Coastal Engineering
Technical Note

Developing Monitoring Plans for Completed Coastal Projects

The Monitoring Completed Coastal Projects (MCCP) Program funds work units that evaluate the performance of projects in their design environment. The objectives are to verify the design methodology and make recommendations to the Districts that contribute to reduced operation and management costs. Conclusions regarding the effectiveness of a design or recommendations for future maintenance practices should be based on observations. The complexity of the physical processes and the lack of available measurements in the coastal zone usually require each work unit to obtain a data base as part of its study plan. A detailed monitoring plan is essential to obtain reliable and useful data. The monitoring plan is an integrated process that includes defining data needs, developing an analysis plan, specifying functional constraints, selecting a data capture scheme, and designing a measurement system.

DATA NEEDS: Defining the data needs is more involved than simply picking measurable parameters as a prelude to instrument selection. Sometimes the most critical quantities to measure in understanding and predicting a process are not the ones intuitively obvious. The most productive approach is to state hypotheses that address each essential design objective, and then develop a verification methodology and a monitoring plan to test those hypotheses. For example, the requirement that no more than a designated percentage of a beach fill migrates outside of a boundary over a designated interval could be verified directly by monitoring the fill's response over that interval, assuming the engineer could wait for the answer. Usually, though, it is necessary to predict future performance or extend the lessons to other locations after a limited observation period. These projections must be based on hypotheses concerning sediment transport processes, the fill's physical properties, and the forcing functions to which the fill responds; i.e., a model of the system.

Validation of the model requires data on both deterministic variables - sediment characteristics, the fill's initial and progressive geometry - and the stochastic hydrodynamic conditions at the site - primarily wave, tide, and wind-induced currents. Since the forcing functions are random, the time at which a response will occur cannot be predicted, but the probability of a response occurring can be estimated. This requires calculating the probability distribution over time of the random variables, either directly by extrapolation of the observations or indirectly from a second hindcast model. The latter may require additional data for calibration. (An underlying hypothesis is that the system can, in fact, be modeled.) The monitoring plan would be designed to provide a sufficient amount of the specific data needed to calibrate and verify the various models and calculate the statistical parameters. How much data would be sufficient is discussed under Functional Constraints, below.

ANALYSIS PLAN: An analysis plan is a set of data reduction equations that document the process of transforming the raw data into quantities that can be used in the verification methodology. Defining the finished data base and the format of its presentation, whether tabular, graphical, or through statistically derived parameters, helps insure the hypothesis will be adequately tested. The analysis plan provides several important benefits early in the study.

- It eliminates the collection of costly but unutilized data sets.

- The resolution and accuracy required from each measured parameter to produce acceptable confidence in the results can be determined using uncertainty analysis on the data reduction equations.

- Since the data reduction software can be developed and tested in advance with simulated input data, data results are available sooner. This allows better quality control as well as faster study schedules.

FUNCTIONAL CONSTRAINTS: When data needs are defined, the functional constraints the system must operate within and still meet those needs can be specified. Initial scheduling and budgeting can also be done at this stage, since time and money are the ultimate engineering constraints. The planner should consider the environment from which the observations will be taken; logistic aspects of building, transporting, deploying, maintaining and recovering the monitoring system; the instrument capabilities and limitations; and the political, i.e. fiscal and legal, aspects.

The physical aspects of the environment which must be considered in designing the monitoring system include: water depth; anticipated extreme wave and current conditions; temperature range, including ice formation; occurrence of high suspended sediment concentrations; degree of biologic activity that might affect sensors or measurements; and fluctuations of weather at the site. In the category of geomorphic factors are: bathymetry, including distance offshore to the monitoring site; adjacent shoreline orientation and/or basin shape; proximity to nearby structures, inlets, shoals and other flow modifiers; and bottom composition.

Logistic aspects are those that affect equipment installation, maintenance and removal such as: availability of support equipment and personnel; transport and delivery of all components; accuracy and resolution requirements of sensor positioning offshore; life expectancy of system components; and, most importantly, risk of loss or damage to the system components.

While physical conditions, (waves, currents, etc.) may endanger instruments and support equipment, by far the highest risk comes from human interference. In the coastal zone in particular, boating and fishing activity is so prevalent that an encounter is almost inevitable. Malicious vandalism may occur, but the bottom-dragging trawler is usually more devastating to floating and fixed equipment alike. Efforts to publicize the schedule and location of instruments to the fishing community are beneficial, but a period of attrition before the existence of the "snag" becomes known to the fleet can be anticipated. In areas where this type of fishing occurs, the monitoring equipment must be designed to be as resistant as possible to impact with the trawl gear.

The most critical scheduling decision is often the most difficult - how long to monitor? If the data are to be used to drive a deterministic model, then it is necessary to obtain a sufficient range of each parameter to insure the model performs over the anticipated conditions. In a high energy environment, this might occur over one year, or even a season. A site in the Gulf of Mexico, on the other hand, may experience years of relative calm during which there is little response of the project; then a single hurricane could remove it overnight. The schedule is by necessity flexible.

If the data will be used to develop a "climate" projection through statistical extrapolation, the schedule is usually based on economic considerations, since the quality of the predictions is directly related to the quantity of data. A general rule of thumb is to measure for approximately one half of the design return interval, but this is rarely done in practice. Projections based on observations of less than three years are, in general, not recommended.

While the ending date of the monitoring plan can be elusive, the start date can be more reliably fixed, though no less variable. Lead time to assemble and deploy the final system can vary from days, for off the shelf instruments in accessible locations, to years, for complex, custom systems at remote and/or hostile sites. In all cases, however, ample time should be allowed to obtain permits, access rights, and easements, and resolve ownership and liability issues. Activity in the coastal zone is regulated by a number of state and federal agencies, including the Corps of Engineers.

Finally, the system must fit within the available budget. The temptation to reduce costs by lowering instrument standards, using lighter, cheaper hardware, or extending maintenance intervals may result in no data at all. If necessary, it is preferable to economize by limiting the quantity of data collected, either by the duration of the study or the number of observation sites, than to degrade the quality of the measurements or accept higher risks through less robust gear or fewer back-up systems. There are always unanticipated failure modes; redundant gaging is one defense against data loss. Reliability is the most expensive commodity in ocean monitoring, but it is a worthwhile investment.

DATA CAPTURE: The fourth major element of the planning process is specifying the data capture scheme. This is the data's flow path for each step from the sensor's output signal to the archived data base. It will involve decisions regarding: the sampling scheme - frequency, duration and interval of sensor output sampling; signal processing - how the sensor output is converted, combined with other signals, sorted, sequenced, and routed; data recording - on site or telemetry; data storage medium; data base management; analysis schedule; quality control/quality assurance procedures; report products and format. The end use of the data products will have a significant impact on the schedule for their delivery, and thus the design of the capture scheme. Monitoring a completed project for research uses may allow the luxury of report preparation after the completion of the monitoring period. Operational use of the data, for example to make decisions regarding construction or repair techniques, would require near-real-time data telemetry, analysis, qualification and presentation.

SYSTEM DESIGN: By this point the requirements of the actual instrument and support equipment should be specific enough to allow detailed design and selection. Sensors must have the accuracy and resolution required by the analysis plan. Instrument capabilities regarding power, memory size, deployment interval, etc., will be dictated by the capture scheme. Pressure housings, mounts, supports, platforms, buoys and other system components will be designed to meet the logistic and environmental constraints.

Because of the variety of study requirements and operating environments, there is no standard instrument type that will be appropriate for all situations. Often, custom-designed systems or even sensors are the only alternative to obtain required data. However, some general rules of thumb have been developed and certain sensors have proven more reliable in measuring the parameters mentioned previously; wind, waves, water levels and currents.

Rotating cup-and-vane type anemometers are typically used on ships and buoys to measure wind speed and direction. They are relatively low cost and simple to install, but not particularly rugged, due to their small size and the need to maintain two rotating bearings in a corrosive environment. A slight improvement in reliability is gained using a hot-film type of sensor; the rotating cups are replaced by a heated wire whose heat transfer rate is dependent on wind velocity. This eliminates one rotating part (direction must still be obtained by a vane that aligns with the wind) but sacrifices accuracy, as precipitation - even relative humidity - affects the calibration.

The pressure transducer, by contrast, is a rugged, reliable sensor that can survive extended periods above or below water. A subaerial transducer provides barometric air pressure readings. The pressure time series from a submerged, bottom-mounted transducer can be analyzed for variations in surface elevations at a wide range of frequencies from sub-tidal to several hertz. Thus, a single sensor can serve as a tide gage, a storm surge gage, and a wave gage. Traditional float and stilling-well tide gages, by comparison, require a robust surface-piercing structure at the measurement site and are susceptible to biofouling and jamming.

Currents have been measured for decades with rotating impeller-type current meters. Developed for fresh water or deep-ocean use, they do not fare well in the coastal zone because of the likelihood of clogging by biofouling or floating debris and the erosive effect of sediment-laden water on the bearings. By contrast, the electromagnetic current meter uses electrodes to sense induced voltages caused by moving water. It is compact, rugged, and has no moving parts to foul, erode or clog. It will still require routine cleaning of attaching organisms at intervals ranging from two to six months, depending on local conditions, to maintain accuracy.

By combining a pressure transducer with an electromagnetic current meter, reliable estimates of near bottom currents, directional wave characteristics and water level fluctuations can be obtained. With proper design and integration into a complete system, this sensor package usually offers the most cost effective option for obtaining long-term (multi-year) continuous data sets of these parameters (McGehee 1989). If current data are not required, an even more reliable instrument is the slope array. Three or more pressure transducers spaced in an array on the bottom will provide accurate directional wave and water level measurements (Howell 1990) with no more than annual routine maintenance.

SUMMARY: Development of a monitoring plan should include investigations into the analysis and eventual use of the data prior to system design. Planning and proper design can produce a cost-effective system to meet the requirements for monitoring completed coastal projects. Consultation with measurement experts familiar with the local environment should be initiated early in this process.

ADDITIONAL INFORMATION: Contact Mr. David D. McGehee, CEWES-CD-P, (601)634-4270, or Mr. Bill Preslan, CEWES-CD-P, (601)634-2020, directly.

Howell, Gary L. 1990. "CERC's New Nearshore Directional Wave Gage," Proceedings of the 53rd Meeting of the Coastal Engineering Research Board, Coastal Engineering Research Center Waterways Experiment Station, Vicksburg MS 39180, pp 90-93.

McGehee, David D. 1989. "A Remote Measurement System for Monitoring Waves and Currents at an Offshore Dredge Disposal Site," Coastal Engineering Technical Note I-II, March 1989, US Army Engineer Waterways Experiment Station, Vicksburg, MS.