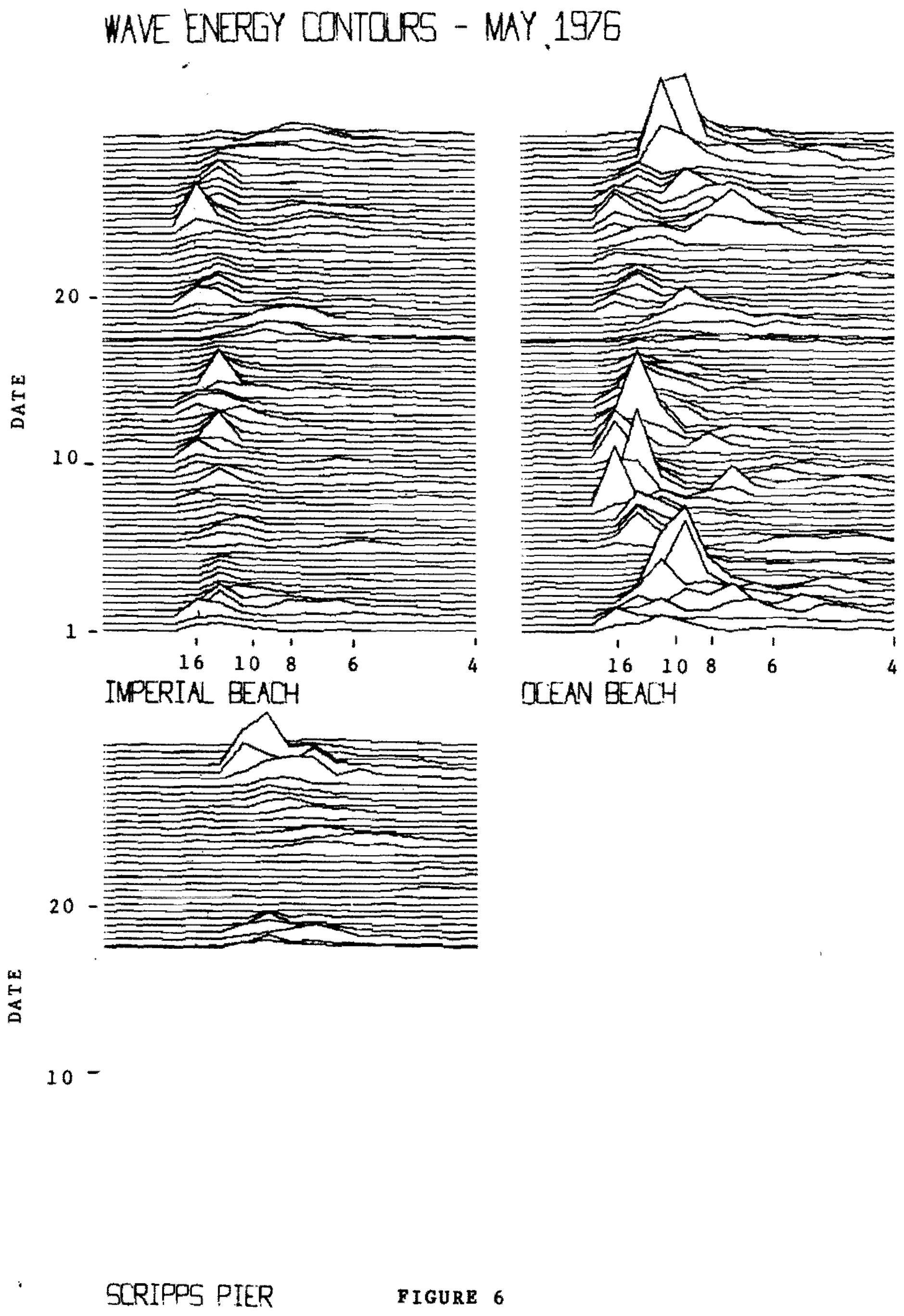


FIGURE 6

this plot is absolute energy plotted at the same scale for all stations.

This variability, both temporal and spatial, reinforces the need for closely spaced nearshore wave measuring stations reporting more than once per day in order to characterize the impact of the wave climate on the shoreline.

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