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Nearshore Oceanographic Measurements: Hints on How to Make Them

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ABSTRACT

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Selection of instruments for coastal oceanographic measurements is difficult. Few people involved with coastal engineering have the experience to make informed decisions about which gage will work best under their particular circumstances. Consideration of a few general characteristics of gage types will help in the selection of the most appropriate gage for a data collection effort.

ADDITIONAL INDEX WORDS: *Data collection, non-directional waves, directional waves, currents, water levels, winds.*

INTRODUCTION

Coastal planners and designers, as well as those who try to operate and maintain coastal works, often have to do their jobs without information critical to success. To be successful in the coastal zone, one must understand the environment in which the work is to be done. Information on the wave climate, tides, currents, and even winds is necessary to the coastal professional; the more information the better. But how should these data be collected? This paper will attempt to provide some general guidelines to those who want to collect these data. It will subjectively review the various types of instruments and discuss their advantages and disadvantages, as well as deployment considerations. The paper is not meant to be a technical evaluation of the various generic classes of instruments, nor is it intended to critique the specific instruments currently available for data collection, but rather to be a guide to the selection of instrument types based on general criteria such as cost to purchase, difficulty to install or maintain, flexibility, reliability, and sensitivity. This paper should help the coastal professional identify the class of instruments that would best satisfy his or her data needs. Once the class of instrument has been selected the reader is encouraged to investigate all instruments available in that class, to include contacting users of the gages, to determine those that best fit their specific application. Throughout this paper, references to the cost of instruments and systems are meant to be relative to the cost of alternative instruments and not to the project for which the data are collected. While an instrument might be expensive when compared to other data collection alternatives, it is likely to be cheap when compared

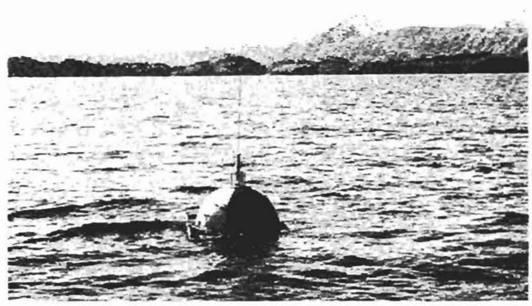

Figure 1. Datawell bv. waverider buoy.

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ADVANTAGES	SURFACE PIERCING/SENSING	PRESSURE SENSING	SURFACE FOLLOWING
1. EASILY DEPLOYED/ MAINTAINED			X
2. DATA COLLECTION FLEXIBILITY			
A. REAL TIME	X	X	X
B. ON BOARD	X	X	X
C. GOES			X
3. RELIABLE			X
4. ACCURATE		X	X
5. COMPACT		X	
6. FLEXIBLE SITING		X	
7. INEXPENSIVE	X		
8. LOW ENERGY WAVE MEASUREMENTS	X		

Figure 2. Non-directional waves—advantages.

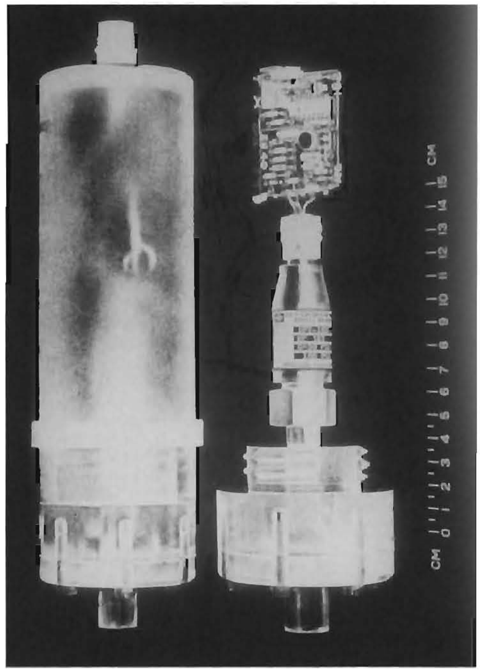

Figure 3. Strain-gage pressure sensor.

to the cost of a navigation, hurricane protection, or beach restoration project. Finally, the data collected will typically provide considerably more in project savings through a more refined design than the cost of data collection.

NON-DIRECTIONAL WAVE MEASUREMENTS

The three general categories of non-directional wave measurement devices are surface following, pressure sensing, and surface piercing or sensing. As the name implies, surface following instruments are buoys (Figure 1). Several buoys of varying quality are available. Figure 2 compares the advantages of the various non-directional wave measuring devices. Some additional comments are in order. While any instrument can be made to be satellite-reporting, buoys are typically the only instruments deployed in that configuration. This capability is most often used to increase transmission range of the buoy. In the United States, the most often used system is the Geostationary Operational Environmental Satellite (GOES) system operated by the National Oceanographic and Atmospheric Administration (NOAA), although the ARGOS network, a cooperative effort between the Centre National d'Etudes Spatiales, NOAA, and the National Aeronautics and Space Administration (NASA), is becoming increasingly popular.

Two general types of pressure sensors are most often used by instrument manufacturers, strain gages and vibrating quartz sensors. Quartz sensors have the advantage of much better accuracy but at a considerably higher cost. Pressure sensing instruments (Figure 3) can be sited with more flexibility since, when in self-recording mode, they require neither cable, structure, nor shore station. This flexibility can also be a liability, since frequent maintenance is required using divers (Figure 4) when deployed in the self recording mode (Figure 5).

The surface piercing/sensing category includes acoustic and optical devices, as well as the more traditional resistance and conductance measuring gages (Figure 6), because they often require a mounting arrangement similar

DISADVANTAGES

	SURFACE FOLLOWING	PRESSURE SENSING	SURFACE PIERCING/SENSING
1. VULNERABLE	X	X	X
2. LIMITED TELEMETRY RANGE	X		
3. EXPENSIVE WHEN GOES EQUIPPED	X		
4. DIVERS REQUIRED		X	
5. EXPENSIVE TO MAINTAIN		X	
6. MOUNTING/ANCHORING REQUIREMENTS			X

Figure 4. Non-directional waves—disadvantages.

Figure 5. Sea Data 635-11 in situ recording gage.

to the parallel wire instruments. While they offer a number of advantages, there are some drawbacks. In every case, they require a structure that pierces the water surface. A particular disadvantage of some parallel wire gages is their inability to operate in fresh water, so they have no use in the Great Lakes. Before selecting a parallel wire gage, make sure that it will operate where data are needed.

All instruments are vulnerable to vandalism or fishing activity. That fact must be understood and considered when choosing a measuring device. The vulnerability of an instrument will dictate the measures that must be taken to protect it. Deployment considerations can overwhelm the advantages or disadvantages of the instruments under consideration. Fishing activity, in particular, can demand extraordinary protective activities. Before any deployment, the type and extent of fishing must be determined (Figure 7). Shrimping in the Gulf of Mexico and along the southeastern Atlantic coast of the United States requires that special tripods or protective structures be considered for bottom mounted instruments, for example. Finally, when deploying instruments in self recording mode, redundancy must be considered. There is no way to verify that an instrument is working between deployment and recovery, so using two instruments helps insure the maximum data return.

The alternative to using self-recording instruments is a real time or near real time collection system. While the ability to regularly check instrument operation is valuable, there are expenses associated with a real time system. Data collected must be transmitted by radio, acoustically, or through a cable to a shore station. The data are stored in memory at the shore station awaiting transfer to the analysis computer. While this hardware can add to the expense of a data collection effort, technology advances have kept costs within reason. When armored cable is required for an installation, costs can escalate quickly. Cable, at several dollars a linear foot, can become a significant part of the installation costs.

DIRECTIONAL WAVE MEASUREMENTS

Directional wave measurements can be made using buoys, Puv meters (gages that combine a

Figure 6. Baylor parallel wire gage.

pressure sensor with an electromagnetic current meter to determine wave height, period, and direction), or arrays. The surface piercing group of instruments is not well suited to making directional measurements, although they might be deployed in an array to determine wave direction. Buoys (Figure 8) are most often used in mid- to deep-water and generally measure pitch, roll, and heave, utilizing the theory developed by LONGUET-HIGGINS *et al.* (1963). They have the particular advantage of reliability and can be installed and serviced entirely from the surface (Figure 9). Unfortunately, they are large, expensive to purchase, vulnerable to fishing activity, and difficult to deploy because of their size (Figure 10). In the United States, the most successful directional buoys deployed to date are those of the NOAA's National Data Buoy Center (NDBC). These discus buoys are fitted with a Dutch made pitch-roll-heave sensor and numerous weather instruments. Their size makes them less vulnerable to incidents with shipping and extensive tests of the buoys have demonstrated the credibility of their data.

Puv meters (Figure 11), most often deployed in shallow water (5 to 15 meters), use pressure sensors to determine wave heights combined with an electromagnetic current meter to determine wave direction. As can be seen in Figure 9, they are compact and relatively inexpensive to purchase. They share many of the same disadvantages, though, as non-directional pressure sensors (Figure 10). While commercially available Puv gages are used primarily in a self-recording mode, some can be modified to provide real time data, as can custom built Puv gages. Calibration of the current meter is difficult and must be done carefully. These calibration problems may contribute to the meters' problems with angular resolution. Recently, commercially available Puv meters have been modified to include solid state memory, replacing the tape memory. This has improved data

DEPLOYMENT CONSIDERATIONS

	SURFACE PIERCING	PRESSURE SENSING	SURFACE FOLLOWING
1. WATER DEPTH	X	X	X
2. LOCATION OF SHORE STATION	X		X
3. FISHING ACTIVITY		X	X
4. BOTTOM		X	X
5. RADIO INTERFERENCE			X
6. MOUNTING SYSTEM	X	X	
7. MAINTENANCE SCHEDULE	X	X	
8. REDUNDANCY		X	

Figure 7. Non-directional waves—deployment considerations.

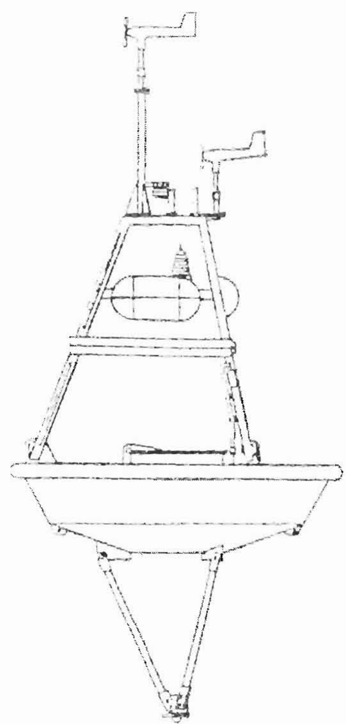

Figure 8. NOAA three meter directional buoy.

recovery and increased potential deployment lengths, making them more cost effective.

Arrays, like Puv meters, are generally used in shallow water and are of two general types, slope/curvature arrays (Figure 12) and linear arrays. It is generally accepted that linear arrays have the best angular resolution of all measurement devices because they are quite large and can use variable spacing between elements (Figure 13), but they are difficult to deploy and quite expensive because of deployment considerations (Figure 10). Slope/curvature arrays use the same pitch-roll-heave theory mentioned earlier (LONGUET-HIGGINS *et al.*, 1963).

Figure 14 reviews the deployment considerations of each of the instrument types. Again, deployment considerations may dictate the type instrument selected.

One other measurement technique deserves mention. While accuracy is not one of the advantages of a Littoral Environment Observation (LEO) program, cost is. LEO is a program operated by the Coastal Engineering Research Center of the US Army Engineer Waterways Experiment Station. Volunteer observers (Figure 15) can provide information on wave height and direction, as well as winds, at little cost (SCHNEIDER, 1981). Similar programs exist in at least two other countries. The Beach Protection Authority of Queensland, Australia has operated their Coastal Observation Programme—Engineering (COPE) for a number of years. Recently, information was received concerning South Africa's Continuous Low-level Environmental Observation (CLEO) Program.

CURRENT MEASUREMENTS

The three categories of instrument types available for measuring current speed and direction represent three levels of technology. They also represent three levels of cost. Ducted impeller meters are relatively inexpensive but provide less accuracy than available from other meters. Electromagnetic meters represent the middle level of technology. Doppler acoustic

ADVANTAGES

	LINEAR	SLOPE/CURVATURE ARRAYS	PUV METERS	BUOYS
1. EASILY MAINTAINED				x
2. DATA COLLECTION FLEXIBILITY				
A. REAL TIME	x	x	x	x
B. ON BOARD		x	x	x
C. GOES				x
3. RELIABLE	x	x		x
4. COMPACT			x	
5. RELATIVELY INEXPENSIVE TO PURCHASE			x	
6. FLEXIBLE SITING			x	
7. DURABLE	x	x		
8. INEXPENSIVE TO MAINTAIN	x	x		
9. HIGH RESOLUTION	x			

Figure 9. Directional waves—advantages.

DISADVANTAGES

	LINEAR	SLOPE/CURVATURE* ARRAYS	PUV METERS	BUOYS
1. EXPENSIVE TO PURCHASE		x		x
2. VULNERABLE			x	x
3. DIFFICULT TO DEPLOY	x	x		x
4. POOR ANGULAR RESOLUTION		x	x	x
5. DIVER REQUIRED	x	x	x	
6. EXPENSIVE TO MAINTAIN			x	
7. VERY EXPENSIVE TO DEPLOY	x			
8. REQUIRES STRAIGHT PARALLEL CONTOURS	x	x		

*CERC DWG-1 ADDRESSES MANY OF THESE DISADVANTAGES

Figure 10. Directional waves—disadvantages.

meters are the current state-of-the-art but are quite expensive, again relatively.

Ducted impeller meters (Figure 16) have the advantages (Figure 17) of low acquisition cost and relative ease of deployment at various depths (Figure 18). They can also be used from the surface to acquire profiles of currents through the water column. Some inaccuracies are inherent in this mode of operation, though, since the meter affects and is affected by the current it is attempting to measure. For position in the water column, the better meters have a pressure sensor to record the depth of the measurements being taken. As might be expected, these meters, except for the vane type used more often in deep water oceanography, are very susceptible to fouling. Fishing line, kelp, plastic bags, or any other material that might be found in the water column can foul the impeller and put an end to current measurements (Figure 19). Impeller bearings are vulnerable to wear from sediment in the water, a common problem in inlets and another cause of data loss. Because the instrument must actually change direction with the current, response is often slow and directional resolution poor. Finally, the instruments typically have limited data storage, so deployments are relatively short (Figure 20).

The electromagnetic current meters (Figure 21) used for mean current measurements are the same as those used for directional wave measurements, so their characteristics are the same. They can collect real-time data, although they are usually deployed in a bottom-mounted, self-recording configuration. These meters provide reasonable, albeit not remarkable, resolution (Figure 17). They are relatively expensive to purchase and maintain, compared to the ducted impeller meters, are susceptible to fishing activity, and provide data from only one point, although they can be used to acquire multi-point measurements through the water column when equipped with a compass (Figures 19 and 20).

Doppler acoustic meters are the state-of-the-art in current measuring instruments. They have high resolution, provide a profile of the entire water column, and appear relatively free of fouling problems (Figure 17). Their most serious disadvantage (Figure 19) is their cost. This meter is considerably more expensive than the other instrument types. While it may not be

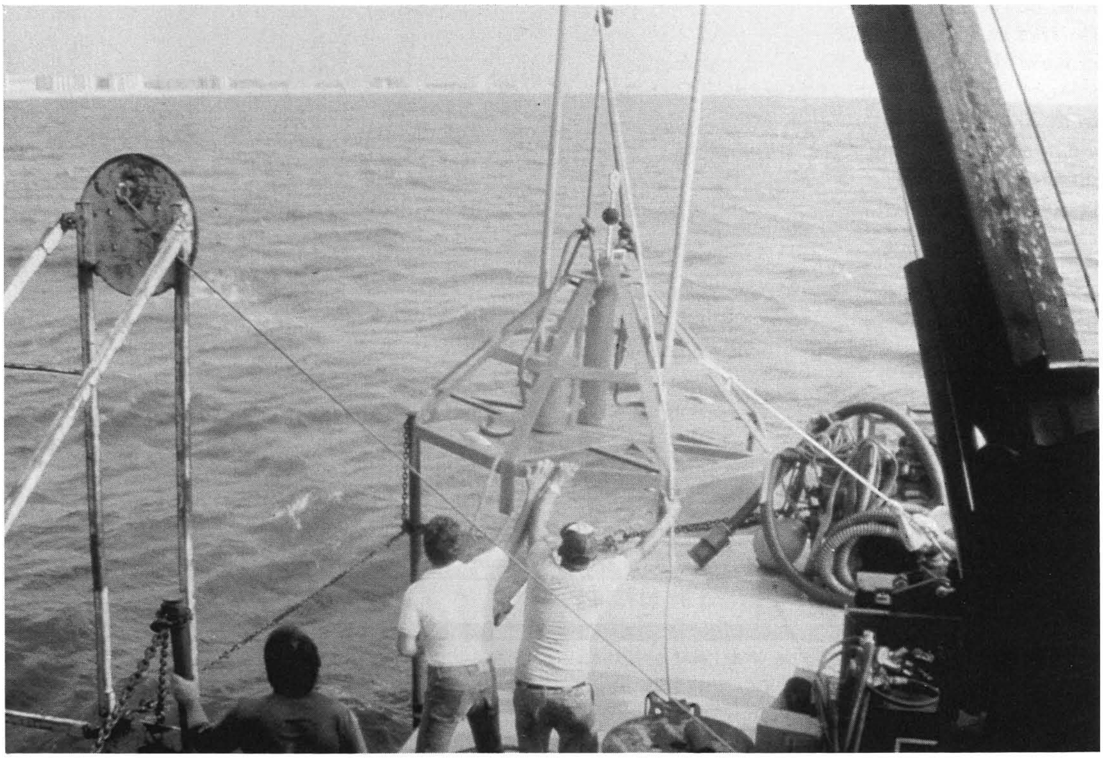

Figure 11. Sea Data 635-12 self-recording directional wave gage. Often, deployment can be accomplished using less sophisticated on-board equipment.

affected by fouling, if it is bottom mounted, it can require the same diver servicing as Puv meters for data retrieval. Because of its cost, deployment of the meter must be accomplished with considerable thought, since loss would be expensive (Figure 19). The chance of instrument loss is a serious consideration in determining where to use the instrument. Although the meter can acquire current data in as shallow as two or three meters, it is unlikely that the limited data that could be acquired are worth the risk of instrument loss associated with such a shallow deployment.

WATER LEVEL MEASUREMENTS

Traditionally, water level measurements have been obtained using instruments with stilling wells. More recently, both pressure sensing and surface piercing instruments have been employed. The traditional stilling well tide gages (Figure 22) have provided records on long period waves for years and are generally the instrument of choice. They have the advantages of accuracy and low cost (Figure 23), but they require a structure and are quite large, making them vulnerable to damage by vessels or vandals (Figure 24). When considering the use of a stilling well instrument, one serious consideration has to be the tide range. In areas of large tidal fluctuations and flat nearshore slopes, for example, the gage must be sited far out on a pier or other structure and use a substantial stilling well (Figure 25). Progress is being made in replacing float and bubbler gages with laser measuring instruments. At present, most stilling well gages measure water level inside the well using a float. Bubbler gages use rate of release of nitrogen from an orifice on the bottom to measure the pressure of the water column above the orifice and infer the water elevation. Laser gages will use the reflection of the laser from the water surface. While this represents an improvement, it still has not elimi-

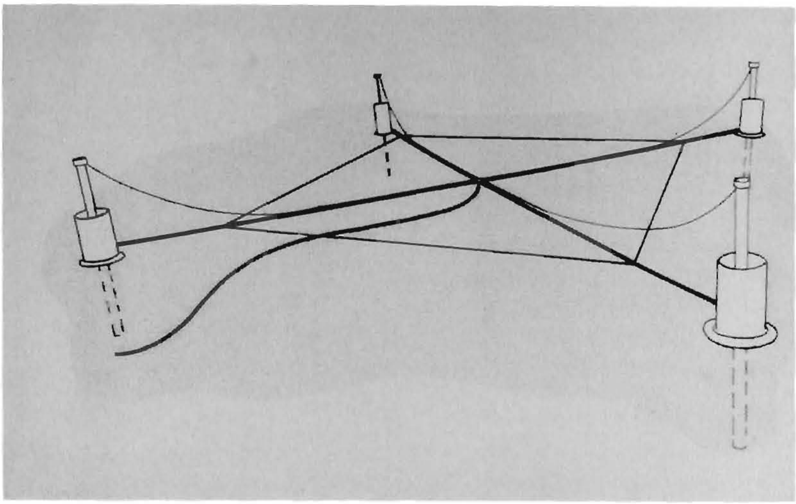

Figure 12. Slope Array. While only three sensors are required, four are often used for redundancy and located at the corners of a square frame.

Figure 13. Slope array deployment.

nated the requirement for a stilling well, since problems exist with spurious reflections from high frequency waves.

Pressure sensing devices are similar to those used for measuring wave heights (Figure 26) and can even be the same. Long period waves can be measured directly by a sensor set to measure those waves or by averaging the wave records (MCGEHEE *et al.*). Figure 23 shows the advantages of a pressure sensing water level recorder, and it can be seen that they are the same as those for pressure sensing wave gages. Their disadvantages (Figure 24) are also the same, as are the deployment considerations (Figure 25).

Surface piercing gages can be used just as the

DEPLOYMENT CONSIDERATIONS

	LINEAR	SLOPE/CURVATURE	ARRAYS	PUV METERS	BUOYS
1. WATER DEPTH	x	x		x	x
2. SHIPPING ACTIVITY					x
3. BOTTOM	x	x			x
4. RADIO INTERFERENCE					x
5. MOUNTING SYSTEM				x	
6. MAINTENANCE SCHEDULE	x	x		x	x
7. REDUNDANCY				x	
8. FISHING ACTIVITY				x	
9. STRAIGHT PARALLEL CONTOURS PREFERRED	x	x			
10. MUST BE EASILY ACCESSIBLE	x				

Figure 14. Directional waves—deployment considerations.

pressure sensing instruments in measuring water level. Data collection can be set to measure long waves directly, or they can be obtained from averaging wave records. It must be recognized, though, that accurately locating the water surface, relative to a datum, is more difficult when using a subsurface gage than one located on a structure and therefore relatively easily surveyed to local monuments. Figures 23 through 25 list the advantages, disadvantages, and deployment considerations for surface piercing gages, which are quite similar to those for wave measurements using the same gages.

WIND MEASUREMENTS

Wind measurements are often forgotten in development of monitoring programs. Data on the direction and magnitude of winds are considerably easier to obtain than oceanographic measurements because the instrument does not have to be in the water (Figure 27). These data are of value to the coastal engineer or planner, because they are so often available when wave data are not. From wind data, considerable information may be derived about the wave cli-

Figure 15. LEO observer making beach slope measurements.

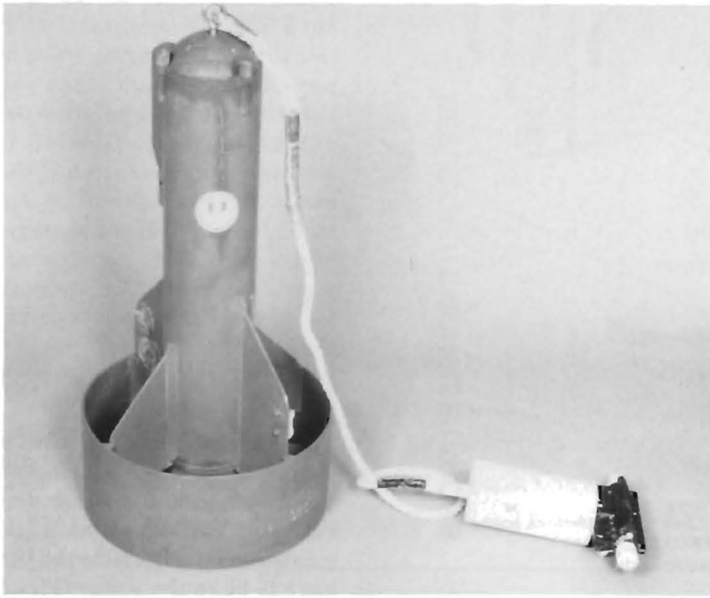

Figure 16. Ducted impeller current meter.

ADVANTAGES

	DOPPLER ACOUSTIC METERS	ELECTRO-MAGNETIC METERS	DUCTED IMPELLAR METERS
1. SURFACE DEPLOYABLE			X
2. RELATIVELY INEXPENSIVE			X
3. EASILY MOORED AT VARIOUS DEPTHS			X
4. DATA COLLECTION FLEXIBILITY			
A. REAL TIME	X	X	X
B. ON BOARD	X	X	X
5. FLEXIBLE SITING		X	
7. HIGH RESOLUTION	X		
6. FAST RESPONSE	X		
8. PROFILE ENTIRE WATER COLUMN	X		
9. LOW MAINTENANCE	X		

Figure 17. Currents—advantages.

mate, so even when funding does not allow the installation of oceanographic instrumentation, wind instruments should be considered. A good anemometer provides data of adequate accuracy for little cost and is easily installed on any structure near the beach. For more accurate over-water data, several buoys are available that can be deployed nearshore and most NOAA buoys are equipped with meteorological instrumentation. Even data from a nearby airport can prove invaluable to the engineer when other data are not available.

SUMMARY

Data collection for coastal projects may sometimes seem expensive, but there is no alternative to having good information in the planning and design process. Many millions of dollars are spent to design and construct projects that then cost many more millions to maintain. With adequate data, at a cost of usually much less than ten percent of the project cost, information on waves, currents, and tides could be obtained with the potential for reducing the cost of maintenance alone significantly. Obtained during

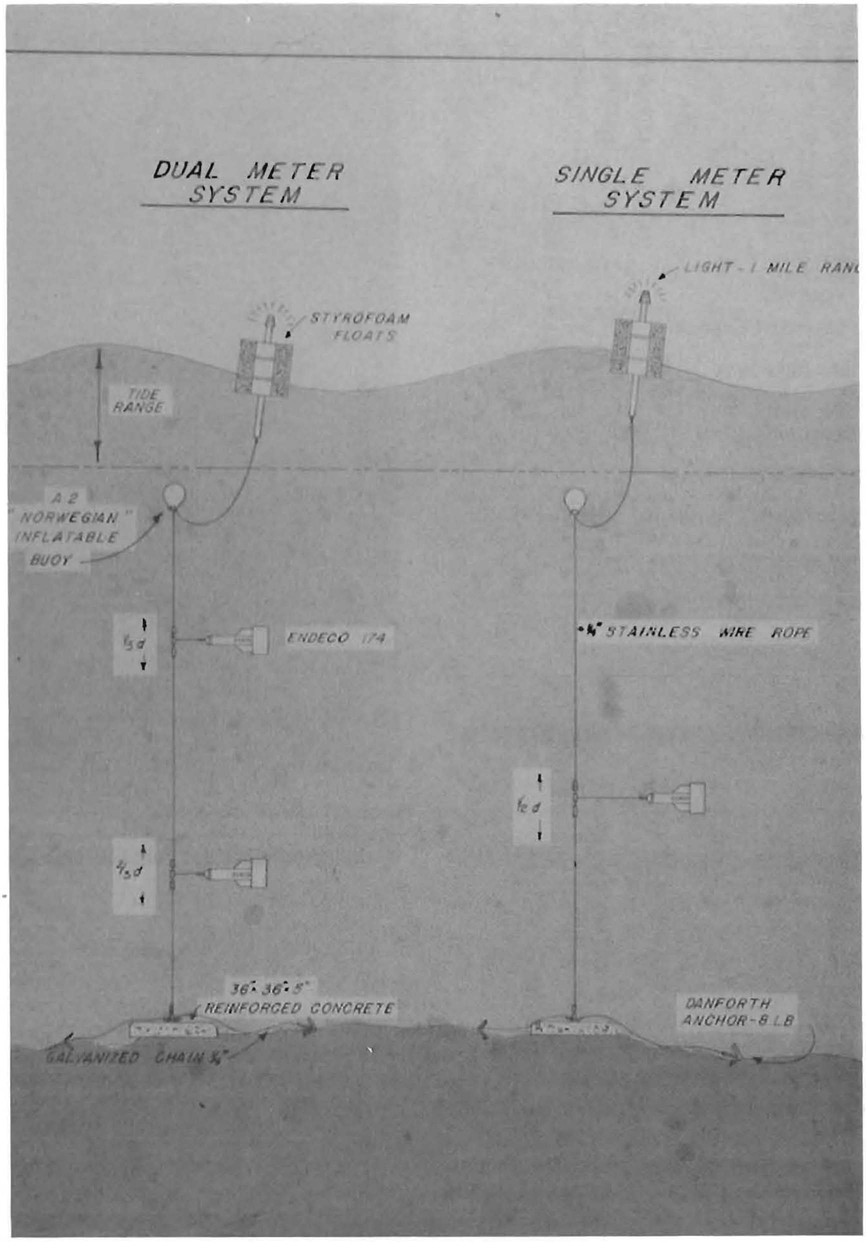

Figure 18. Possible current meter deployment.

DISADVANTAGES

	DUCTED IMPELLAR METERS	ELECTRO-MAGNETIC METERS	DOPPLER ACOUSTIC METERS
1. SUSCEPTIBLE TO			
A. FOULING	X	X	?
B. SEDIMENT DAMAGE	X		
2. SLOW RESPONSE	X		
3. POOR ANGULAR RESOLUTION	X	X	
4. LIMITED DATA STORAGE	X		
5. RELATIVELY EXPENSIVE		X	X
6. EXPENSIVE TO MAINTAIN		X	
7. POINT DATA COLLECTION	X	X	

Figure 19. Currents—disadvantages.

DEPLOYMENT CONSIDERATIONS

	DUCTED IMPELLAR METERS	ELECTRO-MAGNETIC METERS	DOPPLER ACOUSTIC METERS
1. LOW SUSPENDED SEDIMENT LOAD/ BIOLOGICAL FOULING	X	X	
2. SHORT TERM DEPLOY-MENT	X		
3. FISHING/BOATING ACTIVITY	X	X	X
4. MOUNTING SYSTEM		X	X
5. MAINTENANCE SCHEDULE	X	X	
6. REDUNDANCY		X	
7. WATER DEPTH		X	X
8. SUSCEPTIBLE TO LOSS			X

Figure 20. Currents—deployment considerations.

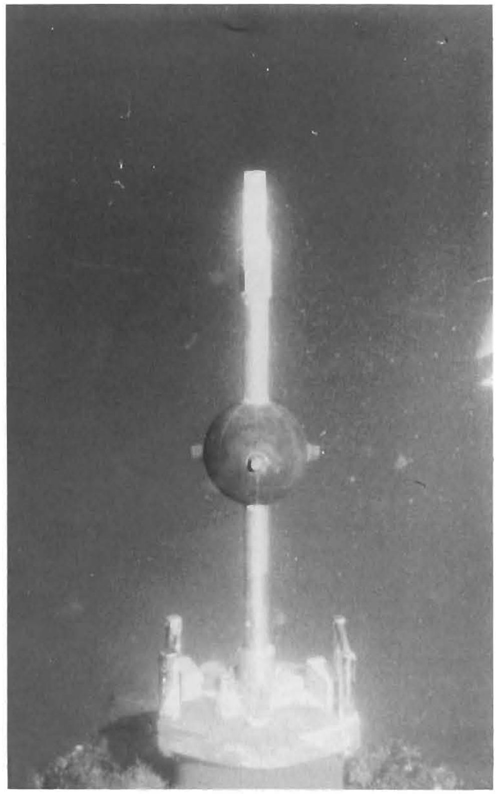

Figure 21. EM current meter.

Figure 22. Stilling well tide gage.

DISADVANTAGES

	STILLING WELL	PRESSURE SENSING	SURFACE PIERCING
1. VULNERABLE	×	×	×
2. BULKY	×		
3. REQUIRE STRUCTURE	×		×
4. DIVERS OFTEN REQUIRED		×	×
5. EXPENSIVE TO MAINTAIN		×	
6. DIFFICULT TO ESTIMATE ELEVATION		×	×

Figure 24. Water level—disadvantages.

ADVANTAGES

	STILLING WELL	PRESSURE SENSING	SURFACE PIERCING
1. ACCURATE	×	×	
2. INEXPENSIVE	×		×
3. COMPACT		×	
4. DATA COLLECTION FLEXIBILITY			
A. REAL TIME	×	×	
B. ON BOARD	×	×	
5. FLEXIBLE SITING		×	
6. OTHER DATA POSSIBLE		×	

Figure 23. Water level—advantages.

DEPLOYMENT CONSIDERATIONS

	STILLING WELL	PRESSURE SENSING	SURFACE PIERCING
1. SECURE STRUCTURE	×		×
2. PROXIMITY TO SURVEY MONUMENT	×		
3. TIDE RANGE	×		×
4. WAVE ACTION	×		×
5. MOUNTING SYSTEM		×	×
6. MAINTENANCE SCHEDULE		×	
7. REDUNDANCY		×	
8. FISHING ACTIVITY		×	
9. WATER DEPTH		×	

Figure 25. Water level—deployment considerations.

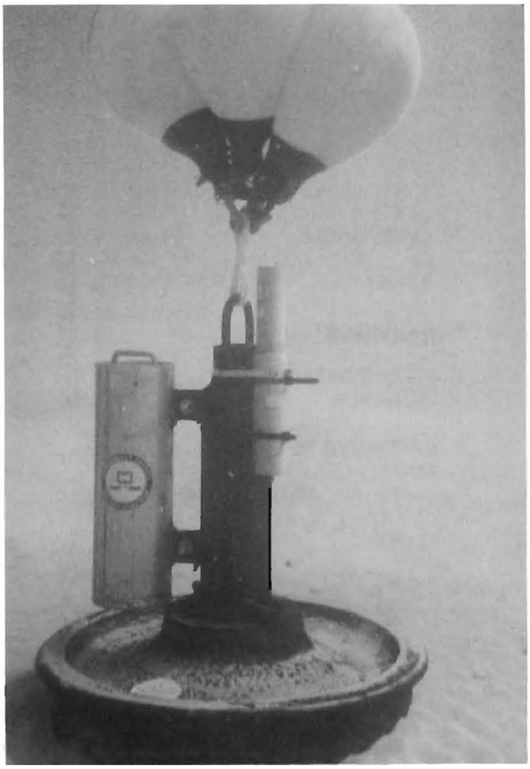

Figure 26. Sea Data TDR (temperature, depth recorder). Railroad wheel deployment.

the planning process, data collected can help refine a design.

Not every instrument is appropriate in every situation. Hopefully, this paper has provided information that will be useful in designing a monitoring effort and tailoring it to the specific requirements of the project.

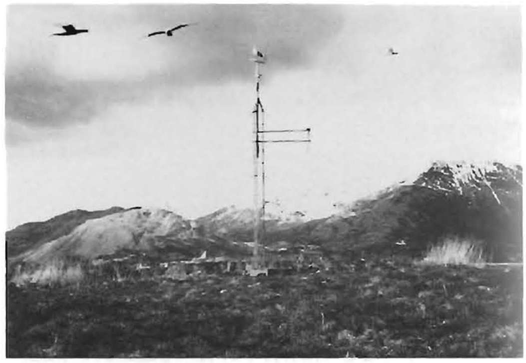

Figure 27. Anemometer.

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□ RÉSUMÉ □

Il est difficile de faire un choix parmi les instruments de mesure en océanographie côtière. Peu nombreuses sont les personnes impliquées dans l'ingénierie côtière qui aient une expérience permettant de prendre des décisions bien informées, assurant ainsi l'utilisation du matériel le mieux adapté aux conditions particulières. Considérer quelques caractéristiques d'ensemble des matériels de mesure aideront à sélectionner celui qui apparaît le mieux adapté à l'effort engagé dans une collecte de données.—*Catherine Bressolier, Géomorphologie EPHE, Montrouge, France.*

□ RESUMEN □

Es difícil realizar la selección adecuada del instrumental necesario para realizar mediciones oceanográficas. Pocas de las personas que trabajan en el campo de la ingeniería oceanográfica tienen experiencia suficiente para elegir el aparato más adecuado en las diferentes circunstancias que se les plantean. Este artículo recoge algunas de las características generales de los distintos tipos de aparatos de medida, con el fin de ayudar en la selección del más adecuado para la toma de datos.—*Department of Water Sciences, University of Cantrabria, Santander, Spain.*

□ ZUSAMMENFASSUNG □

Die Auswahl von Geräten für küstennahe ozeanographische Messungen ist schwierig. Nur wenige, die sich mit Ingenieurstechnik im Küstenbereich befassen, haben die Erfahrung, um sachkundige Entscheidungen über die für die jeweilige Problemstellung geeignetsten Meßgeräte treffen zu können. Die Beachtung einiger allgemeiner Merkmale von Meßgeräten wird bei der Auswahl des für eine Sammlung von Daten besten Typs helfen.—*Helmut Brückner, Geographisches Institut, Universität Düsseldorf, F.R.G.*