TECHNICAL ADVICE SECTION

Approach for Sand Searches On the East Florida Atlantic Coast

1.1 USING ROSS IN COMPREHENSIVE OFFSHORE SAND SEARCHES

There are no universal or comprehensive guidelines dictating which method should be followed when conducting a marine sand search investigation, but several guidelines for specific geographic regions have been developed (Finkl, Andrews, and Benedet, 2003; Finkl, Khalil, and Andrews, 1997; Finkl, Benedet, and Andrews, 2004; Benedet *et al.*, 2004; Finkl and Khalil, 2005a,b, Hatchett, et.al, 2007a and 2007b). This lack of general guidelines is a result of the fact that sand searches are site specific. Because sand searches must be geared or tailored to the geological conditions in the area of the study, the method of conducting the search must be compatible with the specific geographic parameters of that region. This means that exploration methodologies must be capable of resolving required detection limits that are determined by deposit configuration in different geographic areas. The same search techniques would not be deployed, by way of an extreme example, in the search for sand ridges on the West Florida Shelf as would be used for the detection of infilled sediment troughs (inter-reefal sand bodies) that commonly occur along the southeast Florida coast.

These general procedures consist of sequential tasks that are conducted in a phase-wise manner, as illustrated by Figure 1-1. This flow diagram illustrates a systematic approach to offshore sand searches based on ten major phases that incorporate a range of subset activities that are constrained by local circumstances. Each phase is meant to direct the course of subsequent actions so that sand searches follow a logical progression that results in an efficient exploration methodology. The sequence of investigation can be reduced to ten phases that include: (1) literature reviews and analyses of historic data, (2) development of action plans that incorporate the creation of digital (GIS) databases of historic data, (3) reconnaissance geotechnical and geophysical surveys (if needed), (4) identification of target area(s), (5) detailed geophysical surveys, (6) detailed geotechnical investigation, (7) evaluation of geophysical and geotechnical data, (8) hazard, natural resources (seagrasses, hardbottoms *etc.*) and archaeological assessment surveys (9) selection of borrow area(s), and (10) preparation of reports and other final deliverables. The ROSS system provides the information needed to complete Phases 1 and 2. It contains an extensive annotated bibliography to assist in the literature search. The investigator must augment this with the most recent and location-specific published and gray literature sources to compile a complete review. In some areas, where sufficient information is available, the data available in the ROSS system may provide enough information to substantially decrease the survey needs of Phases 3 and 4 by reducing the area to be surveyed in preliminary reconnaissance investigations. These investigations, which traditionally covered large expanses of the seabed, can now be simplified and abbreviated to verify existing data. Subsequent phases are still needed to verify legacy data due to: (1) the dynamic nature of sand ridges, ebb shoals and nearshore sand bodies, (2) advances in survey technology (accuracy and resolution), and (3) permitting requirements (*e.g.* cultural resources clearance).

To optimize resources, including time and effort, it is convenient to conduct detailed cultural resource surveys subsequent to definition of final borrow area boundaries so that only the area to be dredged is 'cleared'. The ROSS system contains several data coverages that can assist with this effort. There are ranges of sub-tasks within each of these main phases of work and the whole process may take up to several months to complete depending on project size, location, amount of previous work completed (assuming that the data collected is adequate, accurate, and relevant), available funding, weather conditions (especially sea state), etc. The availability of a comprehensive GIS database helps to optimize such investigations and significantly reduces costs and time involved with initial data compilation and analysis.

These guidelines are briefly summarized in terms of tasks to be completed within the ten main phases. The descriptions indicate general strategies that logically work toward completion of phases so that future work can build on prior accomplishments that, to a certain degree, direct the course of subsequent actions.

The first phase of a marine sand search involves both a literature search and the design of the exploration program. The ROSS system plays a major role in this phase. In the past, this initial review of background data was sometimes overlooked because it was considered to be too time consuming or possibly even irrelevant as much of the data was old, or in a format that didn't match today's conventions. Experience (CPE, 1992, 1999b; Andrews *et al*., 2002, 2004; Finkl, Khalil and Spadoni, 2002; Finkl, Andrews and Benedet, 2003; Finkl, Benedet and Andrews, 2004; Benedet *et al*., 2004) has shown that this phase is crucial to the re-evaluation of previously collected information, to the development of conceptual models of sedimentary environments, and to guide the planning of future survey activities. Thus, the purpose of the literature (data) review is to familiarize survey planners with local environmental conditions and to flag any special conditions that require avoidance or special attention. Unfamiliarity with the peculiarities of local environments or geomorphological features holds potential for obtaining undesirable results. Tasks proposed for the sand search are, therefore, adjusted to local conditions in the appropriate manner.

Thorough, comprehensive reviews of historical, technical, and scientific literature should include geological, geomorphological, and geophysical information or data. Basic literature sources that should be perused in terms of general geologic framework and coastal processes include books and primary scientific and engineering journals (*e.g. Journal of Coastal Research; Marine Geology; Journal of Sedimentary Research; Marine Resources and Geotechnology*) and conference proceedings (*e.g.* 'Coastal Sediments' sponsored by the American Society of Civil Engineers, ASCE). Data is always evolving as most of these publications are monthly and bimonthly and should be checked in the early stages of marine sand searches.

The gray literature includes materials that are produced on an irregular basis in the form of special reports that include but are not limited to consulting reports prepared for government agencies such as the Florida Department of Environmental protection (FDEP), Florida Geological Survey (FGS), U.S. Army Corps of Engineers (USACE), National Oceanic and Atmospheric Administration (NOAA), and private consultants. These data, particularly individual consulting reports, are often hard to access.

Offshore geotechnical literature and geotechnical data including geological maps, bathymetric maps, seismic cross sections, geotechnical data, both geological and geophysical borehole logs, within an approximate 6.2 mile radius of the project area and adjacent sites should be consulted, analyzed, and reviewed. The intent of this phase is to initiate the development of a flexible reconnaissance survey plan for preliminary geotechnical investigations. This plan should be geared to the identification of potential sites for probable borrow areas by eliminating locations that are unsuitable for any reason.

1.2 PHASE II: PREPARATION OF A SYSTEMATIC ACTION PLAN

The development of a systematic action plan builds on the results of the Phase I tasks and involves reconnaissance geological and geophysical surveys that are guided by interpretation of spatio-temporal information contained in GIS databases. The ROSS system provides readily available data in GIS format, thus, eliminating the transition from analog data to GIS environments that is normally required during this Phase. Data derived from bathymetric, seismic, and limited vibracore surveys is used to map bottom types and to differentiate areas that have potentially useable sediments by using GIS spatial queries. Seismic sub-bottom profiles provide useful information where underlying bedrock restricts the thickness and lateral extent of inner shelf sand bodies. The use of this information in real-time mode via an interactive GIS/MIS platform onboard a survey vessel, for example, provides ready access to archival and legacy data that can assist in the decision-making process for modification of surveys on the fly. Potential targets can often be defined on the basis of bathymetry, image roughness of the seabed surface, sedimentary structures and sediment composition. The delineation of potential target areas excludes all other areas as being unsuitable due to the poor quality or absence of sediments (*i.e.* in the case of exposed bedrock). The purpose of subsequent phases and tasks is then to work toward eventual exploitation of targeted sand sources.

1.3 PHASE III: RECONNAISSANCE GEOLOGICAL AND GEOPHYSICAL SURVEY

This phase of work normally includes several integrated tasks that focus on regional bathymetric surveys, seismic investigation, and preliminary surface – subsurface sampling using grab samples and jet probes (Finkl and Benedet, 2005) to verify historic data and sand deposit location. After reviewing the existing information, supplemental geotechnical investigations are normally conducted to obtain sediment data that helps evaluate potential sand sources and determine the availability of adequate sand volumes in the areas delimited using historic data sources. In some areas, the ROSS system may provide enough legacy data to significantly reduce or eliminate survey needs of this phase.

In situations where reconnaissance data is required, the investigations normally include positioning by DGPS, bathymetric surveys (using digital fathometers), surface sediment sampling, jet probes and seismic survey – sub-bottom profiling (using a sub-bottom profiler such as chirp sonar). Reconnaissance surveys are normally conducted along widely spaced tracklines on a 300 to 1,000 m grid spacing. Preliminary sampling with grab samples and jet probes may be collected for initial evaluation, verification of historical data and delineation of potential sites where detailed surveys could be undertaken. Retrieval of sediment samples also facilitates the calibration of seismic records and thereby increases the interpretive value of geophysical data (Griffiths and King, 1981) for locating potentially usable sand.

1.4 PHASE IV: IDENTIFICATION OF POTENTIAL TARGET AREAS FOR DETAILED EXPLORATION

One of the outcomes of Phase III should be the creation of a base-map depicting potential target areas with detailed survey plans including proposed tracklines and sampling locations. If prepared using a suitable scale, this information can be presented to the sponsoring agencies for discussion and approval. It should be noted that changes and adjustments to the basic or initial plans are anticipated on the basis of the field data and analysis conducted during Phases I through III. In some cases, additional surveys in Phase III may not be necessary because potential target areas were successfully identified on the basis of geophysical and geotechnical data provided by the ROSS system and analyzed in Phases I and II. This situation may occur in areas that have been extensively explored previously or where there is a plethora of recent data that contains information useful to sand searches.

1.5 PHASE V: DETAILED GEOPHYSICAL SURVEY

This phase of work involves conducting detailed geophysical investigations that include bathymetric surveys, and sub-bottom profiling (seismic) surveys. Basic literature about these survey procedures and requirements can be found in Wolf and Brinker (1994), Yilmaz and Doherty (2000), Baker and Young (1999), Baldwin and Hempel (1986), Blondel and Murton (1997), Griffiths and King (1981), Dragoset and Evans (1997), Gorman, Morang and Larson (1998), Hunt (1984), Langeraar (1984), Morang, Larson and Gorman (1997), Verma (1986) and Worthington, Makin and Hatton (1986). Detailed surveys typically follow a trackline grid spacing on the order of 300 m or less. This level of detail normally provides sufficient detail for defining potential borrow sites, but in some specialized cases that are geologically complex, a closer grid spacing may be used.

Planning survey trackline locations is a crucial part of any successful geophysical survey that requires the incorporation of scientific information (derived from the literature) and bathymetric data (from NOAA charts and bathymetric data collected during Phase II) (Hemsley, 1981). When the compiled base-map (result of Phases I and II) is completed, the area selected for detailed study is earmarked for closely-spaced tracklines. The most satisfactory results are generally obtained by running geophysical (especially seismic) surveys in a pattern that is orthogonal to the prevailing offshore geologic structures or surficial topography. If the prevailing offshore geology is not parallel to the shore, the survey lines should be positionally adjusted to best image the terrain. For offshore areas where little is known about the surficial geology, an alternative procedure is to run survey lines in a zig-zag pattern approximately perpendicular to the coast. Planning of track-lines is site-specific and should not be constrained by these broad suggestions and general recommendations.

The components of a comprehensive geophysical survey should include accurate navigational positioning, detailed bathymetric survey, and seismic stratigraphic survey. A basic requirement for detailed high-resolution seismic survey, subbottom profiling of delineated borrow areas is accurate navigational positioning or position control. DGPS is the primary positioning system that is used for hydrographic surveys. DGPS correctors can be obtained from the U.S. Coast Guard (USCG), Maritime DGPS Service, or other differential services, provided they meet accuracy requirements. Echosounders and digital fathometers are used for bathymetric survey based calibrations and corrections mentioned for the earlier phase work. A detailed bathymetric map should be prepared using a suitable isobath interval. Bathymetric surveys are required for many studies of geology and geomorphology in coastal waters (Morang, Larson and Gorman, 1997a, b), including offshore sand searches in attempts to define target areas that may eventually become borrows. Fathometers or echo sounders are most often used to measure water depths offshore. The distance between the sound source and the reflector (seafloor) is computed as the velocity of sound in water divided by one half of the two way travel time. It has been observed that even with the best efforts at equipment calibration and data processing, the maximum practicable achievable accuracy for nearshore depth surveys is about +/- 0.15 m. Errors in acoustic depth determination are caused by salient complicating factors or processes that include:

a) Differences in the velocity of sound in near-surface water (about 1500 m/sec) that varies with water density, which in turn is a function of temperature, depth and salinity.

b) Changes in the vessel's draft as fuel and water are depleted during the survey require boat-specific correction that is carried out by performing depth checks.

c) Waves cause the survey vessel to pitch up and down and the seafloor is recorded as a wavy surface. Transducers and receivers are now installed on heave compensating mounts to obtain the true seafloor. Post survey data processing is the most common means of removing wave signals.

When conducting a seismic survey using a subbottom profiler, (*e.g*. 3.5 kHz high-resolution profilers) a chirp subbottom profiler should preferably be used for proper depth-penetration and better resolution. This equipment comes in a variety of configurations. Each configuration has its own unique settings and methods of operation. Considerable planning is needed to select the proper equipment, operation mode and survey trackline layout. Furthermore, instrumentation continually evolves so the plan needs to include a search for, and evaluation of, the newest equipment. Seismic stratigraphy should be developed on the basis of subbottom profiles thus obtained. Detailed surveys typically follow trackline grid spacing on the order of 300 m or less. This level of detail normally provides sufficient resolution for defining potential borrow sites, but in some specialized cases, where the geology is complex, closer grid spacing may be used.

In the third phase, a comprehensive geotechnical field survey is planned, executed and analyzed. Preliminary maps based on this information can then be developed.

Successful sand searches rely on sonar imagery of the seafloor and sectional depth views along tracklines that show sedimentary layering. Seismic reflection profiling, calibrated to sand searches using vibracore data is crucial to the delineation of potential sand bodies in terms of depth and lateral extent. Sonar surveys provide useful proxy data that can be interpreted in terms of smoothness or roughness of the seabed, information that is useful for differentiating between outcroppings of rock and unconsolidated sediment.

In geophysical surveys, the distance between the sound source at the reflector is computed as the velocity of sound in that medium (rock, sediment or water) divided by one-half of the two-way travel time. This measurement is converted to an equivalent depth and recorded digitally or printed on a strip chart. A recent development that is extremely valuable to interpretation of bottom-sediment grain size is a signal-processing unit that can be interfaced with an echo sounder and used to indicate the size of seafloor sediments in terms of Wentworth or other general classification schemes (ASTM, 1994; Morang, Larson and Gorman, 1997a, b). This is accomplished by measuring two independent variables, roughness and hardness, from acoustic signals and interpreting these data in terms of sediment type.

The basic principles of sub-bottom seismic profiling and acoustic depth sounding are essentially the same. A lower frequency and higher power signal (to penetrate the seafloor) is employed in subbottom seismic devices. The transmission of the waves through earth materials depends on properties like density and composition. The signal is reflected from interfaces between sediment layers of different acoustical impedance (Sheriff and Geldart, 1982). Coarse sand and gravel, glacial till and highly organic sediments are often difficult to penetrate with conventional subbottom profilers, resulting in poor records with data gaps. Digital signal processing of multi-channel data can sometimes provide useful data despite poor signal penetration.

Seismic reflection profiles are roughly analogous to geologic cross-sections of subbottom materials because acoustic characteristics are usually related to lithology (Verma, 1986). Reflections may appear on the seismic record due to subtle changes in acoustic impedance that are associated with minor lithological differences between under- and overlying materials. Conversely, significant lithologic differences may not be recorded because of similar acoustic impedence values between bounding units, due to minimal thickness of stratigraphic units or because reflectors are masked by gas (Sheriff and Geldart, 1982). Because these complicating factors can mislead interpretation of the seismic record, seismic stratigraphy should always be considered tentative until supported or verified by direct lithologic evidence from core samples.

The two most important parameters of sub-bottom seismic reflection systems are vertical resolution, i.e. the ability to differentiate closely spaced reflectors, and depth of penetration (e.g. Parkes and Hatton, 1986). The dominant frequency of acoustic pulses increases signal attenuation and consequently, decreases the effective penetration. To resolve this problem, it is common to simultaneously deploy two seismic reflection systems during a survey. By combining results from one system that maximizes high resolution capabilities with those of another system that is capable of greater depth penetration, it is possible to retrieve high-resolution data to greater depths than would normally be possible with a single seismic reflection system.

The Chirp system has an advantage over single frequency (3.5 kHz) sub-bottom profilers (or “pingers” as they are commonly called) and boomer systems in sediment delineation because the reflectors are more discrete and less susceptible to ringing from both vessel and ambient noise. The full wave rectified reflection horizons are cleaner and more distinct than the half wave rectified reflections produced by the older analog systems.

All of the data collected in Phase V should be incorporated into the GIS database (ROSS) and compared with complementary legacy data.

1.6 PHASE VI: DETAILED GEOTECHNICAL INVESTIGATION

Detailed sampling using vibracores is an expensive procedure that involves significant effort and deployment of large vessels containing hoisting equipment and storage facilities for cores. Descriptions of vibracoring procedures and requirements can be found in Lee and Clausner (1979), Edgington and Robbins (1991), Larson, Morang and Gorman (1997), Finkl and Khalil (2005b). Costs for 20-foot vibracores often settle in the range of $5,000 to $7,000 which includes five to seven sediment samples per core depending on location and logistics. Core description and the analysis of selected sediment parameters adds additional laboratory fees to the total cost, making vibracoring a procedure that should be carefully planned to avoid wasted efforts. Potential vibracore sites should be judiciously selected to achieve the level of information and confidence needed for finding the target area, delineating borrow areas and for qualitative and quantitative evaluation of sand deposits (Finkl and Khalil, 2005b). Vibracore information is most beneficially employed in conjunction with subbottom data to gain maximum interpretive benefit of stratigraphic composition and sedimentary variation. Acoustic reflectors can often be identified on the basis of vibracoring, which in effect, links or calibrates seismic reflection patterns to specific sediment types. Generally, vibracore-sites should be spread throughout the survey area on a rectangular grid but preferably, in an alternative pattern that crosses the prevailing trend of the offshore geology. The standard accepted spacing between the core-sites is usually about 300 m. The minimum accepted recovery from each core is at least 80% in at least three attempts or trials. Core recovery is sometimes problematical, especially where there are contrasting materials that are stratigraphically juxtaposed (i.e. sand vs. shell hash vs. rock clasts).

1.7 PHASE VII: EVALUATION OF GEOTECHNICAL DATA

The vibracores obtained during Phase VI are normally split longitudinally into two halves, with each portion labeled and dated for future reference. One half of the split core should be photographed and archived, the archived half being cut into sections (not longer than 1.5-m) that are also labeled and dated. The archived core sections should be properly wrapped in clear plastic to avoid contamination from other core materials.

The other half of the split core should be sub-sampled for laboratory analyses. The results of the analyses should be used in the development of visual lithologs (boring logs) based on USCS designations (ASTM D2487-92, 1994). One representative sample for grain size analysis should be obtained from each horizon or layer (in a core) subject to a minimum of three samples collected from each core. Grain size and other physical parameters should be analyzed either by mechanical sieving or by settling tube as per ASTM standard (ASTM D421/422). The Unified Soil Classification Scheme should be used to describe sedimentary materials and layering within the core.

A log should be prepared for each core describing the sediments by layer. Each layer description includes layer width, sediment color, texture, and presence of clay, mud, sand or shell and any other identifying features. Grain size analysis should be performed on approximately three or four sediment samples per core. Samples should be obtained from distinct layers in the sediment record, or periodically through the core record. This grain size analysis should be conducted for sand samples in accordance with the American Society for Testing and Materials (ASTM), Standard Material Designation D422-63 for partial size analysis of soils. Mechanical sieving should be accomplished using calibrated sieves, with a gradation of half phi intervals, per U.S. Army Corps of Engineers standards. Grain-size distribution curves should be prepared for each vibracore. The core logs, and raw sedimentological data should be developed into a GIS database and should be made available for electronic transfer to the State. At the end of the process all vibracore information (geographical location, logs, gradation analysis tables, sediment distribution curves and core photographs) should be stored in individual .pdf files that can be made readily available from the ROSS system in the form of download menus or hyperlinks.

All necessary calibrations and other related tests that are considered necessary for the accuracy of the data and survey should be performed as part of this task group. Similarly, all necessary corrections usually carried out as standard operating procedures for reconnaissance surveys should include ascertaining tide and water levels. Once the sedimentary grain-size parameters, and other qualifiers relevant to the suitability as beach sediments are established, potential borrow areas can be delineated.

1.8 PHASE VIII: HAZARD, NATURAL RESOURCES AND ARCHAEOLOGICAL ASSESSMENT SURVEY

Once a potential borrow area has been identified, a cultural resources study is conducted using a magnetometer, detailed seismic, sidescan sonar and bathymetry in compliance with local, state and federal government regulatory requirements. Detailed geophysical data from the archeological surveys should also be integrated into the borrow area design data giving more certainty on sand deposits within the proposed cuts and to avoid duplicate efforts.

The purpose of the magnetometer survey is to determine if there are any metallic objects in the borrow area which may be of historic value, such as shipwreck artifacts. The magnetometer investigations are also useful in identifying non-historical metallic objects that may interfere with the dredging process such as abandoned engine blocks, pipelines, metal cable, etc. The results of the survey are documented by a professional archeologist and reported to the State Division of Archaeology. If needed, the borrow area should be revised and buffers should be implemented to avoid objects of potential historical value.

Cultural resource surveys (Kidder, 1996; Green, 2004; Watts and Finkl, 2004a, b, c, d) should be conducted when required for permitting purposes. These surveys are often necessary to ascertain the presence of drowned habitation sites of paleoindians (paleoanthropological and archeological term referring to Native American cultures prior to 8,000 BC) or other cultural groups and also provide excellent datasets for refinement of borrow area design cuts. Underwater archaeology (continental shelf archaeology) is an important endeavor because it attempts to reconstruct where and how ancient peoples settled on coastal plains, portions of the modern continental shelf that were subaerially exposed during times of lower sea level, and when they began to access and procure near-coastal and marine resources. In addition to the detection of Pleistocene settlements on exposed continental shelves there are important cultural remains on the seafloor that are related to contemporary society. Many of these artifacts (*e.g.* anchors, cables) have no cultural significance, but they can damage dredges. Other cultural features such as buried pipelines and fiber optic cables require identification prior to dredging for definition of setbacks.

Due to the level of detail that is required for cultural surveys, sidescan sonar and magnetometer surveys are conducted on a close line spacing (~30 m). Normally, for such surveys the specifications and guidelines are provided by the permitting agency. Sidescan sonar surveys, which are conducted for identification of surface structures and hazards including debris, pipelines, shipwrecks, normally using dual-frequency sidescan sonar, are normally accompanied by a magnetometer survey (using either Proton or Cesium Magnetometer). Generally, 100% swath coverage is needed for a sidescan sonar survey. This survey is normally done under the supervision of a professional marine archaeologist.

Natural resources are also a major concern. Off the southeast coast of Florida, environmental concerns tend to focus on the presence of hardgrounds. Information that includes shapefiles from the Florida Geographic Data Library (FGDL) like the seagrass beds, salt marshes, tidal flats, artificial reefs and aquatic preserve boundaries and side-scan sonar mapping are used to ascertain the occurrence of sensitive environments. If such environments are detected, they are delineated and avoided.

1.9 PHASE IX: BORROW AREA SELECTION AND CALCULATION OF SAND VOLUME

Finally, the selection of potential borrow areas requires re-evaluation of all geotechnical and geophysical data obtained during Phases I through VIII, including updates or additions to prior surveys, and the determination of outer limits of borrow areas. Geologic cross-sections, compiled on the basis of sub-bottom data and vibracore logs, should be produced showing the sand layers and the proposed depths of cut. Isopach maps showing sediment thickness should be prepared to show the stratigraphic position of target sands and layers that should be avoided.

Because the depth, location, and orientation of borrow areas affects the adjacent shoreline, a thorough impact study should be conducted not only for borrow-site environmental assessment but for physical impact-assessment. These studies tend to focus on induced changes to wave propagation patterns and coastal circulation patterns for different depths of sediment removal (Bender and Dean, 2003).

The cost of dredging potential borrow areas can be a crucial consideration, especially where long haul or pump distances from borrow to project area are an issue. The cost of dredging sediments is affected by the following major factors: type of sediment, distance from the borrow area to the project site, length and width of the beach being restored, depth of water and depth of dredging in the borrow area, depth of water adjacent to the project site, and thickness of the dredge cut.

The type of sediment determines dredge horsepower requirements, which in turn affects the cost of dredging. The distance from the borrow area to the extreme limits of the beach restoration project also affects project cost and equipment selection. When dredging with pumping distances up to 6.2 mi, a cutterhead dredge (including the ocean-going dustpan) is the most efficient method. These dredges have 10,000 to 15,000 horsepower, which can pump non-cohesive sediments over these distances. When the distance from the borrow area to the project site exceeds 7.5 to 9.9 mi, hopper dredges become more efficient in transporting the sediment. Thickness of cut in borrow areas also affects equipment selection and productivity. For cutterhead dredges to be productive, the cut must be at least 1 to 2 m thick. For cuts less than 2 m, cutterhead dredges can still operate but at less than optimum efficiency. For shallow cuts, hopper dredges and the ocean-going dustpan are more efficient because they excavate sediments in layers. If an insufficient number of cores are present in the borrow area, dredging contractors often add significant contingency fees to account for unknown or unfavorable conditions that might be encountered. Once a borrow area is selected, it may be worthwhile to go back for an additional round of vibracoring to effectively determine sediment variability. Additional vibracoring with spacing no greater than 200 m apart may provide greater confidence in sedimentary conditions and significantly reduce dredging costs. Better estimates of sediment volumes by grain size for % sand (D_{50}, D_{85}) or % silt, shells, gravels, *etc.* may also reduce (offset) dredging costs.

1.10 PHASE X: DEVELOPMENT OF GEOTECHNICAL REPORT

The last phase of a sand search involves the preparation of final reports, appendices and digital data deliverables. As far as general guidelines are concerned, this final phase is perhaps the most important because a poorly prepared or presented report, wastes a great deal of effort. In the same way, if the datasets created are not incorporated into a digital GIS database (ROSS) information will be lost and future efforts in the same area may be conducted by uninformed groups. It is thus essential that reporting procedures be followed using correct formats and styles. It is expected that final sand search reports will document the techniques, methods, analyses, and results. It should be common practice that all newly generated data in marine sand searches is submitted in a GIS format that can be incorporated into ROSS with minimal effort.

1.11 FINAL CONSIDERATIONS

Comprehensive reviews of previous offshore sand searches and legacy data is now facilitated by the existence of a comprehensive offshore marine sand search database (ROSS). Careful analysis of these legacy data, for example, should provide clear directives to the survey of target areas with the most potential for locating usable sand sources and significantly optimizing future sand search efforts. Selection of potential borrow areas, the ultimate goal of offshore sand searches, depends on adherence to established search protocols that are tempered by practical adjustments to local conditions.

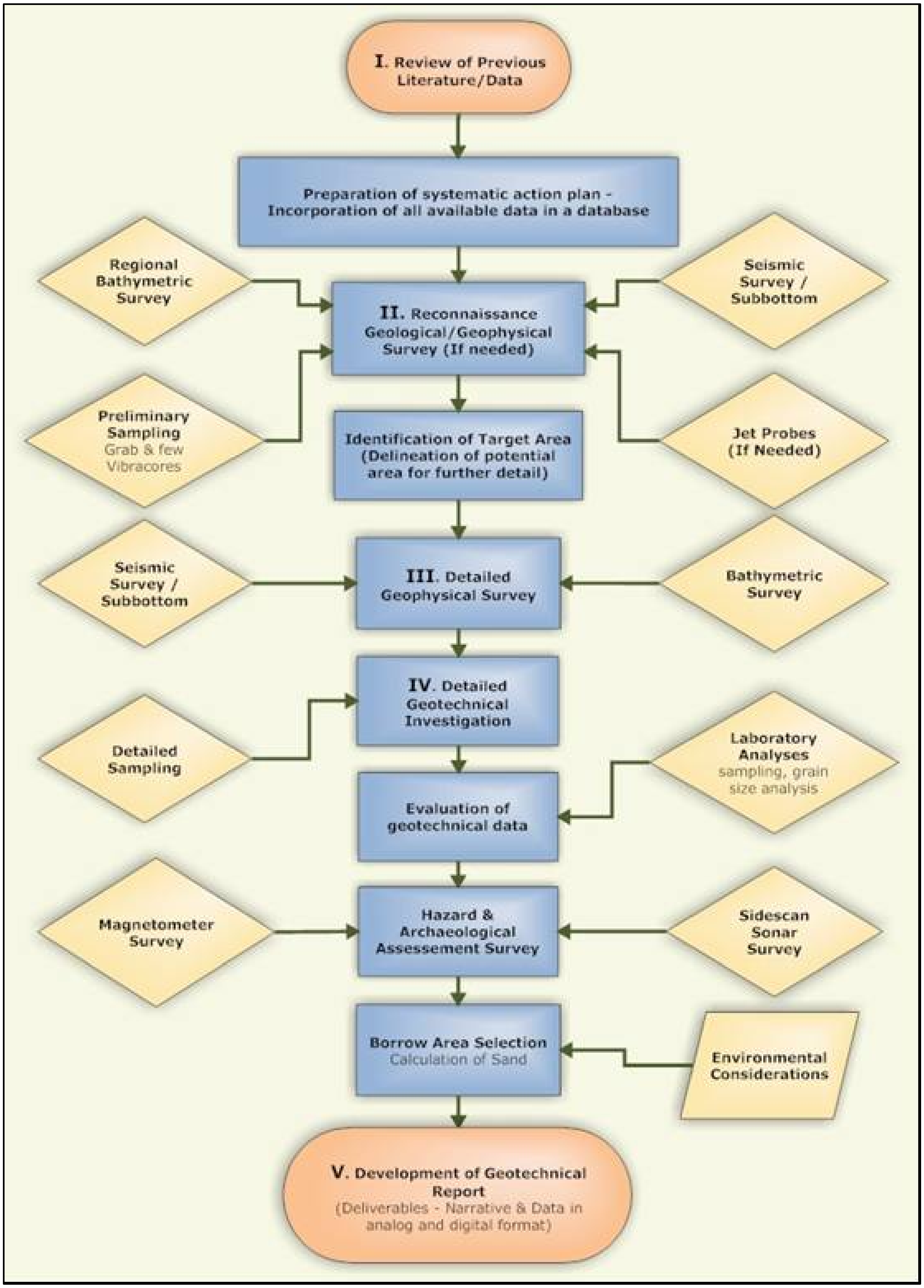

Figure 1-1. Flow diagram showing systematic approaches to offshore sand searches, based on major steps that incorporate a range of subset activities that are restrained by local circumstances. Each task is meant to direct the course of subsequent actions so that sand searches along sandy coasts proceed following a logical strategy that produces an efficient exploration methodology.