Chapter 18
Coastal Engineering Surveys

18-1. Introduction

This chapter addresses guidelines and considerations for planning the type and scope of beach and nearshore surveys and provides an overview of the methods used to perform these types of surveys. An important component in this process is understanding and selecting the appropriate survey tools to collect data that meet project requirements and needs of data end users. Guidance in this direction will be valuable in assisting project planners, designers and surveyors in reaching a common knowledge base for specifying and cost estimating effective survey data collection programs. This chapter also presents summary information on traditional, as well as, newer technologies for surveying. The US Army Coastal Engineering Research Center (CERC--now Coastal and Hydraulics Laboratory) developed most of this chapter in 1998.

Figure 18-1. Coastal surveys (Arc Surveying and Mapping, Inc.)

18-2. Background

Coastal projects of all types typically require extensive and accurate beach and nearshore survey data. Acquiring such data is a labor intensive (Figure 18-1), time consuming and complex process, and it is often difficult to establish the success and quality of the data set after the fact. Part of this problem can be attributed to a lack of consistent guidance for planning, conducting, and properly evaluating coastal surveys. Guidance is lacking especially for defining survey requirements based on the eventual end-use of the data. To date, there are no definitive industry or Federal standards designed to cover these types of survey requirements. Most beach and nearshore surveying standards being used today are based on local practice. Beach and nearshore surveys normally consist of five general survey types: beach profiles, nearshore borrow areas, ebb deltas, coastal structures, and special projects such as dredged material placement (Figure 18-2). For example, surveys are necessary in order to determine construction progress and payment for most of the typical project types. However, the amount and precision of the required survey data may differ between a beach fill project and jetty project. Beach surveys are also performed to monitor beach renourishment projects along the Atlantic and Gulf Coast--common in Jacksonville, Philadelphia, Norfolk, and New York Districts. Hydrographic surveys are performed during design to locate suitable offshore sand sources. During beach pump out operations, profile surveys are run to check placement and compute material quantities placed on the beach.

Figure 18-2. Beach renourishment project--Miami Beach, FL (Jacksonville District)

a. The exact end use may vary, but the essential goal of most survey projects is to characterize the features of a relatively large area, often the equivalent of several square miles. The principal type of survey used to accomplish this has been a series of profile lines and this is the most familiar type of technology still in use. However, there are a variety of newer technologies and alternate approaches available for coastal surveying, summarized later in this chapter. In addition, the same basic technology frequently can be used or applied in more than one way to produce results, which vary in accuracy, coverage density, time, cost and other factors. Interest in these approaches arises from concerns about the numerical inaccuracies of interpolating between traditional profile lines and the possibility of significant bathymetric anomalies being hidden in the blind areas between profiles. Alternate approaches that could provide denser data coverage even at the expense of having less precision in individual measurement points may produce an overall result that better represents those features important to the project.

b. It is important to match the surveying scope, including the selected technology and procedures, with the true requirements based on the eventual data use and it is essential that survey specifications originate from the project's functional requirements and that the requirements are realistic and economical. However, too frequently a survey method is pre-selected based on a combination of peripheral factors, and this selection in effect defines the type, accuracy and characteristics of the data. Surveying a coastal structure, for example, requires a different effort than documenting general changes on a dynamic beach several times a year; reconnaissance or condition surveys may be able to use less accurate, but broader covering, faster technologies than "pay" surveys. If numerical models require profile-type data eventually to be extrapolated and converted into gridded depths or contours, the data can be collected in that manner to start with if the need is identified as part of the surveying scope. Data end-users must have and be able to communicate a complete understanding of their needs.

c. A related issue is who should be responsible for specifying, defining or otherwise deciding among choices for each technical question. In almost all cases the in-house survey branch will ultimately be responsible for accomplishing the work, but limitations on the number of in-house crews and their workload often result in the work being contracted. For most reconnaissance, planning, design and similar projects, the surveys are performed by A-E or specialty surveying firms under delivery order contracts. For construction progress, as-builts, or pay measurement, especially on dredging-related projects, the surveys are often part of the construction contractor's scope of work and are spot-checked by in-house crews.

d. In both basic scenarios, however, a critical point is that the work is often done by outside personnel not under the direct supervision or coordination of the end users. Once a survey request goes from the originator/end user into the survey branch/contract system, there is a danger that the originator no longer has control nor input, and the final surveying contract specifications and standards may not address the original requirements. This type of situation underscores the importance of ensuring a high level of awareness and communication on the part of all the people involved in the data collection planning and decision-making processes for a project.

18-3. Beach Profiling Surveys--General Procedures

Coastal beach surveys are performed in support of beach erosion and/or hurricane protection projects, primarily to measure and monitor beach renourishment placement or condition, or for construction payment of beach fill placed. These surveys combine land topographic cross sections with offshore hydrographic sections.

a. Beach profiles (i.e., cross sections) are run perpendicular to the shoreline relative to fixed monuments on an established baseline or coastal setback line--see Figure 18-3. The fixed baseline is normally established well beyond (inland from) the dune line to ensure permanency for subsequent surveys. Permanent reference azimuths are established for each profile line. Profile elevations are obtained using boats, sleds, aircraft, hand-held rods, and other measuring platforms described in the remainder of this chapter.

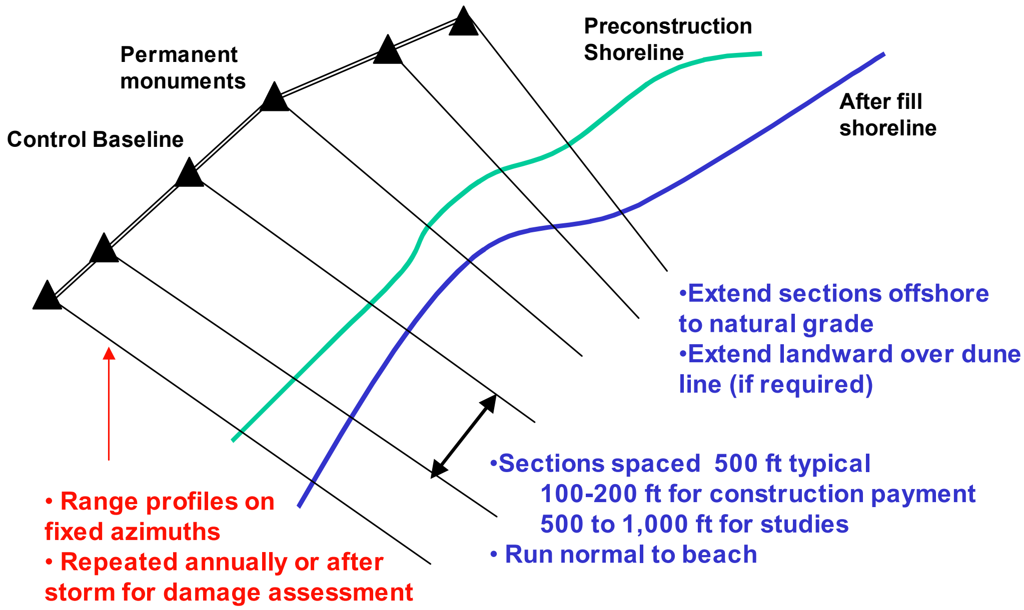

Figure 18-3. Standard configuration for beach profile lines

b. Profile spacing is highly project-dependent. For general coastal erosion studies it may be from 500 to 2,000 ft, depending on the regularity of the coast. Beach renourishment construction measurement surveys for payment require denser spacing--typically at 100- to 200-ft intervals.

c. The junction/overlap point between the two surveys is critical and often subject to large error, especially when heavy surf conditions are present or where tidal modeling is uncertain. Land sections are run at low tide, and are extended as far as possible with the rodman wading into the surf. These concepts are illustrated in Figure 18-4. To obtain maximum overlap, the hydrographic portion of each profile is run at high tide, with the boat operating as close to the beach as surf conditions will safely allow. In heavy surf conditions, survey errors can approach 5 ft; thus, maximum reliance/weight should be given to land-based topographic profiles. The same reference baseline station is used for both land and water sections. Positioning and depth measurement may be accomplished by any acceptable method.

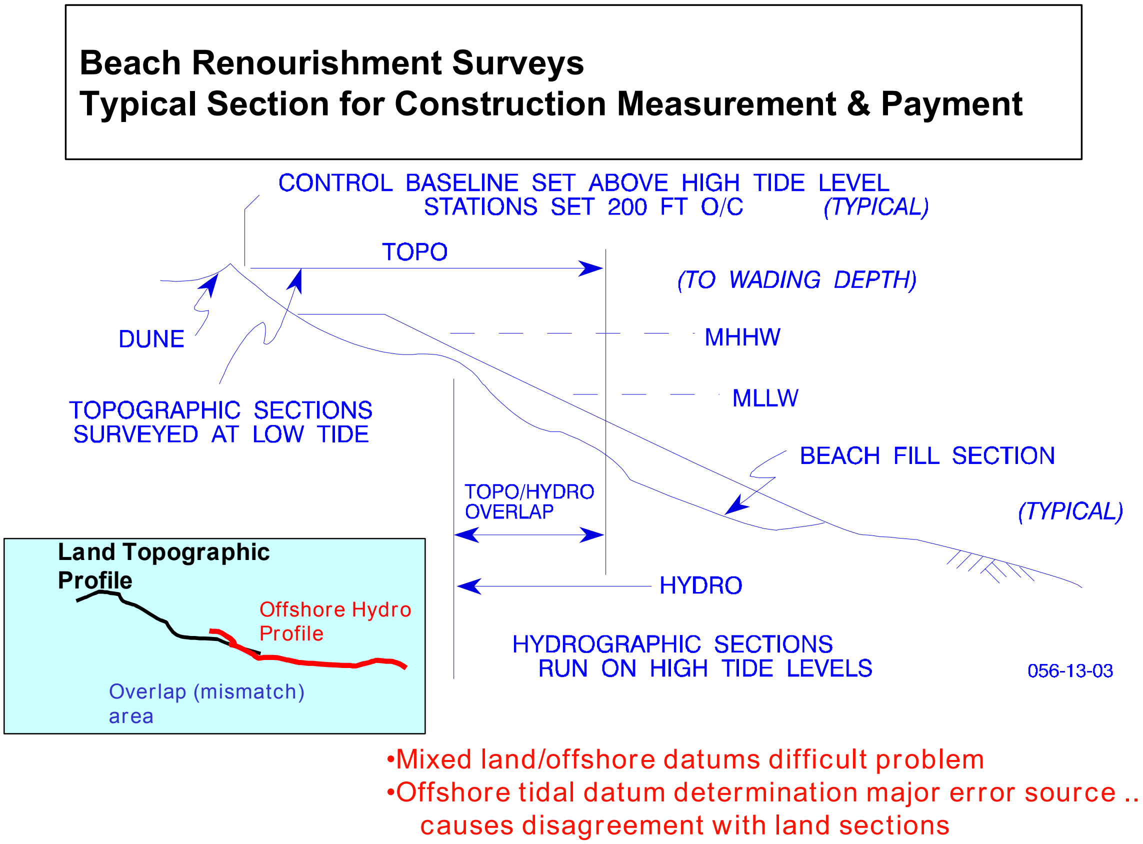

Figure 18-4. Running land and offshore hydrographic sections

d. Some beach protection projects are jointly funded by federal, state, county, city, or other agencies. The land sections to be surveyed may be bounded on the land side according to state tideland boundaries. The many different state laws may appear to be complex to a federal surveyor. Specific procedures for determining these tidal boundaries are usually defined by state regulations.

18-4. Accuracy Requirements

a. The accuracy of beach and nearshore survey data is often stated as a major concern, but accuracy frequently means different things to different groups. Accuracy should be broadly viewed as more than the ideal or theoretical accuracy associated with a particular instrument or system. It includes operational influences such as the site conditions, overall field collection and data reduction procedures used, and any constraints due to datum problems, lack of monuments or other control, or historical incompatibility. Project data planning goals should be less directed toward improving absolute or ideal accuracy and more toward properly understanding, characterizing and communicating the errors and limitations in existing or proposed systems and procedures. The calculation and presentation of realistic error bands on all data is consistent with and supports the trend toward risk-based analyses in project design

b. Although they may recognize the need to do so, many end-users are unable to identify a specific use or type of analysis, which directly translates into a requirement for nearshore hydrographic survey accuracy, spacing or a similar standard. In addition, situations sometimes occur in which ambiguous project goals, together with the inherent lack of precision in many coastal engineering design tools and other inputs such as wave data, result in project personnel feeling that survey precision is not their highest priority. This point can be especially contrasted by surveys in the planning community with the requirement for 3rd order accuracy in real estate maps and the dramatic effect which inaccuracies in that type of data (i.e. building floor elevations and foundation positions) could have on the calculation of project storm damage reduction benefits. It is often recognized that a more formal, comprehensive error analysis to establish the effect of survey limitations on a particular project or calculation should be performed in order to better assess risk and uncertainty, but resources are not typically available for the necessary effort.

18-5. Data Density, Formats, Processing and Archiving

a. The issue of data density or coverage is closely related to accuracy and end-use. A general phrasing of the problem might be: "what changes, features or other data are really important?" Newer technologies are capable of rapidly collecting data over entire surfaces rather than profile-by-profile. However, the trade-off is in additional processing time and computing power, QA/QC difficulties in terms of checking such data, and very significant storage requirements. Procedures for intelligently editing or "decimating" can be developed, but the basic question is more one of knowing how much data is necessary to adequately characterize the site or problem of interest.

b. Some survey sections are still working with paper copies of profile line and "spot" elevations on plan views, however, most district end users use processed data provided to them on disk or tape in one of the many standard CADD formats. This makes subsequent calculations and data manipulation very convenient and is one of the derivative positive results of using outside private surveying contractors.

c. A negative aspect with the more highly pre-processed data is that the user is no longer directly involved in data reduction tasks such as corrections for datum, tides, or waves and does not develop an intuitive appreciation for the variability and limitations of the data. Because the raw survey data itself is no longer "handled" directly by the end users and survey data files often are not plotted and inspected for their own merit, major errors may not be noticed until problems subsequently develop while performing calculations or interpreting model results. By that point the survey data has been so co-mingled with other potential data problems and issues that it may take considerable time and effort to identify the survey as the source of error.

d. Whether the ultimate purpose of a set of surveys is planning, design, construction or pay, the intermediate step in all projects is some type of volumetric change calculation. These calculations are most often performed using a software program, which automates some type of algorithm involving interpolations, point-by-point differencing and extension of 2-dimensional area changes to 3-dimensional volumes. The use of "high resolution" technologies has subsequently established the ability to compare 3-dimensional surfaces derived from digital terrain matrices (DTM).

18-6. Coastal Processes Affecting Surveys

a. The coastal margin is a unique physical environment and as a result, it presents unique challenges for collecting and interpreting all types of data including survey data. The coast is the triple interface of the atmosphere, ocean and land (USACE, 1984). Surveying this interface cannot be done through the straightforward application of conventional terrestrial surveying principles; neither can adequate data be collected exclusively with traditional hydrographic surveying techniques. Both approaches - used with innovation, creativity and intuition - are necessary to properly characterize the beach and nearshore environment.

b. Unlike most terrestrial sites, the coastal margin changes and moves constantly, even within time frames as short as the time of the field survey itself. The coast is said to exist in a state of dynamic equilibrium. That is to say, it is shaped by a unique balance among wind, waves, tides and sediment characteristics (USACE, 1984). The concept of dynamic equilibrium suggests that significant changes to one of these parameters can disturb the balance and produce a new system. Unfortunately for coastal engineers, planners and surveyors, sufficiently significant changes can occur within a time frame of hours, days and weeks.

c. Understanding the equilibrium condition at a particular site is further compounded by the fact that the natural forces producing the equilibrium may not be those observable on the survey day, nor even the average condition observable over a short period of time. Often extreme events or perturbations in the average energy condition are responsible for the equilibrium profile or other features observed weeks or even months after the event. This phenomena may be more important to the analyst reviewing the data set and drawing conclusions for design, but it is useful knowledge for the surveyor planning the program and collecting data in the field as well. A sufficient familiarity with the natural process can ensure that modifications to a scope are made, if appropriate, in the field based on conditions observed and that any atypical events or features are noted which might make data interpretation more meaningful to the problem.

d. Very frequently in coastal planning and design, historical data is either sparse or of questionable accuracy. The reasons for this are varied, but certainly can include a lack of past interest or concern in a site and its problems, or a lack of attention to properly archiving and describing a collected data set. One result of this problem is that the coastal professional may be required to hindcast a historical condition from a very limited present or short-term past data set, and then use the hindcast condition for forecasting a future condition. This process of predicting the future based, not on the "true" past but on a "prediction" of the past is not unique to coastal projects, but is certainly more common than in most other fields of engineering design.

e. This section briefly summarizes those coastal processes that most affect the collection of survey data and is necessarily a very brief overview because of the complexity of the subject. Also, while coastal processes occur at most sites, the range and significance vary greatly from site to site and requires specific analysis of the local conditions as part of the scoping phase. In addition, the problems associated with the physical environment are made more complex by the fact that different data end uses may require different accuracies and density. More detailed information on the natural environment is available from a number of references and resources including: EM 1110-2-1414, Water Levels and Wave Heights for Coastal Engineering Design; EM 1110-2-1810, Coastal Geology; EM 1110-2-3301, Design of Beach Fills; EM 1110-2-1502, Coastal Littoral Transport; The Shore Protection Manual (USACE 1984); and the series of Coastal Engineering Technical Notes (CETN).

18-7. Overview of Coastal Processes

As noted, the coastal margin is a dynamic system that can change significantly during the time it takes to complete the field portion of a survey program. The survey program planner must have an understanding of those features most likely to change, the range of variation, and the time scales associated with each. Some aspects of time scales are straightforward and familiar to most people collecting and using coastal data. For example, it is well understood that if the water level itself is being used for a reference plane, as in most hydrographic segments of a coastal survey, that level must be continuously corrected for tidal variation if the survey extends over an appreciable portion of a tidal cycle. For most traditional surveying methods, in contrast however, wave height variations usually are not individually corrected.

18-8. Time Scales

Classical oceanography introduced this same concept of a relationship between the length and time scales of various physical processes, called *Lagrangian times and scales.* Simply stated, the time frame over which a process is observed or measured should be consistent with the length scale over which the effect is felt. For example, a rough order of magnitude of the time scale for tidal cycles is $\sim 10^4$ seconds. At typical water velocities, the length scale of this single cycle should also be very roughly 10^3 to 10^4 feet. This type of analysis would suggest, therefore, that if a mile-long section of shoreline would require more than three to four hours ($\sim 10^4$ seconds) to survey, tidal influences could be significantly different at the starting point of the survey than at the ending point. While the process time scale influence may not be important for every survey or site, it is necessary to perform some type of scale analysis in order to establish the level of importance. This is especially true in using newer surveying technologies for which the influence of various factors is either unknown or unfamiliar to many users.

18-9. Waves

a. At most sites wave energy is probably the primary natural forcing function responsible for shaping the bathymetry and shoreline alignment (USACE, 1984). As waves approach the shore and move into shallower water depths, the water particles that have been set into orbital motion by the waves increasingly "feel" the sea floor. One effect of this is to transform a portion of the kinetic energy of the traveling waves into potential energy. The visible effect of this energy transformation is that the waves shoal or increase in height, growing steeper and more peaked, until finally they become unstable and collapse or break in the nearshore.

b. A second equally important, but perhaps somewhat less obvious effect, is that the friction imparted to the sea floor by the transforming waves produces a shear stress which may be sufficiently great to lift sediment into the water column and make it available for transport and redistribution. The wave-induced shear is usually too transient and non-directional to drive the sediment very far. However, once it is lifted into the water, other background currents such as those resulting from the angle the waves make with the shoreline, from tides, or direct wind stresses can take over and move the suspended sediment. In any case, the result is that the waves can move sufficient unconsolidated sediment to reshape the bathymetry. The altered bathymetry then produces a new set of water depths, which, in turn, transform the wave field differently. This iterative and continuous interaction between incoming waves and the nearshore bottom is one of the principal sources of complexity and dynamic change in the coastal environment.

c. A further complicating factor in this process is that the waves are not constant either in height or period. For illustration and rough planning purposes, waves are often characterized as regular or "monochromatic," meaning that successive waves in the incoming field are assumed to have the same, constant height and period, and the wave form is sinusoidal in shape. These assumptions result in mathematical simplifications which allow for the use of linear wave theories. However, real waves exist in an irregular spectrum composed of inter-mixed heights, periods, translation speeds and steepness. To an observer at a fixed point in the water, the passing waves appear as a varying time series. In addition, the time series observed on one day, at one location may be very different the next day at the same point, or the same day, but a few thousand feet away. A detailed analysis of such waves requires statistical techniques and so-called non-linear or "higher order" wave theories.

d. The reason such analyses are important and are performed in spite of their complexity is that wave energy and resulting sediment transport potential is proportional to the *square* of the wave height ($\sim H^2$). Alongshore variations in the wave time series cause gradients in energy which can be very significant in influencing local shoreline alignments and on the impact of any existing or proposed coastal structures or other alterations. In addition, because the water depth at which a wave begins to be influenced by bottom friction depends on the wave height and steepness, the different waves in the time series in a given section of shoreline will break over some cross-shore width (i.e. a range of depths) representative of the degree of variability in the wave series. This determines the width of the visible "surf zone" at any time and location, but is important because it may affect total sediment transport volumes and the position and prominence of features such as submerged bars or run-out channels.

e. The wave climate at a particular location is a combination of locally generated wind waves and (usually) longer-period waves that have traveled over some appreciable distance of open water. Local seas respond rapidly to changes in local winds and the arrival timing of waves produced by distant events is unpredictable. As a result, the time scale for significant changes in wave energy and its effect on local bathymetry is often on the order of hours or days. Field work begun at a project site before a weather front moves in, and completed a day or two after it passes when the waves have laid down enough to resume work may be capturing very different and unrelated conditions.

f. Because of the mathematical relationships among different components of all statistical distributions, even limited data or observations - as long as they are consistently taken - can provide insight into the entire wave climate at a site. One parameter often used is the *significant wave height,* H_S, which is defined as the average height of the one-third highest waves in the series. This is a convenient approximate field measure because experience has shown that this is the height an observer will tend to notice anyway when watching a variable time series. Accuracy can be improved by observing the waves for several minutes and comparing their heights, from trough to crest, to some reference object such as a range pole, rod, piling, pier, boat railing or similar. An associated representative wave period is determined by measuring the total time it takes for several waves (typically 20) to pass a fixed object and dividing the total by the number of waves. Several trials should be measured and compared. Lastly, a very rough approximation of the water depth at which a wave will begin to shoal and break is a depth between three-quarters and one full wave height (i.e. solitary wave theory breaking limit, $H_b \sim 0.78d$)

18-10. Currents

a. Along most sections of open coast any sediment suspended by wave action typically is transported parallel to the shoreline by background currents. These currents most often result from the fact that the breaking wave crests form some angle with the shoreline. Waves surging obliquely toward the beach and reflecting at the complementary angle produce net alongshore water movements which are roughly proportional to the size of the approach angle and the square of the wave height. These currents may be either reinforced or opposed by other water movements resulting from tides, local wind shear on the water column, or any similar force which results in a dynamic setup or mounding of the water surface differentially at one location compared to another.

b. Although alongshore transport currents are relatively weak under average conditions, they are persistent and can be much stronger during storms when the wave heights are larger and the seas more directional. The result is that the total sediment transport integrated over the width of the nearshore zone and over a long time period can be very substantial. Average annual transport can range from as little as 30,000 to 40,000 cubic yards to as much as 300,000 to 400,000 cubic yards; values as large as 700,000 cubic yards are not unheard of. The direct measurement of sediment transport has been attempted using traps and various optical instruments, but the techniques are cumbersome and results have been mixed. Most often transport is either predicted using one of several mathematical formulae based on wave height and angle (e.g. energy flux), or it is inferred from dredging records at nearby inlets, comparative surveys, or balancing sediment budgets.

c. Because most sediment transport is related to the wave climate at a particular location and time, the instantaneous transport magnitude and even the direction may change as the wave field changes. The most common pattern of change is a seasonal one in which higher energy periodic winter storms approach a shoreline from a consistent direction (e.g. northeasters, etc.) which is different from the prevailing wave direction under average, milder summer conditions. In such cases there will be associated reversals in transport direction for varying lengths of time. The magnitudes of the transport in each direction are algebraically combined to produce values known as the net annual transport magnitude and direction. This approach is useful in many analyses, but can be misleading in others. As can be seen, if the transport is roughly balanced in both directions, the net value can be very small even though many hundred thousand cubic yards are actually moving in the system.

18-11. Profile Closure

a. Coastal project designs usually focus on that portion of the beach that is actively changing or fluctuating. This zone is defined by seeking to identify the opposite situation: those boundary points - landward and seaward - which appear to be stable or at least changing very infrequently. Such a point on the seaward end of a beach cross-sectional profile is often referred to as the *closure point or closure depth*. To establish an accurate assessment of an entire beach system, surveys should extend from the dune crest seaward to depth of closure, which ranges from between 5 and 18 meters depending upon location (Dally, 1993). The coastal engineering community has been criticized recently for implying that this closure point is a point of 'no change' or one at which 'nothing' ever happens. Sediment actually may be transported offshore and onshore through the closure point, and other changes may be occurring over longer periods which are too subtle to be distinguished using typical surveying techniques. Perhaps a better perspective is that some point on the profile exists at which the net change is either not measurable or is of no engineering significance.

b. In any case, it is desirable that surveys (using any technology) should extend seaward to the closure depth. The best method for determining this point is experience gained by looking at past data to assess any changes noticed. Because the bathymetry and profile shape is determined largely by the wave climate, there should be some theoretical relationship between closure depth and wave height. One such suggestion is that the limiting offshore depth can be approximated as twice the height of the extreme wave likely at the site. Obviously judgment and experience must be applied to the manner in which the wave height is estimated.

18-12. Tides and Other Water Level Changes

a. Tidal fluctuations and other water level changes are of particular interest in coastal surveying when the water surface itself is used as a measurement reference plane. The basic procedures for accounting for water level variations, using tidal benchmarks and adjusting to specific datums are familiar to most survey personnel and are extensively discussed within this manual. Only two additional points will be mentioned in this chapter: project variability and vertical changes from other sources.

b. Most tidal reference stations are located in sheltered waters, not on the open coast. It can be challenging to correlate the water level data at an interior reference station to the fluctuations at a beach location. Tidal phase and amplitude shifts are related to hydraulic distances and not necessarily geographic proximity. For example, because of complexities in bathymetry, channel characteristics and frictional effects, beaches at the opposite ends of a barrier island may have very different, even anti-correlated, water level variations when compared to the same tide station equidistant between them on the bay side of the island. Simultaneous observations at several locations in the project area (over a short time period) may be the only feasible way to assess the variability and correlate station data.

c. Other factors may affect local water levels on the open coast. One such influence is the dynamic setup caused by mass transport of water shoreward by waves after breaking. The still water setup is proportional to the wave height and can be as great as 5% of the breaker height (e.g. ~0.3 ft of super-elevation for 6-foot waves). The real difficulty with dynamic setup is that it is not uniform. No setup is present outside the surf zone (a "setdown" effect may even occur), and the setup increases inside the breaking point the closer to shore the depth is measured. It may not be practical to make sufficient simultaneous observations to correct for setup. It should, however, be recognized as a potential source of uncertainty when data are analyzed and reported.

18-13. Survey Planning Considerations

a. Planning a data collection program obviously should take place in advance of the field effort. The objective of the planning process should be to carefully think through the eventual uses for the data and the manner in which they will be analyzed, develop the equipment and procedural requirements and anticipate as thoroughly as possible what the site conditions might be and what the data should look like. However, in most cases over-planning and over-specifying the work is just as counter-productive as not planning at all. Situations will always arise in the field that require judgment and flexibility. The planning goal should be to communicate among all interests the purposes and uses for the survey and the ranges or thresholds of "typical" data, so that atypical conditions are noted and evaluated, even by further discussion while field work is in progress.

b. A survey program ideally should be developed as a team effort among the data users, a representative familiar with the available surveying technologies and procedures, and perhaps a contracting representative if work will be done by outside sources. It is extremely helpful for the team to research and have access to any existing data, past surveys or similar information about a particular site or project area. Existing or historic information is valuable in several ways. A principal use of such data is to allow for a pre-project, preliminary analysis of the area to identify any natural features, shoreline segments or coastal structures which are of particular interest or potential impact on the final project, research effort or monitoring assessment. This type of analysis may suggest areas in which the survey data, however it is collected, may need to be more densely spaced to evaluate an important feature, or can be relaxed to save time and money in more uniform, less critical sections. Another value in carefully reviewing all existing information during planning is to help estimate the likely ranges in the various coastal processes discussed previously and to assess what impact they might have on the field effort. This could include the basic approach to tide corrections, expected wave climate, influences of nearby inlets, and the offshore extent of the data (closure depth). The review can also provide a preliminary look at the existing horizontal and vertical control in the area and the need for any additional benchmarks and/or datum conversions.

18-14. Additional Considerations in Survey Planning

There may be a number of other factors that the planning team might consider along with any existing data or information about the site and personal experience in order to select appropriate surveying methods and to optimize the data collection effort. The goal is to provide the planning team with information which will allow for matching requirements to capabilities. Several of these additional planning considerations are presented in Table 18-1. The table lists a number of typical types or uses of survey data. It is recognized that in some cases surveys may be performed and the data used for more than one of these purposes over the planning and engineering design cycles of a major project. Some uses are listed twice to suggest that one type of survey may be better at the preliminary stages of a project and a different type for similar data, but at a more detailed stage of the work. Similarly, different considerations may be appropriate for a Project Feasibility study if the *principal* design approach will be based on historic conditions, or if it will be based on extensive numerical modeling.

Table 18-1. Considerations Affecting Coastal Surveys

Purpose or Type of Survey	Accuracy Requirements (Table 3-1) Nav	General	Data Collection Patterns Pnt	Lin	Spat	Process Time Scales Hour Days	Month Season	Annual Years	Responsibility In-Hse	A-E Cont	Const Cont	Data Processing Requirements Low	Avg	Advan
Dredge/Disposal posit monitoring		X	X	X		X			X		X	X		
Post-storm damage assessment		X		X		X			X	X			X	
Nav Proj Cond	X			X	X			X	X	X			X	X
Beach fill project monitoring	X			X			X	X	X	X	X		X	X
Borrow area feasibility	X				X			X	X	X			X	X
Shore/inlet evaluation		X		X	X	X	X		X	X			X	X
Dredged mat'l movement	X				X		X	X	X	X	X		X	
Coastal proj plan feasibility historic		X		X	X		X	X	X	X			X	
Coastal proj plan feasibility modeling		X			X		X	X	X	X			X	X
Borrow area detailed investigation	X			X	X		X		X	X			X	X
Plans & Specs	X		X					X	X	X			X	X
Pre-post project pay quantities	X		X				X	X	X	X	X	X	X	
Final as-builts	X			X	X		X				X		X	

The following are brief explanations of the fields in Table 18-1:

a. Accuracy Requirements. Accuracy requirements for coastal engineering surveys fall under the special survey category listed in Table 3-1. Thus, accuracy standards in Table 3-1 are not mandatory but are recommended.

b. Data Collection Patterns. "Point" (Pnt) is intended to suggest that one or a very few individual data points are used to describe or characterize a feature. In the case of detailed borrow area investigations or plans and specifications, it is understood that many such points may be collected, but each soil boring, each break in elevation on a design template, etc., is represented as a "point." "Linear" (Lin) data are the typical profiles, cross-sections and similar lines of data which also certainly are comprised of individual points, but which are usually analyzed and used as a group or whole. "Spatial" (Spa) refers to data collected and analyzed in a more three-dimensional manner.

c. Process Time Scales. These time frames are rough approximations of the periods over which significant changes might occur in the coastal processes primarily affecting each type of project. For example, a post-storm assessment of beach conditions ideally should be performed within days of the storm, or else natural recovery processes will have begun to mask the effects of the storm at the site. Significant changes in an inlet shoal can occur in a period of days to months and, therefore, data collection should not take longer than that time or results will not be synoptic *for that type of feature.* Some types of data collection may be affected by more than one time scale depending on specific site conditions and project goals.

d. Responsibility. This consideration addresses both the availability of specific technologies in a district office versus those available by contract, and the degree of supervisory control necessary and desirable for certain types of surveys.

e. Data Processing Requirements. Some of the newer surveying technologies require substantially greater post-processing than more conventional methods. This means that, if the computing and storage capability is not available in-house, either it will have to be a part of the contracted work or such technologies should not be specified. "Average" implies typical 486DX or Pentium processor-based personal computers, while "advanced" might be networked workstations on a mini computing system. The point is simply that post-processing, including editing, calculations, printing and storage should be considered as part of the pre-project planning.

In summary, the recommended approach is that a team-based planning process take place prior to specifying a survey method or field procedure. That planning process should begin with a preliminary characterization of the coastal environment at the project site, and proceed by using a decision-guiding matrix such as Table 18-1, or other local adaptation, in combination with the technical information on various technologies presented below in order to better define and match the requirements to the capability.

18-15. Overview of Surveying Methods

a. There will always be a need for accurate beach and nearshore survey data. However, several surveying technologies are available for collecting survey data in these zones with each method having its advantages and disadvantages for specific applications and requirements. However, it is essential that survey specifications originate from the project's functional requirements and that the requirements are realistic and economically attained. This section presents the most commonly used technologies in performing beach and nearshore surveys and summarizes their performance capabilities and limitations. The information presented here is intended to provide engineers and scientists with the essential knowledge to select the appropriate survey technology in order to meet project requirements.

b. Several survey technologies are available that may meet the requirements for specific projects. These technologies range from basic rod and transit methods to complex airborne platforms. Some methods directly measure topographic elevations through direct contact with the surface being surveyed, while others remotely measure water depth and must be corrected for water surface conditions such as waves and tides. Each method has its own inherent performance specifications, operational limitations, cost of operation, and special considerations. The type of technology selected to survey a project will largely depend upon a combination of requirements related to data end use accuracies, spatial data density, and survey budget.

18-16. Technology

Included in the following sections is a summary of the most commonly used techniques for performing beach and nearshore surveys as well as some of the more recently developed high technology methods that are now available for collecting this type of data. Technologies addressed in this section include conventional rod and transit, survey sleds, acoustics, airborne LIDAR, GPS, and jet ski boats.

18-17. Rod and Transit

a. Description. The rod and transit (Figure 18-5) is among the most traditional and very adequate methods used in performing beach surveys. It is capable of providing highly accurate survey data. A level (or transit) and survey rod is used to directly measure surface elevation while a distance measurement is obtained using a tape or stadia producing a set of distance-elevation points along selected shore-normal lines at a specific range. Points are measured at regular intervals or in some cases only where there is a break in elevation. This method is typically used to collect two-dimensional cross shore profiles spaced about 30 - 300 meters (300 - 1000 feet) apart that originate from the dune or backshore extending seaward to wading depth. Data collection does not have to be restricted to cross shore applications. The technique can be used to establish longitudinal shoreline or dune crest positions relative to a vertical datum such as NGVD, MHW, MLW, etc.

b. Surveying using the rod and transit relies on a person traversing the survey line with a survey rod and stopping at regular intervals while another team member reads and records the elevation data. The rod holder progresses seaward until waves and water depth prevent the rod from being held steady. For this reason, it is desirable to conduct this type of survey during low tide so that the profile extends as far seaward as possible. When collecting longshore measurements, data can be collected until the rod becomes too far away to obtain clear readings. Errors associated with this method typically occur as a result of human error such as incorrect stadia readings, improper instrument leveling, or inability to steady the survey rod.

Figure 18-5. Rod and transit beach surveying provides accurate beach profiles to wading depth along widely spaced range lines

c. Combining the use of more sophisticated equipment such as an electronic total station (ETS) can automate the process and improve positioning accuracy (Dally, 1993). This method combines a distance meter with an electronic theodolite to measure distance and horizontal and vertical angles from reflective prisms on a staff. A data reader can be added to automatically record data. Data collected in this manner can be easily downloaded to a PC computer for required processing.

Performance Characteristics:

vertical accuracy:	+/-1 cm to +/- 10 cm
horizontal accuracy:	3 meters RMS
spatial resolution:	typically shore-normal lines 300 m (1000 ft) apart
positioning system:	ranging/ETS relative to established benchmarks
minimum crew:	2
cost:	about $1000/Km ($1600/mile) of beach assuming 300-m profile spacing

d. Surveys performed using this method provide a fast and cost effective means of collecting beach data to represent general coastal trends. Inherent limitations exist with these surveying methods in that they may not produce adequate spatial resolution potentially missing information which may lead to a misinterpretation of coastal conditions. The wading portion of the survey is typically limited to calm conditions where breaker heights are less than 1 m. As the rod-man enters the surf zone, vertical accuracy quickly deteriorates (Dally, 1993). In circumstances where surveys extending beyond wading depth are required, other methods and technologies should be considered.

e. A variation of the fixed rod survey method is the Coastal Amphibious Research Buggy (CRAB) used by the US Army Coastal Engineering Research Center (Coastal and Hydraulics Laboratory) at its field research facility in Duck, NC. The CRAB is shown in Figure 18-6.

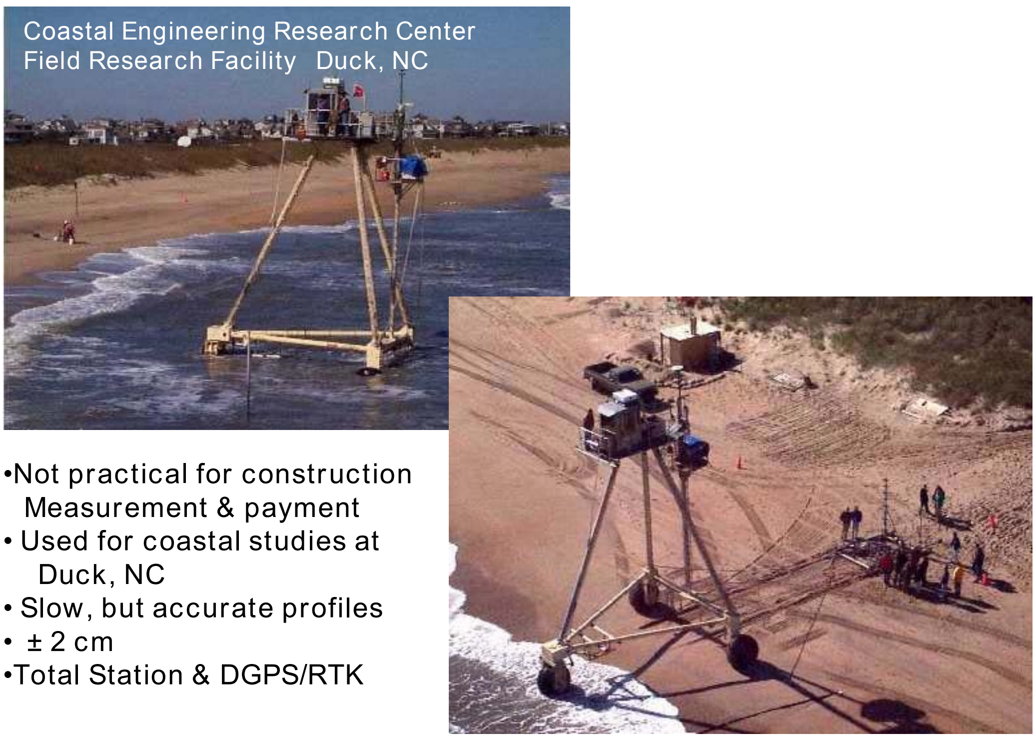

Figure 18-6. CRAB. Hydrographic survey platform used for research purposes by the Coastal Engineering Research Center (Duck, NC)

18-18. Survey Sled

a. Description. Sled survey systems were developed to collect continuous survey data from the dry beach, through the surf zone, and into the nearshore (Langley, 1992). As with the rod and transit method, sled surveys provide direct elevation measurements. The system consists of a mast 10 to 11 meters tall with a cluster of reflective prisms at the top--see Figure 18-7. The mast is mounted to an aluminum frame sled. The sled and mast can be pulled along predetermined lines across the beach and into the nearshore by a vessel as small as an inflatable boat to a maximum depth of about 10 meters (Miller, 1991). A land vehicle may be necessary for pulling the sled onto the beach from the water. As the sled is being towed, an electronic instrument such as an ETS or geodimeter (Lee and Birkemeier,

1993) automatically tracks the prisms on top of the mast and records the horizontal and vertical positions at regular time intervals. Horizontal and vertical control are typically taken from existing benchmarks. This method provides a fast, portable, and economic means of collecting complete profile surveys. As with the rod and transit method, sled surveys provide a shore normal profile typically spaced at about 30 - 300 meters. Line spacings can be adjusted closer or farther apart depending on project data density requirements. However, as line spacing decreases, the total survey time and associated costs increase. Approximately 25 - 30 minutes are required to sample along a 300-m profile (Birkemeier, 1994).

b. Performance Characteristics. (Clausner et al., 1986) (Howd and Birkemeier, 1987)

vertical accuracy:	+/- 3 cm
horizontal accuracy:	3 meters RMS
spatial resolution:	typically shore-normal lines 30 - 300 m apart
positioning system:	ETS/Geodimeter relative to established benchmarks
minimum crew:	2-3
cost:	approx. $4500/Km ($7500/mile) of beach assuming 300-m profile spacing. Additional costs may be required for mobilization and/or data processing)

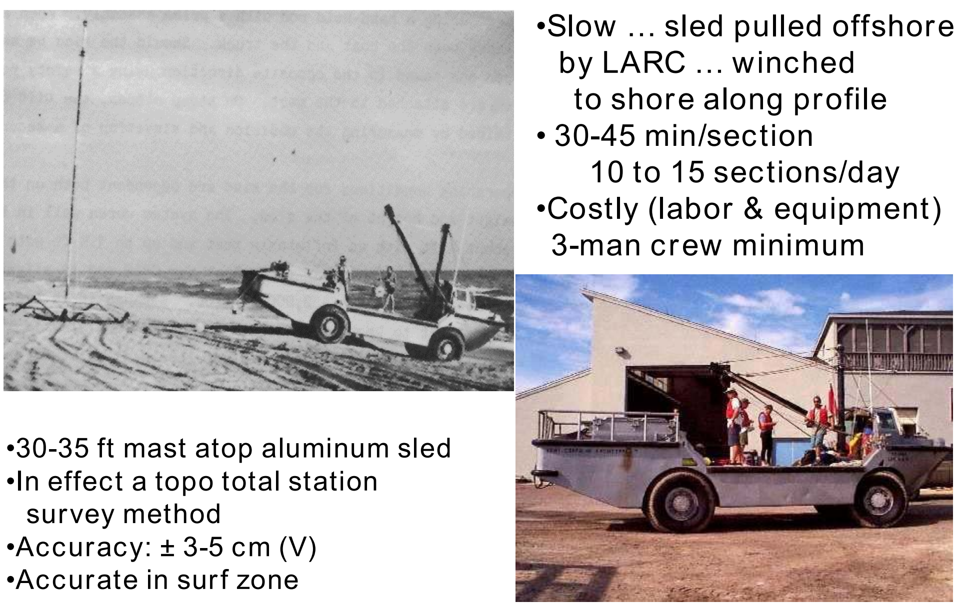

Figure 18-7. Sled profiling system--LARC with towed sled. Used to collect profile data through the surf zone and into the nearshore areas

c. Other Considerations. For projects that do not require a high degree of spatial resolution, sled survey methods provide a portable, low cost means of acquiring accurate beach and nearshore survey data, including the surf zone. Sled surveys are often supplemented with traditional rod-based methods to capture the dune and back-shore areas. As with the rod and transit method, survey sleds may not produce adequate spatial resolution, which may introduce error during data interpretation or when conducting volumetric calculations. Survey sleds do not perform well on irregular bottoms or areas where rock or reef outcroppings are prominent. Such conditions can cause the sled to tip over or become snagged. Surveys can be conducted using this method in areas where the beach is easily accessible. Sleds have been shown to be stable in breaking waves up to 5 m (Sallenger et al., 1983), however, these instruments are typically towed by boat in the nearshore and should, therefore, be restricted to breaking waves one meter or less (Dally, 1993).

18-19. Single Beam Fathometer

a. Description. Single beam fathometer systems or echo sounders utilize sonar to acquire depths by measuring the time of travel of an acoustic pulse or ping between a transducer and the sea bottom. Single beam fathometers are commonly used to survey the offshore portion of coastal projects in conjunction with beach profiles collected out to wading depth with attempts to overlap the two data sets. The extent of overlap and survey accuracy are highly dependent on the amount of wave action at the time of the survey. Fathometer soundings are a measure of water depth. Therefore, actions must be taken to correct for water level variations such as tides and waves, making it necessary to collect water level information at the time of the survey (Clausner et al.). Accounting for water level fluctuations in the coastal zone is difficult and may have an effect on vertical accuracy. Motion compensation sensors can be utilized to isolate and remove some fluctuations due to vessel motion resulting from wave action (Dally, 1993). Horizontal accuracies are highly dependent upon the type of positioning system used.

b. Characteristics. This technology has undergone major advances in recent years with the advent of sophisticated GPS technology, motion compensation sensors, and computerized data processing. Highly accurate three-dimensional positioning technology may eliminate the need for water level corrections.

<u>Performance Characteristics</u>.

vertical accuracy:	+/- 30 cm (1 foot)
horizontal accuracy:	3 m RMS
spatial density:	30 - 300 m (nominal)
platform:	small boat
positioning system:	variable - ranging, Loran, GPS
minimum crew:	2-3 (assuming a support person onshore)
cost:	approx. $1000/Km ($1600/mi) of offshore portion of profile.

c. Other Considerations. Single beam fathometer systems provide a fast, cost effective method of extending beach surveys into the nearshore areas. The effects of wave motion may be difficult to remove which may drastically decrease vertical accuracy . In most cases, overlapping the wading beach profiles with the fathometer portion of the survey is difficult and may lead to large gaps in the data. For this reason, it is best to conduct the wading profile at low tide and the fathometer portion at high tide (Clausner et al.). Coordinating the survey times as such will maximize the opportunity for data overlap. Even when an overlap is achieved, water level fluctuations and platform motion may lead to closure problems.

18-20. Multibeam System

a. Description. In recent years there have been major advances in sonar technology for scanning pulse-based acoustic sensors that can be applied to coastal areas. Expanding upon single beam technology, multibeam systems use multiple frequencies and receiving channels to collect soundings over a swath that can be four times as wide as the water depth. Echosounders used with this type of technology are capable of utilizing 60 (+ or -) beams covering large corridors with each pass and literally providing 100% bottom coverage. Systems utilizing this technology are restricted to the offshore portions of the coastal zone. Used in conjunction with sophisticated positioning systems they can provide an effective means of improving vertical and horizontal accuracies for collecting high resolution bathymetry. Minimum depths are dependent upon the size of the platform used. In addition to the collection of nearshore bathymetry, some systems have the capability to laterally direct the echosounding beam for surveying submerged coastal structures such as jetties, breakwaters, or groins. Related advances in motion compensation sensor technology have further added to the suitability of this method for use in the coastal environment.

b. Performance Characteristics.

vertical accuracy:	+/- 15 cm
horizontal accuracy:	2 m RMS
minimum depth:	platform dependent
spatial density:	up to 100%
operating speed:	platform dependent
platform:	boat
positioning system:	GPS
minimum crew:	3
cost:	approx. $2000/Km (3,250/mi) full bottom coverage of offshore portion of beach.

c. Other Considerations. Because multibeam technology requires a boat platform, it is not suitable for extreme shallow water applications and is subject to the same shortcomings as single beam systems when used to supplement rod surveys. The shallower the water, the narrower the bottom coverage. Due to the multiple channel characteristics and to provide the spatial coverage, this technology generates high volume data sets. Data users should be prepared to handle large volume data sets or to account for data processing in the survey budget.

18-21. Airborne LIDAR Bathymetry

a. Description. A state-of-the-art LIDAR system coupled with high precision GPS positioning is an emerging technology that can be utilized for conducting both hydrographic and topographic beach surveys. The term LIDAR stands for <u>LI</u>ght <u>D</u>etection <u>A</u>nd <u>R</u>anging. The SHOALS system operates by emitting laser pulses from an airborne platform that travel to the water surface. For each laser pulse, some of the light is reflected back from the surface to onboard receivers. The remaining energy propagates through the water column, reflects off the sea bottom, and returns to the airborne sensor. The time difference between the surface light return and the bottom return corresponds to water depth (Guenther et al. 1996). The maximum depth detection is limited predominately by water turbidity. As a rule-of-thumb, the system is capable of sensing depths equal to two or three times the visible depth (Estep et al, 1994). The laser is scanned in a 180^0 arc across the flight path of the helicopter producing a swath width approximately one half the surveying altitude. At a speed of 60 knots and an altitude of 200 meters, the system can provide a survey coverage of 16 km^2/hr. (Lillycrop et al, 1996). Sounding densities can be adjusted by flying higher or lower at different speeds or by selecting multiple scan widths. With the ability to collect both topographic and hydrographic survey data this method can simultaneously conduct complete beach and structure surveys above and below the waterline and could be particularly useful in areas where human access is difficult or restricted. The technology is a useful tool for post-storm erosion assessments. Data acquired using this type of technology can be used to generate vertical profiles, cross sections, contours, and volumetric analysis..

b. Performance Characteristics. (Lillycrop et al. 1996)

vertical accuracy:	+/- 15 cm)one-sigma)
horizontal accuracy:	3 m RMS (one sigma)
spatial density:	4 meter grid (nominal)
coverage:	9 km^2/hr (nominal)
	60 knots (nominal operating speed)
	200 Hz data acquisition rate
platform:	Bell 212 helicopter
positioning system:	GPS
minimum crew	5
cost:	approx. $1800/Km (3000/mile of beach.

c. Other Considerations. This technology is capable of rapidly collecting dense survey data over large areas in a short amount of time. However, the technology is highly dependent on water clarity and should not be considered for areas with chronic high turbidity. Costs pertaining to system mobilization can be high and may be a limiting factor when considered for surveying small projects. It is beneficial to schedule surveys along with other projects in the same general vicinity to share and minimize mobilization costs. Users of LIDAR survey data should possess data processing equipment and software capable of handling large data sets.

18-22. Airborne LIDAR Topography

a. Description. Other airborne LIDAR systems are available that are used exclusively for topographic applications. The system shown here (Figure 18-8) operates at 6000 Hz, flies at a speed of 30 knots, and collects data over a wide swath. Its state-of-the art kinematic OTF (On-the-Fly) satellite positioning system allows for highly accurate three-dimensional geographic positioning. The system is small, cheap to operate, and produces high resolution survey data for use in various mapping applications. Although not yet widely used in coastal areas, this type of technology could be useful for surveying subaerial beaches, dunes, and the above water portions of coastal structures. As with other airborne sensors, this technology could be useful where direct access is difficult or restricted. The technology could prove useful for above- water storm damage assessments. Data acquired using this technology can be used to generate vertical profiles, cross sections, contours, and volumetric analyses.

Figure 18-8. Airborne LIDAR topographic survey system. Used exclusively for topographic applications. The system shown here called FLI-MAP was developed by John E. Chance & Assoc.

b. Performance Characteristics.

vertical accuracy:	+/- 5 cm
horizontal accuracy:	10 cm RMS
spatial density:	0.5 m grid spacing
coverage rate:	approx. 5 km^2/hour 30 knots (nominal) operating speed 6000 Hz data acquisition rate
platform:	small helicopter or fixed wing aircraft
positioning system:	GPS
minimum crew:	2 (pilot and operator)
cost:	approx. $1200/km ($2000/mi) of dry beach. May have associated data processing costs.

c. Other Considerations. This technology can only be used for topographic surveying. This instrument detects whatever is on or covering the ground. Care must taken when collecting data near vegetation or other ground cover to assure that the data collected is what the user intends to survey. If hydrographic survey data are also required, this technology must be used in conjunction with other technologies. A high resolution system such as this generates extremely large data sets. Data users should possess resources capable of handling large data files or be prepared to budget for data processing costs.

18-23. GPS Total Station Backpack

a. Description. Another alternative for the collection of detailed topographic information is through the use of a GPS total station (receiver and antenna) contained in a backpack and staff or mounted on a motorized vehicle such as an ATV. Differential GPS positioning (DGPS) for improved accuracy levels is possible but would require establishing a base station. This type of configuration permits rapid detailed digital elevation data to be collected on a continuous basis by walking or driving over the project survey area (Solomon, 1996). Sample rates for collecting real time positions are 0.5 - 1 second. For normal walking rates this translates to readings roughly every meter (3 feet) (Solomon, 1996). Sampling intervals using a motorized vehicle would be greater depending upon the survey speed. Conventional profiling methods (rod and transit or sled) involve re-occupying a series of profiles marked by benchmarks, stakes, rebar, etc. Unfortunately, such benchmarks are frequently removed, buried, or obscured in some manner by natural processes or human activity. The GPS technique allows reestablishment of profile lines without multiple benchmarks as long as a single base station point is well known. This capability can be extremely beneficial when surveying in areas where control data are deficient or absent such as in remote areas or in areas of severe storm damage. This system can also be useful for rapidly and cheaply mapping reference contours such as high water lines, back beach and dune lines, etc.

b. Performance Characteristics.

vertical accuracy:	15 cm or less (depending on GPS receiver)
horizontal accuracy:	5 - 10 m
data acquisition rate:	0.5 - 1.0 sec sampling rate
spatial density:	1.0 m spacing depending upon operating speed
operating speed:	variable
platform:	backpack or suitable motorized vehicle (ATV)
positioning system:	GPS/DGPS
minimum crew:	2
cost:	about $1200/Km ($2000/mile) of beach assuming 300-m spacing. May require some processing costs.

c. Other Considerations. This method would be suitable only for conducting beach surveys extending to the low tide line or out to wading depth maximum. If hydrographic survey data are required through the surf zone and nearshore, this type of technology must be used in conjunction with other survey methods. As with any technology involving GPS positioning, problems may be encountered with unfavorable satellite configurations which may degrade positioning accuracies. In such instances, survey work should be coordinated during times of optimal satellite configurations. Most GPS systems provide software to facilitate this process (Solomon, 1996).

18-24. Jet Ski Beach Surveys

Jet ski boats have recently been adapted to performing surveys in surf zones (Figure 18-9). They have proven more effective than conventional skiffs in running with wave troughs into shallow beach areas. When equipped with RTK DGPS and inertial roll-pitch-heave sensors, date quality is maintained in the difficult surf zone. These survey techniques have applications in other difficult or inaccessible survey areas, such as near power plants, ponds, and in wetlands. A Yamaha Wave Runner system owned by

Brunswick Surveying (Supply, NC)--Personal Watercraft Surveying System (PWSS)--includes an Innerspace 455 Survey Depth Sounder, Innerspace 453A RF modems, Innerspace 603 Remote Indicator and Innerspace Datalog with Guidance Software (DLWG). The GPS used in Brunswick's PWSS is an Ashtech GG24 RTK system. Position accuracy can be either sub-meter DGPS or a few centimeters RTK. Depth resolution is 0.1 foot or 1 cm as selected by the operator. A special multiplexer was developed, the Innerspace 905, to synchronize the depth and RTK position data at 1PPS available in the GPS receiver. A bi-directional voice radio system is also included. The balance of the equipment includes: system batteries for power & associated charger and wiring junction box. All the equipment is mounted out-of-sight, in closed compartments, except for the 603 which provides guidance for the operator and the GPS and RF antennas and depth sounder transducer. The instrumentation is all mounted with quick release mechanisms to facilitate easy removal so the equipment may be used on projects where the personal watercraft is not applicable. The Innerspace 455 Survey Depth sounder is mounted under the rear seat. The Innerspace 603 Remote Indicator is mounted above the steering bars in full view of the operator. The GPS antennas and three separate RF systems antennas are located about the craft and the depth sounder "kickup" transducer is transom mounted. The watercraft's electronics systems are powered from a separate battery/charger installation located under the 455 sounder in the rear compartment. The watercraft's engine/starter power system is not used for the electronics except to power the battery charger that charges the separate battery that powers the electronic systems.

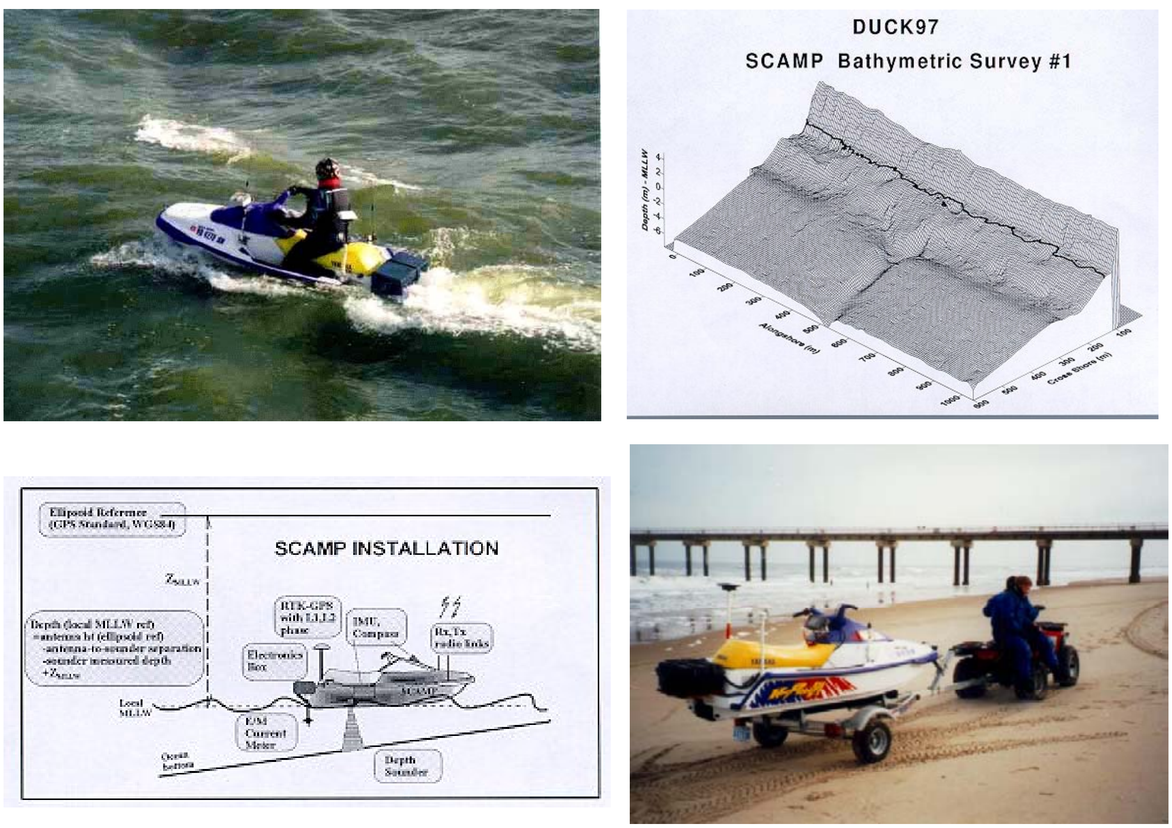

Figure 18-9. Yamaha Wave Runner equipped with hydrographic survey equipment (SCAMP at Duck, NC)

18-25. Offshore Jetty, Breakwater, and Groin Surveys

Surveys for these structures are performed for design, construction, and maintenance. Typically, a baseline is established atop the centerline of the structure (if above water), and cross sections are run (by tag line or total station EDM normal to the structure every 50 or 100 ft O/C, extending past the toe of the foundation stone (Figure 18-10). Depths are measured by lead line, level rod, or sounding pole at a relatively dense interval. Echo sounding (vertical beam or multibeam) may be used if return signals are adequate. During stone placement submerged areas may be surveyed using standard hydrographic echo sounding methods. Condition survey of offshore breakwaters or jetties are performed using a variety of techniques, depending if the structure can be occupied or if portions are below water. Multibeam systems may be pointed horizontally to assess underwater conditions of the armor or foundation stone. On inaccessible or broken breakwaters, airborne topographic LIDAR surveys can be flown to map the rock placement and voids above the surface--see Figure 18-11. The LIDAR topography and multibeam hydrography models may then be merged in order to evaluate the overall condition of the structure and estimate repair quantities needed.

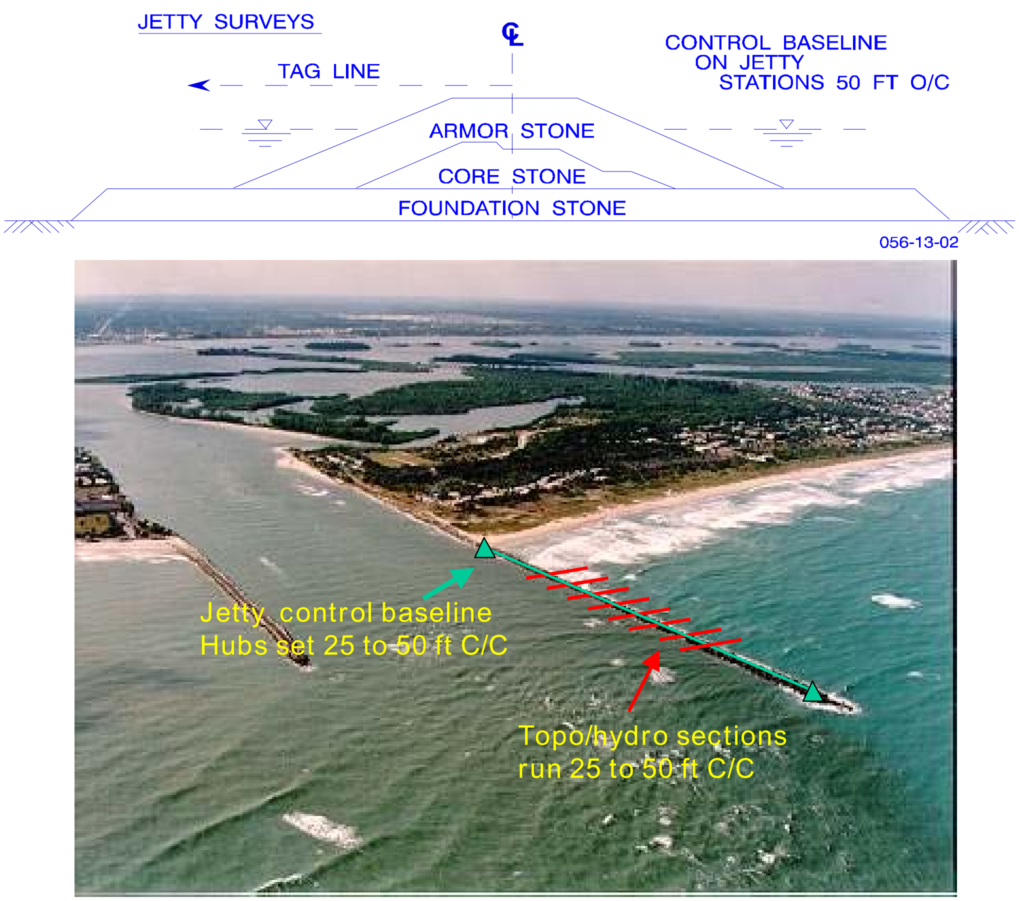

Figure 18-10. Jetty and breakwater surveys

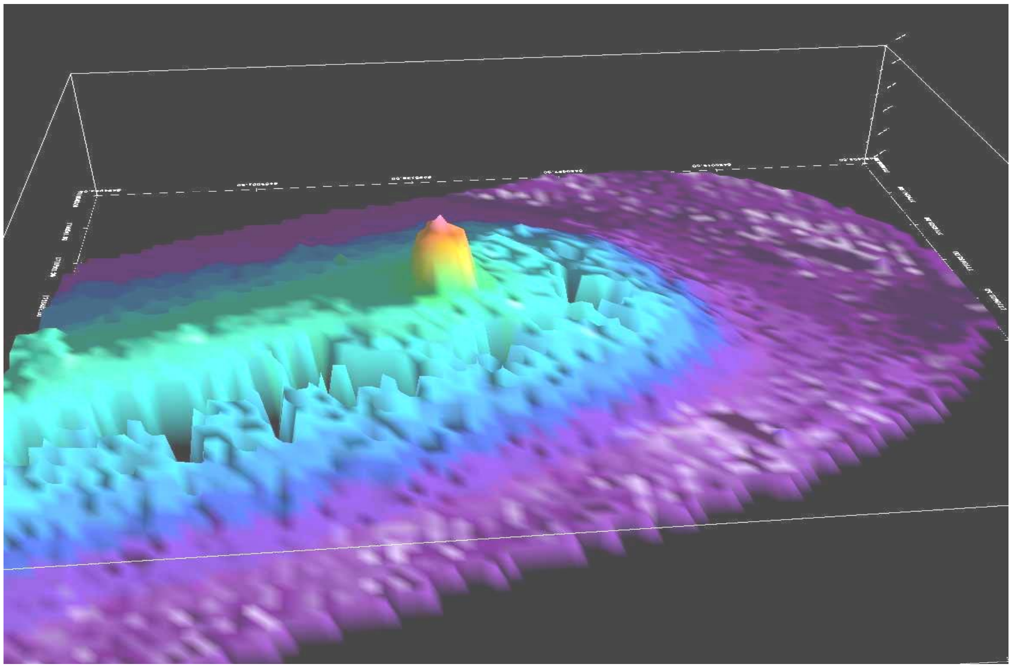

Figure 18-11. Combined LIDAR topographic and multibeam hydrographic surveys of San Pedro Breakwater, Los Angles District (JE Chance & Assoc.)

18-26. Probings

Hydrographic survey crews are occasionally tasked to obtain either dry rod or washed offshore probings, often over potential sand sources for proposed beach renourishment projects. When such geotechnical data are intended for use in contract plans and specifications, DGPS survey positional accuracy is required for the probe location and offshore elevation reductions. Sample field notes are shown in Figure 18-12.

STA	+ ROD	H.I.	- ROD	SDG.	PROBE
BM-1					
	5.15	35.20			
10+00			5.6		
					0
					12.2
12+00			6.6		
					0
					14.2
			9.2		
13+50				5.0	
					0
					5.0
					16.0+
BM-2			5.05		

NOTE: THE FIELD NOTES WILL SHOW IF DRY ROD OR PUMP USED FOR PROBINGS. IF PUMP USED SEE CRITERIA FOR DRIVE BORINGS AND PROBINGS WHICH WILL BE FURNISHED WITH REQUEST FOR SURVEY.

ELEV		REMARKS:		10 MAY 70	
30.05					
29.6		TOP GROUND			
29.6		TOP GROUND			
17.4		TOP HARD MATERIAL, UNABLE			
		TO PENETRATE			
28.6		TOP GROUND			
28.6		TOP GROUND			
14.4		TOP ROCK			
26.0		WATER SURFACE OF CANAL			
21.0		TOP WATER			
26.0		BOTTOM CANAL			
21.0		BOTTOM CANAL			
10.0		REQUIRED PROBING			
30.15		PUB. ELEV = 30.13			

Figure 18-12. Probing field notes

18-27. Sub-bottom Profiling by Seismic Reflection Methods

Seismic reflection systems operating between 400 Hz and 14.0 kHz are useful for continuous high-resolution profile recordings of the top 30 m of material below the sea floor. The high-energy signal will penetrate and reflect from interfaces between nonhomogeneous materials. The receiving package will detect the reflected signals and convert them into a profile recording. The display is real time with relatively high ship speeds of 10 to 12 knots. Typical resolution is 0.5 m. When properly calibrated, the systems can also be used for obtaining bathymetric profiles. Depth of sub-bottom penetration varies inversely with frequency. Sub-bottom depths over 200 ft have been recorded.

a. Sub-bottom reflection data have been very useful in numerous investigations in which information pertaining to the sub-bottom strata is important. These include predredging investigations, pipeline route locations, and offshore foundation investigations.

b. In operation, an instrument package is towed which contains both transducer and receiver. Outputs can be either analog strip charts or in digital form, which facilitates post-survey processing that enhances resolution. Other systems rely on ship-mounted transducer/receivers. For these, resolution can be reduced by ship heave, but accelerometer packages are available to measure heave for correction purposes.

18-28. Sub-bottom Profiling by Ground Penetrating Radar (GPR)

Recent experience with GPR indicates that under some conditions this technique can provide sub-bottom information. Radar designed to obtain subsurface information usually operate at frequencies between 20 and 500 MHz. To best resolve echoes from subsurface interfaces, broadband antennas are used to radiate a very short duration pulse. Low-frequency (20-100 MHz) antennas with high radiated power (0.5-2 kW) provide the greatest penetration and in most situations would be best suited for sub-bottom profiling. The depth that radar can penetrate is strongly limited by attenuation in the water and bed material, with greatest signal loss in electrically conductive water and sediment. High attenuation limits the use of this technique, making it best suited for surveys in low-conductivity fresh-water lakes and streams. On-site conductivity measurements should be taken before using radar equipment. These measurements will estimate the radar penetration. The radar frequency used will also be a trade-off between resolution and penetration. Plots of amplitude versus time for the returning pulses are usually compiled into a graphic display, producing an apparent profile of subsurface reflectors and interfaces. When the electrical properties (dielectric permitivity) of a layer are known, propagation time to the base of the layer can be converted to layer thickness, with resolution of about 0.5 m. More information on GPR techniques may be obtained from the US Army Cold Regions Research and Engineering Laboratory (CRREL).

18-29. Offshore Disposal or Borrow Area Surveys

Disposal areas (Figure 18-13) are frequently surveyed during planning, design, construction, and maintenance phases of a project. The most frequent surveys are conducted during dredging operations and for subsequent general condition purposes. The purposes of these surveys are varied. Normally, offshore submergent disposal areas are periodically surveyed to monitor material placement grade during construction--to ensure minimum depths are not exceeded. Surveys are also performed to locate any misplacement of dredged material outside the disposal area limits. Subsequent surveys may be required to monitor settlement or material movement. Offshore borrow area surveys are similar; however they are used to monitor the amount of material removed from the site--usually a sand source for renourishment projects. Emergent disposal areas in offshore locations and upland confined disposal areas are periodically surveyed during construction and later to monitor settlement and available quantities for additional placement.

a. Submergent disposal and borrow areas are typically cross-sectioned at 100- to 200-ft spacing. Survey lines are run 200- to 1,000-ft outside the disposal area limits to monitor for any misplaced material. Material quantities can be computed using either average-end-area or grid methods.

b. In the past, single, vertical beam echo sounders were used for disposal area surveys. For deep water disposal areas, multibeam survey systems are now recommended. Multibeam systems can be set at maximum beam width to obtain maximum swath widths of coverage.

c. During construction, offshore disposal areas may be surveyed weekly or biweekly. Subsequent monitoring surveys are performed at quarterly or annual intervals, depending on any environmental requirements/restrictions that may have been imposed on the use of the area.

d. Upland disposal areas are surveyed using standard topographic techniques. Fixed baselines are established along the top of the confining dikes and standard cross-sections are run internally within the disposal area and externally into the water. Total station or DGPS RTK survey methods may be employed. In cases where the confined material has not settled, a small skiff may be needed to obtain measurements. Extreme caution should be exercised when spoil material has only crusted on the top--the rodman should use a life jacket and/or lifeline should there be a danger of breaking through to water-suspended material. A sounding pole with a bottom plate may be needed in soft material.

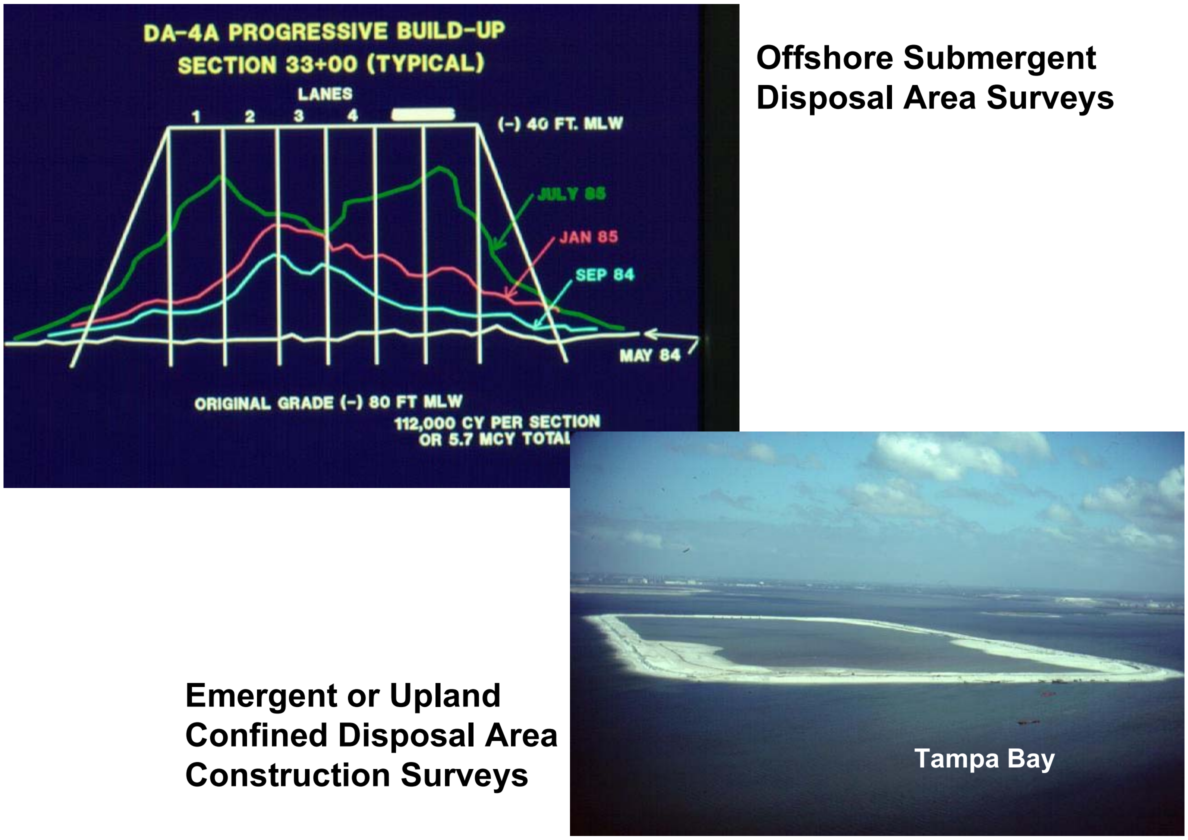

Figure 18-13. Submergent and confined disposal area surveys (Jacksonville District)

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Note that USACE Engineer Manuals referenced in this chapter are listed in Appendix A.

18-31. Mandatory Requirements

There are no mandatory requirements in this chapter.