Technical Memorandum

To:	Bureau of Ocean Energy Management Marine Minerals Program
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SEDIMENT CLASSIFICATION SCHEME FOR OFFSHORE SEDIMENT RESOURCES

OVERVIEW

Sand and other sediment types are valuable resources that are needed for coastal restoration, construction, and manufacturing. Within coastal environments, sediment of suitable quality is an extremely limited resource, with an estimated 4.8 billion tons lost globally every year to coastal erosion (Laudon, 2009). The volume of sediment needed to mitigate this loss and preserve coastal communities and ecosystems is substantial, with an estimated total of 1.5 billion cubic yards of material placed along the coastline of the United States alone between 1920 and 2020 at a generally increasing decade-over-decade rate (Elko et al., 2021). This high and increasing need for sediment will elevate the cost of identifying and sourcing sediment for coastal restoration projects, as well as potentially lead to regional shortages of readily available sediment that meets desired characteristics such as grain size and color.

One of the most frequent methods used to obtain sediment for coastal restoration is to extract it from nearshore or offshore borrow areas, with the latter stewarded in the federal waters of the United States by the Bureau of Ocean Energy Management (BOEM) Marine Minerals Program (MMP). BOEM MMP recognizes the challenges of identifying suitable sediment sources for coastal restoration or other purposes, as well as the opportunity to address these challenges and enable more efficient development of sediment resources through more effective use of data and information available for the continental shelf and potential offshore sediment resources. As such, BOEM MMP has worked with APTIM and the Water Institute to develop a classification scheme for potential sediment resources and develop performance metrics for the National Offshore Sand Inventory (NOSI). This effort can enable more efficient, effective, and holistic management of offshore sediment resources as part of short- and long-term solutions for coastal sustainability.

This project was designed to provide initial results to inform continued development of a classification scheme, and this tech memo describes findings in that context. The remainder of this overview gives relevant background information, describes the planned project trajectory, and provides suggested modifications based on initial results. Next, the classification scheme development process is described, followed by the draft scheme, associated metrics, and information types. The tech memo concludes with lessons learned relevant to future work.

BACKGROUND

A *sediment resource* is a geologic deposit; these deposits include clay, silt, sand, and gravel size particles and shell found on or below the surface of the seafloor (as defined in Section 2(a) of the OCS Lands Act (43 U.S.C. § 1331(a)). Sediment resources refer to broader geologic deposits, and a portion of a given resource may be developed into a specific *borrow area* (Figure 1). Borrow areas are regions of a sediment resource that have been delineated for use in placement projects. Not all sediment resources are suitable for development into a borrow area, depending on factors such as physical characteristics, economic and engineering constraints, accessibility, and sediment suitability and compatibility for intended use.

Sediment within a designed and permitted borrow area can be extracted for use (i.e., a *designed borrow area* becomes a *used borrow area*), and the portion of the designed borrow area that is used becomes a *dredged area*. For the purposes of this tech memo, a used borrow area and a dredged area are synonymous. Sediment resource areas are classified by BOEM in the Marine Minerals Information System (MMIS) in terms of the likelihood that an area can be developed into a dredged borrow area: unusable, possible, potential, probable, and proven.[1] These categories are useful for first-order assessment of resource confidence level, but do not attempt to classify the underlying sediment resource deposit based on geological, engineering, and accessibility characteristics. Such characteristics could aid BOEM and sediment resource users in making regional comparisons of potential borrow area quality, determining what types of data investments provide the most value for resource development, and predicting additional sediment resource occurrence.

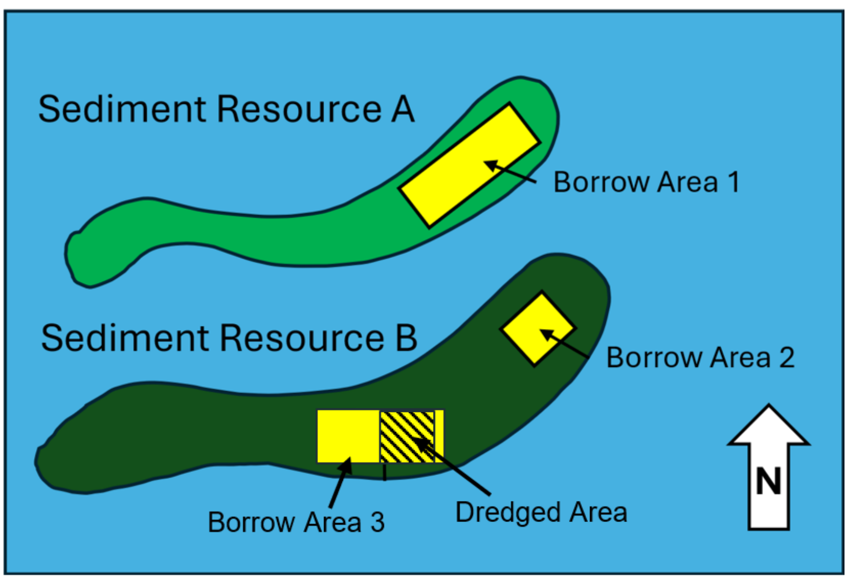

Figure 1. Conceptual diagram of sediment resources and borrow areas. Three borrow areas (1–3) are defined within two sediment resources (A–B), with a portion of borrow area 3 used and becoming a dredged area.

[1] https://mmis.boem.gov

In a typical project-driven prospecting workflow, a resource user begins by screening a broad area for geologic deposits that could contain sediment resources based on preliminary geologic and environmental knowledge of the area. This screening could consist of cataloguing the locations of known shoals in a region based on their presumptive sand content. Next, the potential sediment resources are evaluated to assess their potential for further development into borrow areas (Figure 1). Borrow areas within sediment resources may be defined based on their *internal* characteristics, such as average grain size, percent fines, average thickness, amount of overburden, potential inclusion of contaminants or foreign material, and the like. Borrow areas may additionally be defined by their avoidance of *external* limiting factors, such as critical marine habitat, offshore infrastructure, or nearby cultural resources. The development of a potential sediment resource into a designed borrow area and an ultimately dredged borrow area is supported by focused data investments to reduce risk. The overarching risk considered during sediment resource prospecting is the risk of not finding suitable sediment that is economically feasible to recover. Deposits which may have been viewed by a resource user as promising may not be developed into borrow areas based on internal risks, external risks, or logistics influencing recovery economics.

PROJECT GOALS

BOEM and the project team articulated that the goal of the classification scheme is to characterize potential sediment resources into meaningful typologies, or classes, whereby a resource's typology could be predicted based on available data ahead of expensive coring or detailed site surveys. For example, typology "A" might correspond to sediment with a grain size of 0.4–1 mm, minimum shell and silt content, and no conflicts such as pipelines. This type of scheme would enable resource users to focus sediment searches in locations where they are most likely to find sediment with the characteristics and volume they need. In addition, classification metrics that provide detailed information on key sediment characteristics and available volume can be directly translated to performance metrics for NOSI as parameters for evaluating success in determining the quantity and quality of available sediment resources on a regional and coastwide basis.

Borrow area classification, sediment resource classification, and risk/uncertainty analysis can also support the broader programmatic efforts of BOEM MMP and NOSI. NOSI supports and incorporates numerous studies and program elements including resource evaluation studies, supply and demand studies, borrow area optimization strategies, risk mitigation, and potential environmental impacts. Resource evaluation studies are designed to identify potential sediment resources within the Federal Outer Continental Shelf (OCS) and assess which resources are most promising for development into borrow areas. These efforts would be enhanced by a classification scheme which can be used to assess what factors (internal and external) were the most important for successful borrow area use, early de-risking of potential resources, and aid in screening of large coastal regions in advance of the reconnaissance and appraisal level data investments conducted during resource evaluation. A classification scheme at the sediment resource and borrow area level would also enable the application of early assessment and a tailored mitigation strategy of risks to successful borrow design and sediment extraction.

PLANNED PROJECT STRUCTURE

This project team used the principles of Structured-Decision-Making (SDM). SDM is an objectives-orientated approach to support decision-making that can be used to consider tradeoffs across multiple objectives (Dalyander, 2021; Gregory & Keeney, 2002; Hammond et al., 1999). The SDM process consists of the "PrOACT" cycle (Figure 2) which includes:

- Defining the **Pr**oblem or decision context , including the spatial and temporal scope, constraints, and other underlying factors;
- Identifying **O**bjectives, or what the decision-maker hopes to achieve;
- Articulating **A**lternatives, or the different decisions or options;
- Evaluating **C**onsequences by assessing the alternatives against the objectives; and
- Determining **Tr**adeoffs in terms of how different alternatives perform against different objectives.

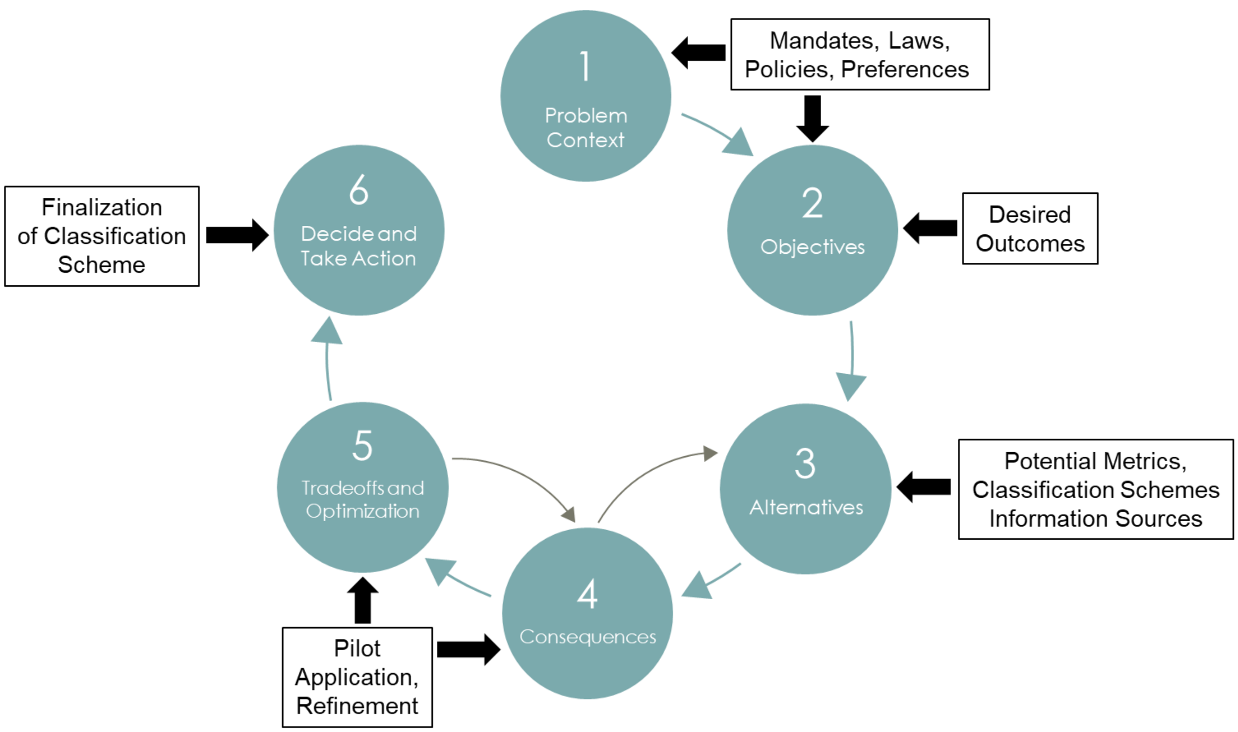

Figure 2. The Structured Decision-Making (SDM) cycle, which consists of refining the problem context (use cases of the classification scheme, mandates or policies that must be considered, etc.); articulating objectives (desired outcomes and preferences); identifying alternatives (potential metrics for borrow area classification); using consequence and tradeoff analysis to refine alternatives (i.e., pilot application and scheme refinement, as noted by the feedback arrows on the interior of the cycle); and making a decision (i.e., finalizing a classification scheme).

The project team aligned the project tasks to components of the SDM framework (Figure 3), with the first phase of classification scheme development (Subtask 1B) funded and additional subtasks (Subtask 1C, 1D, and 1E) set up as optional.

The first task—Subtask 1B, which is reported on in subsequent sections of this technical memo—was composed of the first three components of SDM. The project team's intended outcomes were to identify use cases and objectives for resource classification and develop metrics for a classification scheme through application at used borrow areas. The project's classification scheme development began with a pilot focused on dredged borrow areas because additional data is collected during borrow area design and dredging beyond what is available for other identified sediment resources, thereby providing more information for developing typologies (borrow or sediment resources classes) that are meaningful to sediment users.

The project was originally designed to then proceed to optional Subtask 1C, during which the project team would take the classification scheme process, typologies, and sediment parameters identified in Subtask 1B and extend the work to a conceptual framework for sediment resources. In this initial plan, potential approaches to the classification scheme for sediment resources would have been assessed (i.e., consequence and tradeoff analysis) in Subtask 1C against objectives identified in Subtask 1B. The team would have then addressed risk in Subtask 1D by adding uncertainties associated with factors impacting available sediment within delineated resources, including internal risks (e.g., contaminants, fines, etc.) as well as external environmental or anthropogenic risks (e.g., cultural resources, pipelines, etc.). Lastly, Subtask 1E would have identified and compiled quantitative and qualitative performance metrics for NOSI, informed by the classification of borrow areas and sediment resources conducted in Subtasks 1B–1D.

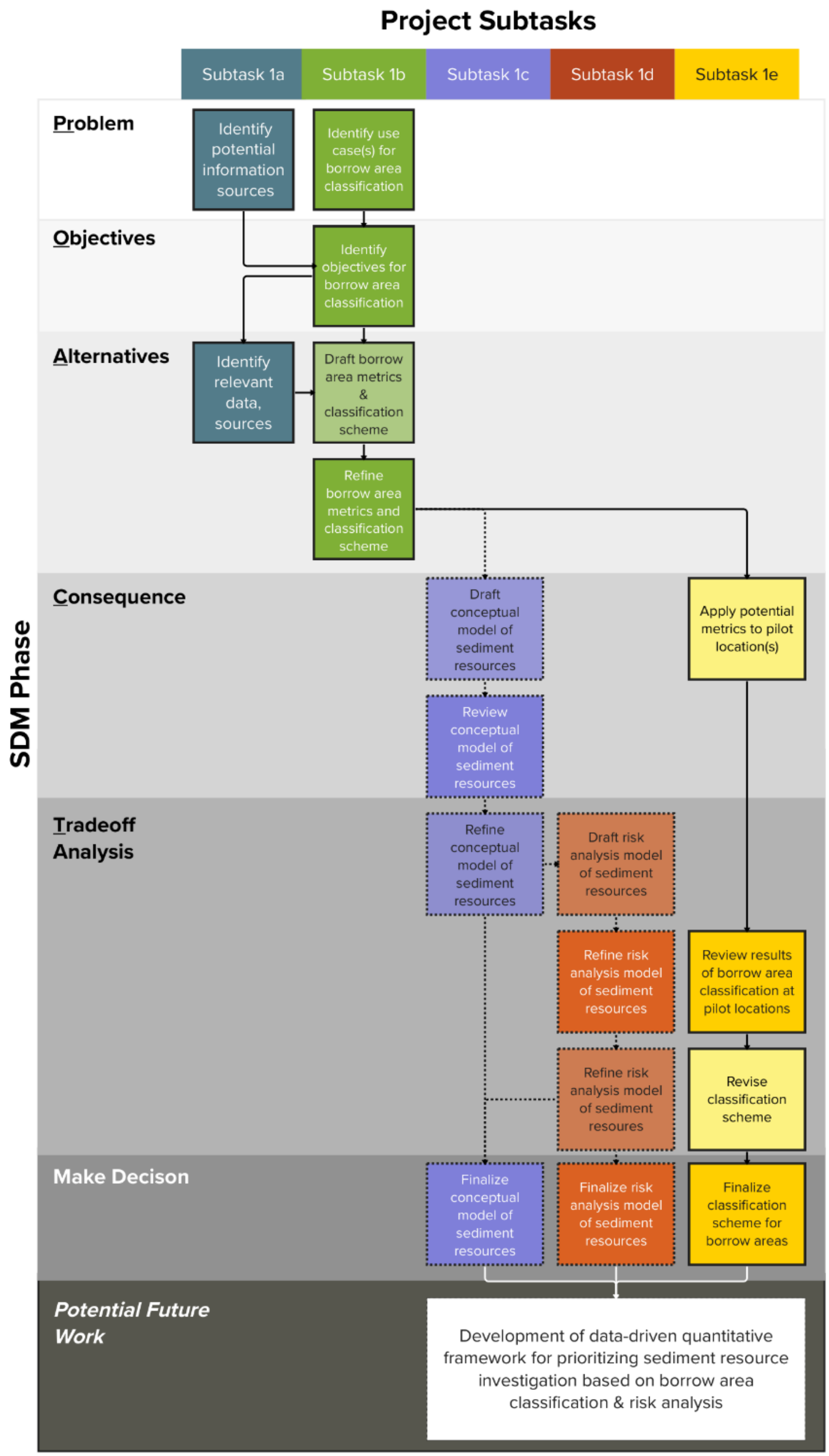

Figure 3. Planned stepwise approach to project implementation, which aligns to components of a Structured Decision-Making (SDM) framework.

SUGGESTED PROJECT STRUCTURE REVISION AND NEXT STEPS

Subtask 1B resolved uncertainties relevant to the next steps in project execution. One such uncertainty was the quantity and quality of data available for borrow area and sediment resource classification. Collection of offshore geologic and geophysical data is time-consuming and expensive, therefore geophysical data is not often collected systematically on regional or coastwide scales. Instead, surface and subsurface data and sampling are typically only collected in localized areas for specific purposes, such as designing a borrow area for a restoration project with particular needs; there are no universal standards for the type or density of data collected. The project team discovered through an initial assessment of existing databases and a review of a select set of borrow areas (described in *Classification scheme pilot: Borrow areas*) that there is often missing information that would be highly beneficial for classification scheme development. Sediment resource users do not systematically collect the same data, metadata, or other documentation, and in some cases the associated reports are not readily available. In addition, data collected in deposit areas that do not meet dredging project requirements in terms of volume and sediment characteristics such as grain size, color, or that present other issues with compatibility, are often not well-documented.

However, the project team also found that the assessed borrow areas have limited variability when only considering sediment characteristics, reflecting that sediment users often have similar priorities when designing them. For example, implementers of amenity beach restoration projects typically seek proximal sand deposits with minimal use conflicts. The team determined that minimizing the risk of encountering internal and external conflicts is a primary driver of borrow area delineation and thus sediment resource utilization. As an analogy: sediment users are akin to Goldilocks all seeking the same perfect bowl of porridge, who then quickly move on when they sample something that is not “just right”.

A robust classification scheme—and, by extension, performance metrics for NOSI—would include characteristics and variability in potential sediment resources that might often be considered suboptimal now in order to:

1. Enable users with different priorities to more readily find suitable resources;
2. Eliminate a user collecting new data in an area where prior investigation has likely established it as unsuitable for their needs;
3. Limit time and money being spent by multiple users sampling the same areas; and
4. Prepare for a likely shift in priorities and standards as readily available sediment resources are depleted (i.e., Goldilocks may re-consider her options when the “just right” porridge is gone).

The outcomes of Subtask 1B do, however, provide confidence of success in future subtasks under a suggested modification to the planned approach. A diagram is provided (Figure 4) that shows the inputs, activities, and outcomes associated with each Subtask as well as the linkages between them. For example, there was uncertainty in regards to data availability and variability in sediment parameters across used borrow areas prior to executing Subtask 1B. These uncertainties were resolved during subtask execution. In addition, the project team identified risk factors that could be quantified or qualified using readily available data, including external risks such as pipelines and internal risks such as excess fine-grained material. That information, in turn, is a key factor providing confidence in the success of Subtask 1D.

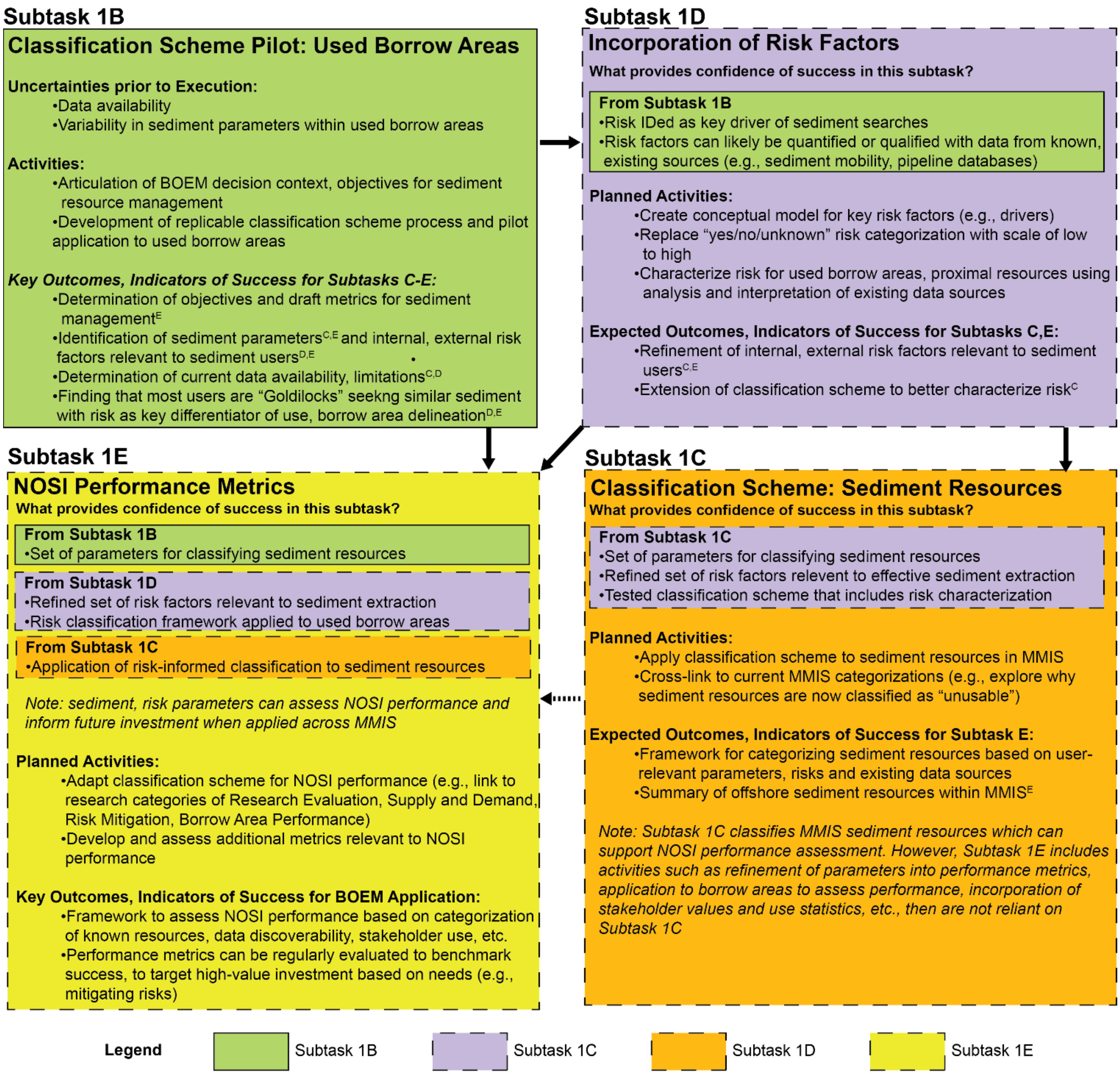

Figure 4. Flowchart of subtasks under suggested project revisions. Each subtask has outcomes and indicators of success that form the basis for future work, indicated as superscripts with letter of the subtask the outcome supports. For example, completed Subtask 1B identified risk as a primary driver of borrow area delineation and sediment resource use, determined key risk factors, and identified potential data sources to inform that risk, which are indicators of success for Subtask 1D. Similarly, these parameters underpin certain performance metrics for the National Offshore Sediment Inventory (NOSI), and—when combined with the completed articulation of objectives for sediment resource characterization—provide confidence in execution of Subtask 1E.

By identifying and populating classification scheme parameters (see *Classification scheme parameters: Expanded parameter*), the team confirmed there is a limited range of sediment variability across used borrow areas and that minimizing risk of encountering conflicts is a primary use consideration (i.e., borrow areas are often located or delineated to avoid those risks). Unfortunately, data on prior conflict avoidance in borrow area design is difficult to obtain since this information is not consistently included within MMIS and acquiring it from original sources, such as borrow area design reports, is extremely time-consuming. As part of Subtask 1B, however, the team identified types of readily available screening data that can be used to spatially characterize or inform risk (e.g., maps of pipelines; estimates of shelf-wide sediment mobility to inform potential for presence of surficial fine-grained material), providing confidence of success in executing Subtask 1D. Therefore, the team suggests that Subtask 1D be executed immediately and ahead of Subtask 1C.

Subtask 1D extends the framework to include risk, defined as the likelihood of encountering issues during dredging across internal and external factors. That effort will build on Subtask 1B by replacing the "Yes/No" categorization of parameters (see *Classification scheme parameters: Expanded parameter*) with qualitative, ordinal scale (e.g., high, medium, or low risk) for each factor. The assessment of priority risk factors can be quantitatively calculated or qualitatively informed through analysis and/or documented interpretation of readily available screening data. By focusing Subtask 1D on used borrow areas and their immediate proximity, the team can inform and calibrate the approach by comparing the developed risk assessment to previously identified information on dredging and borrow area design.[2]

The project team anticipates that once executed, Subtask 1D will provide outcomes and indicators of success that support successful execution of Subtask 1C (Figure 4). Subtask 1B also provides confidence in the eventual success of Subtask 1C: conflict avoidance—for which there is readily available data—is a shared concern that must be incorporated in the classification scheme that can enable useful classification despite the potential for data gaps in sediment characteristic information. The development and application of an ordinal scale for risk (from Subtask 1D) will provide confidence that the data needed for Subtask 1C are readily available and can be used to assess risk. Calibrating the results with the design of used borrow areas and dredging outcomes (also Subtask 1D) similarly provides confidence that the overall approach is viable and can be applied to sediment resources.

Once these indicators of success are achieved, through confirmation of data availability and preliminary, positive results in translating that information to an ordinal risk scale, Subtask 1C can begin with high confidence of success. In the meantime, BOEM can use the Subtask 1B parameter template as a guide for collecting additional information for borrow areas and/or sediment resources currently part of active sediment sources, which further supports Subtask 1C. The updated classification scheme, applied to sediment resources in Subtask 1C, will enable users to prioritize areas with minimal conflicts or, as needed, to consider tradeoffs between a high risk of conflicts and other relevant factors such as distance to placement area. In addition, the results can be compared to the existing MMIS sediment resource

[2] For example characterization of high risk of encountering pipelines would be supported if noted during the Subtask 1B investigation, and/or if a borrow area extent appears truncated due that conflict when overlain with a pipeline map.

classification to provide additional detail, such as why some resources are classified as “unusable” and if, with additional targeted research or risk mitigation efforts, those resources may be potentially usable.

Lastly, the outcomes of Subtask 1B have provided the project team with confidence for the success of Subtask 1E (Table 1). The project team worked with BOEM to articulate fundamental objectives for the classification scheme that informed the identification of parameters in Subtask 1B, and will continue to inform work in Subtask 1C and 1D.

These objectives include:

- Maximizing the volume of nearshore and offshore sediment resources characterized for sediment users. In order to inform use, these resources must be characterized with sufficient detail;
- Maximizing the effectiveness of sediment resource extraction; and
- Minimizing the temporal and financial cost used to identify and extract sediment resources.

Each of these objectives is closely tied to the value provided by MMIS as a tool for finding and effectively using sediment resources. By extension, these objectives are then also tied to the benefits provided by NOSI and supported research across categories of research evaluation, supply and demand, risk mitigation, and borrow area performance. Performance metrics for measuring and communicating NOSI’s effectiveness and progress should therefore be related to these objectives.

Other outcomes of Subtask 1B provided confidence in Subtask 1E, including the project team’s identification of specific classification parameters that can measure and inform progress related to these objectives and, by extension, form the basis of performance metrics for NOSI (Table 1). Because several of these metrics will be advanced in Subtask 1D, preliminary work on that effort—particularly the preliminary assessment of data availability and an initial application to a subset of risk factors—is expected to provide additional confidence in, and support for, Subtask 1E.

Lastly, Subtask 1C applies the risk-informed framework developed in Subtask 1D to sediment resources and can thereby provide information for the NOSI assessment. However, Subtask 1E will include developing metrics related to information discoverability and use, which can begin at any time since the work is not reliant on a prior subtask. In addition, Subtasks 1B and 1D provide the core foundation of Subtask 1E by identifying and refining parameters for NOSI performance metrics; while Subtask 1C provides data for Subtask 1E through applying the scheme to sediment resources, it is not foundational for the development of the NOSI assessment approach.

Table 1. Preliminary, partial list of draft performance metrics for the National Offshore Sediment Inventory (NOSI). Note, development of performance metrics is the goal of Subtask 1E, which has yet to be executed. This information is provided to illustrate how the outcomes of Subtask 1B and expected outcomes of Subtask 1D support the development of a framework for assessing, tracking, and communicating the value of NOSI. Subtask 1C provides data that can be used in assessing the current value of MMIS in advancing NOSI goals; however, the development of the performance assessment is more directly supported by Subtask 1B and 1D.

Objective	Example Metrics and Supporting Basis from Subtasks 1B, 1D	Example Linkages to NOSI Research Categories
Maximize volume of nearshore and offshore sediment resources characterized for sediment users.	Number and extent (volume, area) of resources characterized by sediment parameters, with list of parameters developed in Subtask 1B (estimated sediment volume, average sediment phi mean from samples; average sand percentage; interquartile range of sediment grain size).	Resource Evaluation: identifies progress in evaluating potential resources and focuses future work by, e.g., identifying regions where there are few resources that can be characterized using the identified parameters.
	Number and extent (volume, area) of resources with and without risks, with risk factors identified in Subtask 1B and refined/characterized in Subtask 1D (internal risk of: shell, rock, clay/fines, munitions and explosives of concern (MEC) or unexploded ordinance (UXO); external risk of: shipwrecks or cultural resources; pipelines; environmental/species conflicts, such as essential fish habitat).	Supply and Demand: Benchmarks resources characterized with user-relevant parameters against estimates of current and future needs, and can focus sediment searches in areas where the gaps are largest.
	Available sediment resources characterized as meeting different sediment parameter and use conflicts as a fraction of estimated sediment need identified through desktop research and user surveys.	
Maximize effectiveness of sediment resource extraction	Summary of internal and external risk factors by region and coast-wide to inform high-value research and development into risk mitigation. Risk factors identified in Subtask 1B and refined/characterized in Subtask 1D.	Risk Mitigation: identifies and tracks regionally which risks are driving reduction in sediment availability, and can focus risk mitigation research in those areas.
	Statistics and indicators of MMIS discoverability and utilization by sediment users. These are new metrics that will be developed in Subtask 1E, but may include direct indicators such as websites hits or polls of users, as well as indirect indicators such as MMIS being cited in reports and other publications.	Borrow Area Performance: Provides a framework for tracking conflicts used in borrow area design and an approach to benchmark expected sediment volumes with actual dredged material.
Minimize cost used to identify and extract sediment resources	Time and resources invested by BOEM in classification scheme maintenance and across each of the Research Categories.	This category provides the information necessary to evaluate return on investment across the other categories.

CLASSIFICATION SCHEME DEVELOPMENT WORKFLOW

Development of a classification scheme requires several steps. Typologies must be created by first identifying key parameters that meaningfully differentiate sediment resources and are relevant to users (sediment grain size, shell content, etc.). Then, ranges and combinations of parameters must be determined and assigned to each typology. For full utility to sediment resource users, the classification scheme would characterize sediment parameters as well as other factors relevant to dredging and usable sediment volume (pipelines, cultural resources, unexploded ordinance, etc.). Typology creation therefore relies on detailed information acquired through site-specific assessment (e.g., core data), in addition to information only available after dredging, such as usable resource volume (Figure 5).

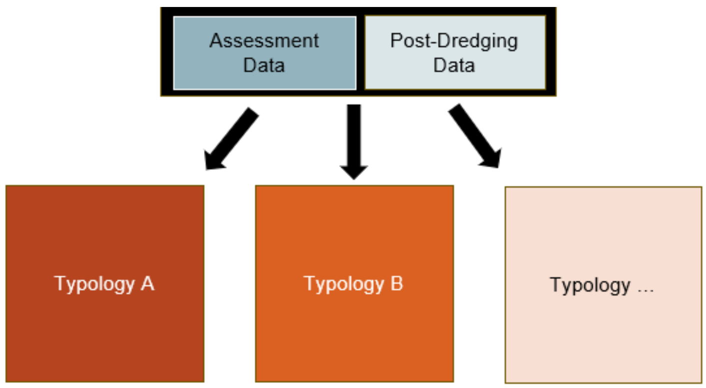

Figure 5. Conceptual diagram illustrating the creation of typologies. Typologies are unique combinations of factors such as range of grain size, color, presence of shell or rock, etc. Sites are sorted based on grouping key parameters derived from assessment data, which includes information available from detailed site surveys, as well as information only available after dredging, such as usable sediment volume.

Once typologies are defined, a method must be developed and applied that predicts the typology of sediment resources (Figure 6). This step is challenging because typology classification must often be made for sediment resources using only readily available screening data. In most cases, the available screening data provides proxy information for a variable of interest; for example, seafloor mobility data can indirectly inform predictions of sediment grain size since areas with high mobility will tend to coarsen over time as finer-grain material is winnowed away.

The classification scheme also needs to consider risk—the uncertainty bands characterizing the likelihood of a sediment resource falling within different typologies—since the classification will not be 100% certain until after a site is dredged. Incorporation of risk also informs BOEM data collection. If users are particularly interested in Typology "B", BOEM can prioritize investments that reduce the uncertainty surrounding potential "Typology B" resources. Similarly, if sediment resources assigned to "Typology C" resources are less desirable to users because of a high risk of Munitions and Explosives of Concern (MEC), BOEM could potentially invest in detailed surveys to better differentiate presence/absence.

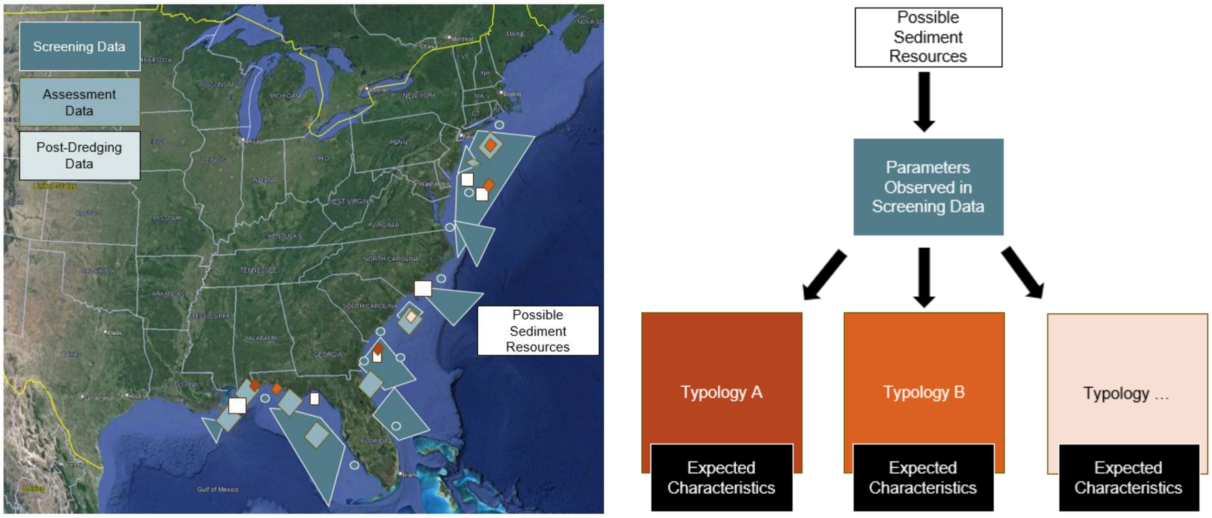

Figure 6. Illustration of assigning sediment resources to typologies (Figure 5).

The project team developed a stepwise workflow to create a classification scheme as described above. The first step, summarized here, was a pilot application using data from used borrow areas. Key outcomes of the pilot include: (1) identification of sediment parameters for defining typologies, including an in-depth evaluation of available data; and (2) a replicable process, preliminarily applied to available borrow area data, that can be expanded to include more parameters and to consider risk when applied to the larger sediment resources in which borrow areas are located.

CLASSIFICATION SCHEME PILOT: BORROW AREAS

The project team worked through first three steps of the SDM process in a series of biweekly working sessions with a core team of representatives from BOEM MMP (Ashley Long, Doug Piatkowski, and Kerby Dobbs). In addition, the team held three workshops with a broader group of representatives from BOEM to elicit additional input on the classification scheme.

The problem context developed in coordination with BOEM for the classification scheme, which includes identification of intended users and use cases, is as follows:

> The status quo in sediment resource management is for users to identify potential borrow areas for a specific project based on limited available information for quantifying the probability of finding sediment resources that meet their needs and to conduct minimal archiving of new data they collect for future use. This approach is unsustainable due to increasing demands for sediment by multiple users and depletion of readily available resources. BOEM MMP has recognized that a more holistic, programmatic approach to offshore sediment resource management is needed.

In response, BOEM MMP is developing a classification scheme for sediment resources to support prioritizing data collection and research; evaluating and communicating risks and tradeoffs in the context of intra- and interagency regulatory responsibilities; inform Outer Continental Shelf lease management; and support coordinated offshore spatial planning across BOEM and with external users. Sediment users could also use the scheme to evaluate and tradeoff the suitability of, and uncertainty in, sediment resource areas meeting their desired criteria.

The classification scheme will be developed through pilot application at a set of existing borrow areas. Later, the scheme will be expanded and updated as needed and applied nationwide to sediment resources across state and federal waters using data from federal, state, local, academic, and private partners. The classification scheme must be flexible in data used, with data quality considered as part of characterizing uncertainty and risk. Compatibility with MMIS will also be considered in classification scheme development.

The initial focus is on internal BOEM use and interagency coordination, with a strategic, mid-term objective of sediment resource classification and uptake of the scheme by sediment users. In the long term, the classification scheme may be integrated with data relevant to non-consumptive users to support holistic and sustainable seafloor management more broadly.

The team also worked with BOEM to identify objectives for sediment resource management and potential (preliminary draft) metrics, including:

- Maximizing the volume of nearshore and offshore sediment resources characterized for sediment users;
- Maximizing the effectiveness of sediment resource extraction; and
- Minimizing the cost (in time and dollars) used to identify and extract sediment resources, including in classification scheme maintenance.

This decision context and objectives guided the Subtask 1B pilot application to used borrow areas, including the identification of parameters for use in sediment resource classification and consideration of alternatives for the classification scheme framework.

CLASSIFICATION SCHEME PARAMETERS: INFORMATION FROM MMIS

As identified in the decision context, the primary intended users of the classification are BOEM and, in the long-term, other uses of nearshore and offshore sediment. Therefore, classification scheme parameters were identified through elicitation from representatives of BOEM and APTIM (as a representative sediment user). Parameters relevant to both sediment resource extraction and utilization were included based on the SDM objectives. First, the team worked with BOEM to identify parameters (Table 2) to extract from the BOEM MMIS (https://mmis.boem.gov/), an existing database managed by BOEM that archives information on dredged areas and sediment resources.[3] The team also evaluated other available databases, including the Florida Regional Offshore Sand Source Inventory (ROSSI) and the Louisiana Sand Resources Database (LASARD), but determined that limited relevant information was available in those databases beyond what is already included within MMIS.

[3] One challenge is that the sample data used to design and delineate borrow areas from sediment resources is not always shared with BOEM and may not be found within MMIS for all sites.

Table 2. Descriptions of parameters included within the pilot classification scheme framework that were extracted from the Marine Minerals Information System (MMIS). White rows indicate baseline information extracted about the borrow areas; gray rows represent values calculated directly from information in other rows (e.g., construction time calculated from start and end dates); and light blue rows represent parameters derived from data within MMIS. Included is both a description of each parameter and the method of calculation.

Header Term	Description	Source & Calculation Method
State	State with boundaries closest to the borrow area. Borrow area may fall within the state's jurisdictional boundaries or within federal waters	Data taken directly from BOEM MMIS
LeaseNo	Lease identifier	Data taken directly from BOEM MMIS
ProjectID	Project identifier	Data taken directly from BOEM MMIS
BorrowArea	Borrow area name	Data taken directly from BOEM MMIS
ConstructionStart	Date of start of dredging	Data taken directly from BOEM MMIS
ConstructionComplete	Date of end of dredging	Data taken directly from BOEM MMIS
Construction Time. Automatically Calculated [days]	Length of time between ConstructionStart and ConstructionComplete	Calculated within the datafile as the length of time from ConstructionStart to ConstructionComplete
DredgeVolCalc [m^3]	Volume of dredged sediment in cubic meters (m^3)	Data taken directly from BOEM MMIS
Dredged Area [km^2]	Surface area of dredged area in square kilometers (km^2)	Calculated as the area of polygons within BOEM MMIS corresponding to the dredged area for this borrow area. Includes all dredging events in MMIS.
Other Notes on White Columns	Comments on the borrow area description or characteristics	This column allows for notes to be added by individual(s) populating the classification scheme.
Number of core boring samples in the dredge area (num_samples)	Number of core boring samples in the dredged area	Calculated by (1) identifying the number of cores falling within the dredged area polygon from BOEM MMIS; then (2) identifying the number of core boring samples within those cores. All data from BOEM MMIS.
Density of cores per unit area of borrow area. Automatically Calculated [cores/m^2]	Number of cores within the borrow area divided by the surface area of the dredged area, in cores per square meter	Calculated by dividing the number of cores within the dredged area by the surface area of the polygons that comprise the dredged area.

Header Term	Description	Source & Calculation Method
Average phi_mean from all of the samples in the dredge area (phi_mean_mean) [phi]	Average (arithmetic mean) of phi_mean from all samples in the dredged area.	Calculated as the average (arithmetic mean) of all valid phi mean values of core boring samples within the dredged area. All data from BOEM MMIS.
Wentworth Scale from Mean Phi Mean. Automatically Calculated [scale]	Wentworth Scale designation	Can be calculated through identification of class on this scale based on phi_mean_mean, above
USCS Scale from Mean Phi Mean. Automatically Calculated [scale]	United Soil Classification Scheme (USCE) Scale designation	Can be calculated through identification of class based on phi_mean_mean
fraction of samples in the dredge area that contain valid phi_mean data (phi_mean_good)	Fraction of samples in the dredge area that contain valid phi_mean data, i.e., that do not include placeholder or no data values	Calculated as the number of samples in the dredge area (i.e., those counted within num_samples) that contain valid phi_mean data divided by the total number of samples (i.e., num_samples). All data from BOEM MMIS.
interquartile range of all valid phi_mean samples in the dredge area (phi_mean_iqr)	Interquartile range of all valid phi_mean samples in the dredge area	Calculated as interquartile range (i.e., difference between the 25th and 75th percentiles) of phi_mean for all valid samples (i.e., real data values, not a placeholder or no data value) in the dredge area. All data from BOEM MMIS.
average sand percentage from all of the samples in the dredge area (pct_sand_mean)	Arithmetic mean of sand percentage from all of the samples in the dredge area	Calculated as the average (arithmetic mean - sum of all values divided by the number of values) of percent sand for all valid samples (i.e., real data values, not a placeholder or no data value) in the dredge area. All data from BOEM MMIS.
fraction of samples in the dredge area that contain valid percent sand data (pct_sand_good)	Fraction of samples in the dredge area that contain valid percent sand data, i.e., that do not include placeholder or no data values.	Calculated as the number of samples in the dredge area that contain valid percent sand data divided by the total number of samples (i.e., num_samples). All data from BOEM MMIS.

Header Term	Description	Source & Calculation Method
interquartile range of all valid percent sand samples in the dredge area (pct_sand_iqr)	Interquartile range of all valid percent sand samples in the dredge area	Calculated as the interquartile range (i.e., difference between the 25th and 75th percentiles) of percent sand for all valid samples (i.e., real data values, not a placeholder or no data value) in the dredge area. All data from BOEM MMIS.
average percent shells from all of the samples in the dredge area (pct_shell_mean)	Arithmetic mean of percent shells from all of the samples in the dredge area	Calculated as the average (arithmetic mean - sum of all values divided by the number of values) of percent shell for all valid samples (i.e., real data values, not a placeholder or no data value) in the dredge area. All data from BOEM MMIS.
fraction of samples in the dredge area that contain valid percent shell data (pct_shell_good)	Fraction of samples in the dredge area that contain valid percent shell data	Calculated as the number of samples in the dredge area that contain valid percent shell data divided by the total number of samples (i.e., num_samples). All data from BOEM MMIS.
interquartile range of all valid percent shell samples in the dredge area (pct_shell_iqr)	Interquartile range of all valid percent shell samples in the dredge area	Calculated as the interquartile range (i.e., difference between the 25th and 75th percentiles) of percent shell for all valid samples (i.e., real data values, not a placeholder or no data value) in the dredge area. All data from BOEM MMIS.
percent of comments in the samples within this dredge area that contain the text “shell” (pct_text_contains_shell)	Percent of comments in the samples within this dredge area that contain the text “shell”	Calculated by dividing the number of samples within the dredge area that contain the word "shell" by the number of samples in the dredge area and multiplying by 100. All data from BOEM MMIS.
number of unique hue values in the layers that are associated with cores in this dredge area (unique hues)	Number of unique hue values in the layers that are associated with cores in this dredge area	Calculated by aggregating all hue values given for layers that are associated with cores in the dredge area, removing the duplicates, and counting the remaining, unique values. All data from BOEM.

Header Term	Description	Source & Calculation Method
most common hue value in the layers that are associated with cores in this dredge area (most common hue)	Most common hue value in the layers that are associated with cores in this dredge area	Calculated by aggregating all hue values given for layers that are associated with cores in the dredge area and identifying the value that appears across the most. All data from BOEM.
fraction of the layers that have the most common hue value (frac most common hue)	Fraction of the layers that have the most common hue value	Calculated as the number of layers in the dredge area that contain the most common hue divided by the total number of layers across all cores found in the dredge area. All data from BOEM MMIS.
fraction of the layers in this dredge area that are in the yellow range, identified as one of these four values: 2.5Y, 5Y, 7.5Y, 10Y (frac_yellow_hues)	fraction of the layers in this dredge area that are in the yellow range, identified as one of these four values: 2.5Y, 5Y, 7.5Y, 10Y	Calculated as the number of layers in the dredge area that contain hue values of 2.5Y, 5Y, 7.5Y, or 10Y by the total number of layers across all cores found in the dredge area. All data from BOEM MMIS.
Other Notes on Light Blue columns	Comments on the dredged area or other information in MMIS	Notes added by individual(s) populating the datafile

The classification scheme parameters spreadsheet is included as a separate file with this technical memo.

TYPOLOGY DEVELOPMENT: PILOT APPLICATION

The project team considered several conceptual methods for creating typologies based on the identified MMIS parameters. Alternatives ranged from those based on data-informed, subjective interpretation (i.e., a person with geologic knowledge uses the available data to define the typologies and assign borrow areas or sediment resources to them) to those based exclusively on automated determination (i.e., an algorithm is used to automatically create typologies and assign borrow areas or sediment resources to them based on available data).

To finalize the approach, the team considered a number of factors. These factors were primarily related to the SDM objectives to maximize the volume of nearshore and offshore sediment resources that can be characterized and to minimize the financial and temporal cost used to identify and extract sediment resources, including in classification scheme maintenance. A fully manual process for creating typologies and classifying sediment resources would be significantly time-intensive given the extensive list of included parameters (Table 2, Table 3); the large spatial extent over which BOEM would be applying the scheme; and the potential need to update classes whenever a new spatial area was included or priorities of user preferences evolved. Conversely, an initial evaluation revealed that there are significant gaps in readily available data to populate the parameters of interest. These gaps, and the uncertainty associated with the available data, suggest that a fully automated approach to typology development and application would lead to errors. The project team therefore chose a process that combined an initial, algorithm-based approach with quality control by a subject matter expert (Figure 7).

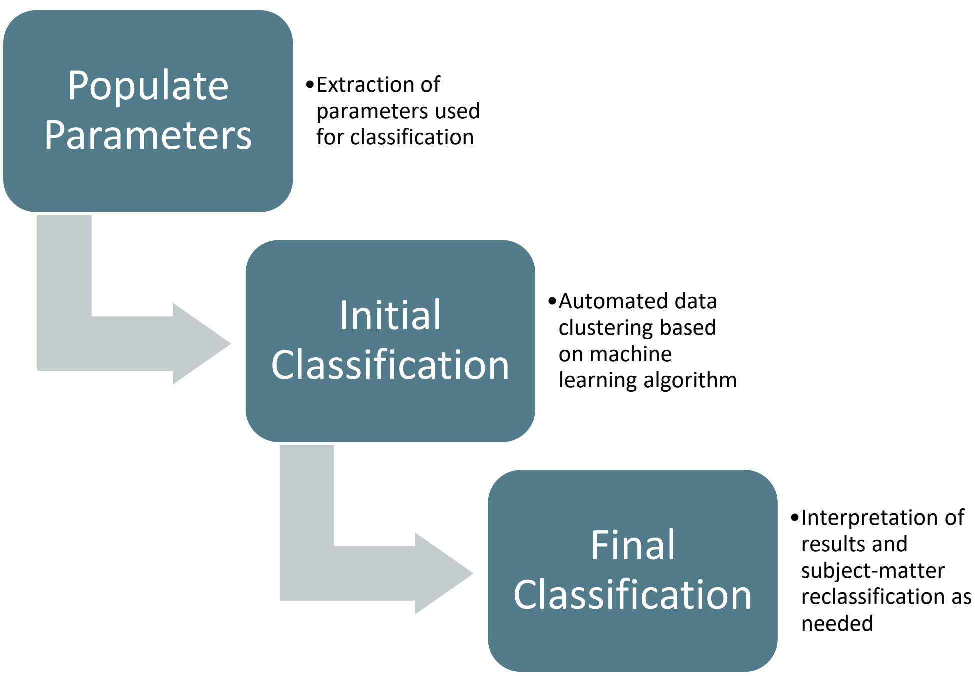

Figure 7. Conceptual diagram of the method used for classifying borrow areas or sediment resources into typologies.

This approach reduces the time a subject matter expert spends in developing and applying typologies, while also ensuring that the classification results are meaningful and robust.

The project team tested this approach by applying an unsupervised Neural Network algorithm (Bruneau et al., 2020; DeLancey et al., 2019; Jain et al., 1996; Zhou et al., 2020) to the MMIS data within the classification scheme parameter spreadsheet. A Neural Network is an unsupervised algorithm that maps high dimensional data, such as borrow areas with many different parameters, into a user-defined number of clusters, where each cluster contains borrow areas that are similar to each other based on the input parameters. The team specified 9 clusters for the initial testing, then evaluated the impact of varying the number of clusters. Preliminary results were encouraging, in that the algorithm tended to group borrow areas together that were geographically close to each other. This result suggests the scheme is robustly classifying the borrow areas because borrow areas located closer to each other are more likely to be similar than those far apart and the scheme grouped them as such without having geographic information as an input parameter (Figure 8).

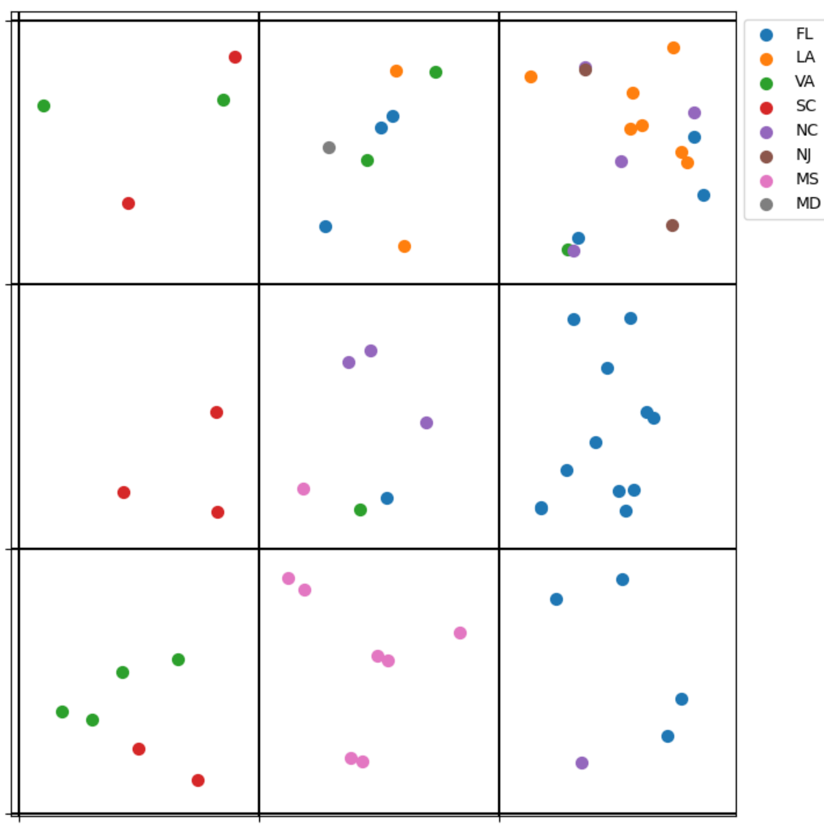

Figure 8. Nine clusters (borrow area typologies) created using a Neural Network with individual borrow areas colored by the closest state (Florida, FL; Louisiana, LA; Virginia, VA; South Carolina, SC; North Carolina, NC; New Jersey, NJ; Mississippi, MS; and Maryland, MD). Missing data was a primary factor in classification, which prevented the team from finalizing a set of meaningful typologies.

The algorithm also determined that missing data was a primary factor driving classification (Figure 9). This was true regardless of the number of clusters used in the classification. In many cases, key parameters necessary for classifying sediment resources, such as the percent sand, were not available in the underlying data. These data gaps prevented the creation of a final set of meaningful typologies for the borrow areas. Overall, the approach illustrated a proof-of-concept that a Neural Network can be used for automated classification of parameters if sufficient data are available. However, the project team determined that in this study, too much data were missing across the included parameters to develop a meaningful classification scheme for used borrow areas through a quantified and analytic approach.

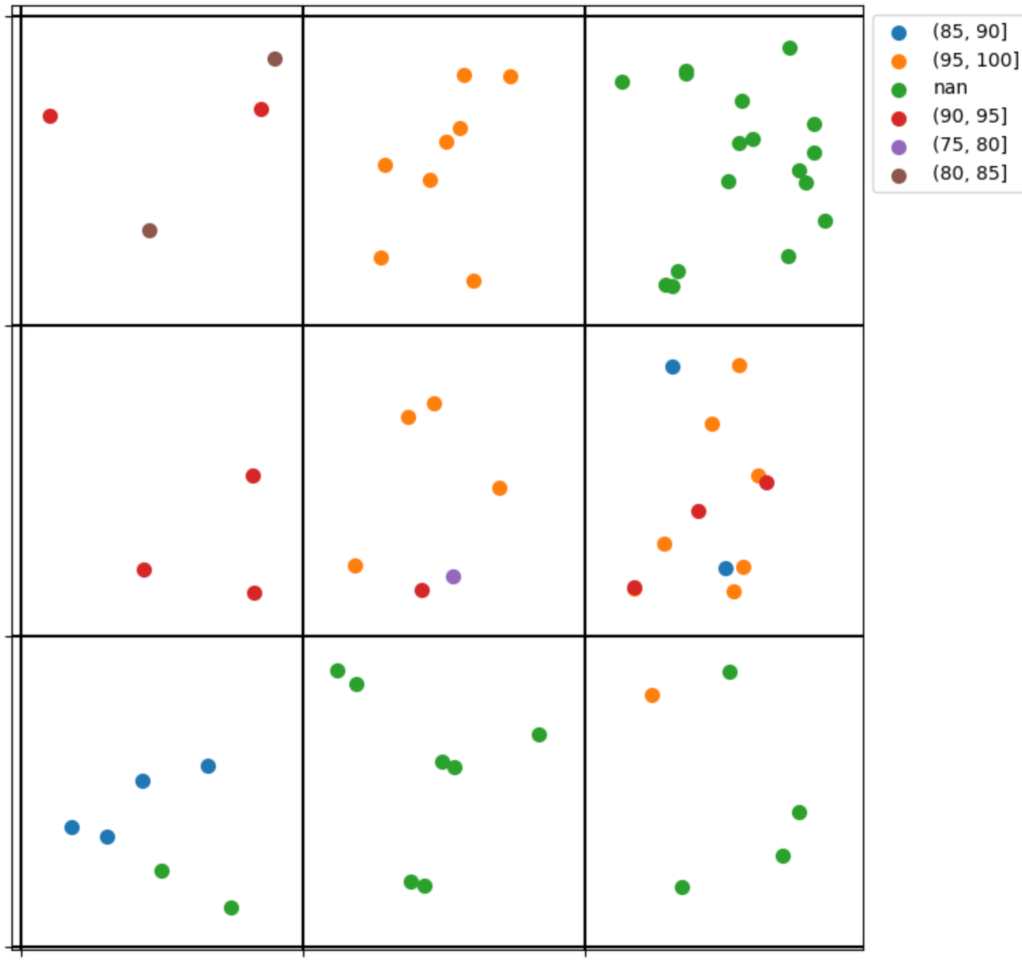

Figure 9. Nine clusters (borrow area typologies) created using a Neural Network with individual borrow areas colored by the percent sand. Each borrow area is binned into a range of percent sand, as indicated by the legend values (i.e., percent sand falls between the two numbers given). The green dots represent "not a number" (NaN), i.e., missing data.

CLASSIFICATION SCHEME PARAMETERS: EXPANDED PARAMETER SET

The results of the pilot application indicated the priority next step in classification scheme development is to fill data gaps. The team worked with BOEM to identify an expanded list of parameters that would ideally be incorporated into the classification scheme, but which were not readily available in MMIS or other compiled databases (Table 3). The project team determined that this information falls into two categories: information found in reports compiled after borrow area design but prior to dredging, such as 30% design reports (e.g., Coastal Planning and Engineering, 2023), and those compiled after dredging occurs, such as project completion reports and QAQC reports (e.g., Coastal Planning and Engineering, Inc, 2007).

Table 3. Descriptions of parameters identified by the project team as valuable to include in the classification scheme framework but which are not readily available in MMIS or other databases. Purple rows indicate information that would typically be available in borrow area design reports, and dark blue rows indicate information that would typically be available in post-dredging reports. Because this information was only available through data-mining from reports, the table also includes rows for individuals that compile the data to provide their information. This table is taken from the classification scheme parameter spreadsheet; column indicators refer to that spreadsheet. Values are provided in imperial units because that is the unit system predominantly used in the reports from which this information would be taken.

Category	Description
What is your name and organization (i.e., who filled out purple columns for this row) [short answer]	Name and organization of respondent for borrow area design information.
Borrow area design / planning report(s) used. List reference(s), note where found, include dates (e.g., APTIM servers, CIMS, etc.) [short answer]	Reports used for filling in the datafile for borrow area design information
Link to borrow area design planning report(s) if available online [short answer]	Weblinks and/or file locations for reports used in filling in the datafile for borrow area design information
Data found in borrow area design report(s) that could be used to fill in missing data in MMIS (white & light blue columns)- note what is available and in which reports [short answer]	Indication if there is data available in the borrow area design reports on cores or samples from the borrow or dredge area that are not within the MMIS data. If present, description of the information and citation or link for report containing it.
contractor - organization that designed borrow area [short answer; indicate District if USACE]	Organization(s) responsible for borrow area design. If borrow area was designed by the U.S. Army Corps of Engineers (USACE), the District should be indicated.
POC at organization that designed borrow area, if readily available [short answer]	Individual(s) responsible for borrow area design (i.e., the Point of Contact, POC)
name of borrow area used in design reports, if different than column E [short answer]	Name of borrow area used within borrow area design reports, if different than what is used within BOEM MMIS.
Was there a dredge sector plan considered / associated with borrow area design? [yes/no]	Indicator on if cut areas were designed and designed to be sequenced in a specific way or order. Could be referred to as a "dredge sector plan", but that terminology might not be used, particularly in older reports.
Is this borrow area the site of prior or planned recurring dredging? [yes/no; if yes, provide details in Other Comments]	Indicator if borrow area had been previously dredged and/or is the planned site of recurring dredging.
Other borrow areas considered but NOT used and reason they were excluded, if applicable. Include ID from Column A if applicable, or provide name/description if not part of MMIS [short answer]	List of other borrow areas that were considered as part of the same project that used this borrow area, but that were ultimately not included as part of sourcing sediment.
Borrow areas planned to be used as part of the same project, if applicable. [short answer]	List of other borrow areas that were considered as part of the same project that used this borrow area, and that ultimately were included as part of sourcing sediment.

Category	Description
date range(s) of cores or samples collected taken during or prior to borrow area design (include multiple if applicable) [short answer]	Dates corresponding to cores and samples used in designing the borrow area, including either historically available data or collected as part of borrow area design.
Are there reasons sample(s)/core(s) taken during or prior to borrow area design may no longer be indicative of site (e.g., age of sample, quality of equipment, expectation of infilling)? [short answer]	Reasons that the data available in sample(s) or core(s) might not indicative of site condition, either as noted within the reports or based on the judgement of the individual populating the database.
range of thicknesses of core sampled portions used in borrow area design [minimum-maximum, in feet; provide additional information in column AU, if applicable]	The range (i.e., distance between top and bottom) of the core samples used in borrow area design. Given as the minimum value in the report to the maximum value in the report.
types of data used in borrow area design (cores, surface grabs, subbottom geophysical) [short answer - list all that apply and include source in column AU, if available]	List of information that reports indicate was used in borrow area design.
other notes on samples, cores, or other data used for borrow area design (e.g., links to reports with data) [short answer]	Additional information on data used in borrow area design, including providing additional information on "yes" answers in previous columns on sample data.
range of borrow area cut depths [minimum - maximum, in feet NAVD88]	Range of planned borrow area cut depths, given as the minimum value to the maximum value across the spatial area of the design. Provided in feet reference to North American Vertical Datum of 1988 (NAVD88)
was borrow area designed to extend deeper than depths of the cores [yes/no; if yes, provide additional information such as why in column AY]	Indicator on if the cut depth extended deeper that the maximum depth of the cores (i.e., extended beyond where data where available). If core depths varied spatially and borrow area cut depth varied spatially but stayed within the local maximum depth of coring, the answer would be "no".
was max design cut constrained by sediment quality or other factors [yes/no; if yes indicate why, depth constraint, and buffer used in column AY]	Description of if cut depth was limited by core, sample, or other data. If the cut depth was designed based solely on design reaching necessary value for sediment volume, answer would be "no", indicating there is potentially still usable sediment available.
additional information on borrow area cut design [short answer]	Any additional information the individual(s) populating the datafile believe to be relevant to borrow area cut design that was not already provided in previous columns.
borrow area "boundary" material (e.g. is it underlain by rock) [short answer]	Material that underlays the area of interest in the borrow area design. If, for example, cores indicate sand or rock below the cut depth, this would be indicated here.
range of expected depth to top of deposit from seafloor for borrow area design [minimum-maximum, in feet]	Range of distances from the seafloor to the top of the deposit of interest within the borrow area design, provided as the minimum to maximum value across the spatial extent of the borrow area.
expected overburden thickness from borrow area design [minimum - maximum, in feet]	Estimated range of overburden thickness, provided as the minimum to maximum value across the spatial extent of the borrow area.

Category	Description
estimated overburden volume from borrow area design [cubic yards]	Estimate of the volume of overburden that would need to be removed to access the sediment deposit of interest for the associated placement project.
expected overburden type considered in design (e.g., ODMDS, sand sheet, shoal, paleo channels, etc.) [short answer, if applicable; n/a if none]	Expected type(s) of expected overburden per the borrow area design report.
planned use of overburden material, if applicable [short answer]	Indication on if and how overburden material was planned to be used beneficially, and/or an indicator of if/how/where it was planned of to be otherwise disposed of.
dredge sediment volume estimated during borrow area design [in cubic yards)	Estimate of the volume of usable sediment that would be dredged based on the borrow area design. Value should correspond to the borrow area plan, not the volume of sediment needed for the placement project.
method of calculating estimated volume [short answer]	Description of how usable sediment volume for borrow area was estimated (e.g., what calculation(s) were used, if material/volume was excluded from the usable volume and why, etc.)
qualitative assessment of sediment grain size expected to be found, such as Wentworth or USCS scale. Indicate which scale if applicable. [short answer]	Description of expected grain size in sediment volume designated for use in the associated placement project based on Wentworth, USCS, or other scale. Values can also be given as expected ranges of grain size (i.e., in phi), if included.
expected sediment composition (e.g. quartz, carbonite) [short answer]	Description of expected sediment composition in sediment volume designated for use in the associated placement project.
distance from designed area to placement area [in miles or range of miles]	Estimate of distance or range of distances (for large borrow areas and/or placement areas) from the borrow area to where the sediment volume will be placed.
designed to avoid shipwrecks or other cultural resources? [multiple choice; if yes, fill in columns BT - BV]	Indication on if one of the considerations in borrow area design was avoidance of shipwrecks or other cultural resources.
designed to avoid pipelines or cables [multiple choice; if yes, fill in columns BT - BV]	Indication on if one of the considerations in borrow area design was avoidance of pipelines or cables.
consideration of shell in borrow area design or dredge plan [multiple choice; if yes, fill in columns BT - BV]	Indication on if one of the considerations in borrow area design was avoidance of shell deposits.
consideration of rock in borrow area design or dredge plan [multiple choice; if yes, fill in columns BT - BV]	Indication on if one of the considerations in borrow area design was avoidance of rock.
consideration of clay/fines in borrow area design or dredge plan - cementation, turbidity, mudballs [multiple choice; if yes, fill in columns BT - BV]	Indication on if one of the considerations in borrow area design was avoidance of clays or other fine-grain material.
consideration of MEC or UXO in borrow area design or dredge plan [multiple choice; if yes, fill in columns BT - BV]	Indication on if one of the considerations in borrow area design was avoidance of known or suspected munitions and explosives of concern (MEC) or unexploded ordnance (UXO).

Category	Description
consideration of commercial fishing (e.g., prime fishing areas) in borrow area design [multiple choice; if yes, fill in columns BT - BV]	Indication on if one of the considerations in borrow area design was avoidance of commercial fishing areas.
consideration of environmental or species issues in borrow area design (e.g., turtles, essential fish habitat, reefs, etc.) [multiple choice; if yes, fill in columns BT - BV]	Indication on if one of the considerations in borrow area design was avoidance of environmental, habitat, or species issues, either due to specific requirements of a permitting agency or in general.
consideration of other unlisted conflicts, hazards, incompatibilities, or potential negative issues in borrow area design or dredge plan [multiple choice; if yes, fill in columns BT - BV]	Indication on if one of the considerations in borrow area design was avoidance of any other conflicts not specifically listed in previous columns.
If answered "Yes" to any avoidance conflict in borrow area design (columns BK-BS), what specifically was the conflict? [short answer, with as much detail as possible)	Notes on what conflict (from the previous column "yes" answers) resulted in borrow area was design or re-design considerations.
If answered "Yes" to mitigation planned for in conflict avoidance (columns BK - BS), what specific mitigation was planned? [short answer, with as much detail as possible)	Notes on if/what mitigation strategies were used due to one or more avoidance issues indicated in previous columns (e.g., use of screens, redesign of borrow area, etc.).
If answered "Yes" to borrow area design including conflict avoidance (columns BK - BS), indicated buffer used [meters or range in meters]	Notes on if/how borrow area was designed or re-designed due to one or more avoidance issues indicated in previous columns, and specifically the buffers used around the conflicts.
indicate any other factors considered in borrow area design or dredging plan - vertical or lateral variability in sediment characteristics, etc. [short answer]	Notes on any other factors that informed the borrow area design beyond what has been noted in previous columns.
Other Notes on Borrow Area Design, e.g., was redesigned multiple times, mitigation expected to impact dredging efficiency, etc. (Purple Columns) [short answer]	Any other addition notes on the borrow area design process beyond what has been noted in previous columns.
What is your name and organization? (i.e., who is filing in dark blue columns for this row) [short answer]	Name and organization of respondent for dredging information.
Dredging report(s) used. List reference(s), dates, and note where found (e.g., APTIM servers, CIMS, etc.) [short answer]	Reports used for filling in the datafile for dredging information
Link to dredging report(s) if available online [short answer]	Weblinks and/or file locations for reports used in filling in the datafile for dredging information
Indicate if data were found in dredging report(s) that could be used to fill in missing data in MMIS (white & light blue columns)- note what is available and in which reports [short answer]	Indication if there is data available in the dredging reports on cores or samples from the borrow or dredge area that are not within the MMIS data. If present, description of the information and citation or link for report containing it.
Contractor -organization that did the dredging. Indicate which District if USACE. [short answer]	Organization(s) responsible for dredging.
POC person at dredging organization, if readily available [short answer]	Individual(s) responsible for overseeing dredging operations.

Category	Description
name of borrow area in dredging reports, if different than column E [short answer]	Name of borrow area used within dredging reports, if different than what is used within BOEM MMIS.
Was there a dredge sector plan? [yes/no]	Indicator on if a specific plan or schedule for cut areas was followed during dredging. Could be referred to as a "dredge sector plan", but that terminology might not be used, particularly in older reports.
Dredge Type - select from dropdown or choose 'Other' and indicate in Dark Blue "Other Notes" column [multiple choice]	Type of dredge used, selected from a dropdown of clamshell, dipper, cutterhead, hopper, or other.
Name of Specific Dredge(s) Used [short answer]	Names of the specific dredge(s) used as part of operations.
Sediment conveyance information, if applicable (e.g., hopper dredge: number of pumpout locations and distance from pumpout corridor from fill, how pumpout was conducted - dredge pump only, unloader, booster pump, etc; for cutterhead: direct pipe and length, boosters used, or scow barges) [short answer]	Detailed information on how sediment was transported from the borrow area to the placement site. For example, for hopper dredge: number of pumpout locations and distance from pumpout corridor from fill, how pumpout was conducted, dredge pump only, unloader, booster pump, etc.; for cutterhead dredge: direct pipe and length, boosters used, or scow barges)
Other Borrow Areas Dredged as Part of the Same Project, if Applicable. Provide as List using ID from Column A or as name/short description if not listed [short answer]	List of other borrow areas dredged as part of the same project that used this borrow area.
Construction Start Date from Dredging Reports [date]	Date of start of dredging, from dredging reports.
Construction End Date from Dredging Reports [date]	Date of end of dredging, from dredging reports.
dredging time - actual time dredge on site [days]	Time spent dredging (i.e., difference between the start and end dates of dredging, excluding downtime indicated in report(s))
Notes on Construction Timeline from Dredging Reports (e.g., restriction to specific seasons, environmental windows, delays due to equipment malfunction, extended timeline due to dredge operations, etc. [short answer]	Indication if the timeline for dredging was delayed, and for what reason (e.g., restriction to specific seasons, environmental windows, delays due to equipment malfunction, extended timeline due to dredge operations, etc.)
date range(s) of additional cores or sample collection taken DURING dredging (include multiple if applicable) [short answer]	Dates of additional core or sample data taken between the start and end dates of dredging.
Are there reasons sample(s)/core(s) taken DURING dredging may no longer be indicative of site (e.g., age of samples, quality of equipment, known infilling)? [short answer]	Reasons that the data in sample(s) or core(s) taken during dredging might not be indicative of site condition, either as noted within the reports or based on the judgement of the individual populating the database.
other notes on samples taken DURING dredging (e.g., links to reports with data) [short answer]	Additional information on samples, cores, or other data taken during dredging, such as links to the data or corresponding reports.
estimated volume dredged from dredging report(s) [in cubic yards]	Estimate of the volume of usable sediment that was dredged.
method of calculating estimated volume [short answer]	Description of how dredged usable sediment volume was estimated (e.g., what calculation(s) were used, if material/volume was excluded from the usable volume and why, etc.)

Category	Description
qualitative assessment of sediment grain size found if given in dredging reports, such as Wentworth or USCS scale. Indicate which scale if applicable. [short answer]	Description of dredged grain size in sediment volume designated for use in the associated placement project based on Wentworth, USCS, or other scale. Values can also be given as expected ranges of grain size (i.e., in phi), if included.
sediment composition found (e.g. quartz, carbonite) [short answer]	Description of expected sediment composition in sediment volume designated for use in the associated placement project.
range of cut depths from dredging reports [minimum - maximum, in feet NAVD88]	Estimate of distance or range of distances (for large borrow areas and/or placement areas) from the borrow area to where the sediment volume will be placed.
was borrow area dredged beyond planned cut depth [yes/no; use column CY to provide more information such as reason]	Indication on if dredging was done deeper than the planned cut depth from the borrow area design.
was max cut less than design for any reason [yes/no; use column CY to indicate why, depth constraint, buffer used, etc.]	Indication on if the max cut depth used in dredging was significantly less (i.e., difference of > 5') than planned in the borrow area design at any location within the borrow area.
additional information on cut depth response in columns CW and CX [short answer]	Additional information on dredging cut depth based on "yes" answers in the previous columns.
depth range from water surface to seafloor from dredging report(s) [minimum-maximum, in feet]	Range of water depths where dredging occurred, given as a range from the minimum water depth to the maximum water depth.
depth range to top of deposit from seafloor from dredging reports [minimum-maximum, in feet]	Range of distances from the seafloor to the top of the deposit of interest, provided as the minimum to maximum value across the spatial extent of the dredged area.
range of overburden thickness from dredging report(s) [minimum - maximum, in feet]	Estimated range of overburden thickness, provided as the minimum to maximum value across the spatial extent of the dredged area.
overburden volume from dredging report(s) [in cubic yards]	Estimate of the volume of overburden that was removed during dredging to access the sediment deposit of interest for the associated placement project.
overburden type (e.g., ODMDS, sand sheet, shoal, paleo channels, etc.) [short answer; fill in n/a if not applicable]	Type(s) of overburden encountered during dredging.
use of overburden material, if applicable [short answer]	Indication on if and how overburden material was used beneficially, and/or an indicator of if/how/where it was otherwise disposed of during dredging.
shipwreck or other cultural resource encountered during dredging? [multiple choice; if yes, fill in columns DO - DQ]	Indication on if shipwrecks or other cultural resources were encountered while dredging.
pipeline or cable encountered during dredging? [multiple choice; if yes, fill in columns DO - DQ]	Indication on if pipelines or cables were encountered while dredging.
shell encountered during dredging? [multiple choice; if yes, fill in columns DO - DQ]	Indication on if shell was encountered while dredging.
rock encountered during dredging? [multiple choice; if yes, fill in columns DO - DQ]	Indication on if rock was encountered while dredging.

Category	Description
clay/fines encountered during dredging? [multiple choice; if yes, fill in columns DO - DQ]	Indication on if clay or other fine-grained material was encountered while dredging.
MEC or UXO encountered during dredging? [multiple choice; if yes, fill in columns DO - DQ]	Indication on if munitions and explosives of concern (MEC) or unexploded ordnance (UXO) were encountered while dredging.
conflict with commercial fishing (like prime fishing areas) encountered during dredging? [multiple choice; if yes, fill in columns DO - DQ]	Indication on if there were conflicts with commercial fishing while dredging.
was any environmental or species issue encountered during dredging (e.g., turtles, reefs, etc. - add details in comments) [multiple choice; if yes, fill in columns DO - DQ]	Indication on if environmental, habitat, or species issues were encountered while dredging (e.g., turtle take, etc.).
any other conflicts, hazards, incompatibilities, or other issues encountered not listed that disrupted dredging (add details in comments) [multiple choice; if yes, fill in columns DO - DQ]	Indication on if any other conflicts, hazards, or issues were encountered while dredging.
If answered "Yes" to any conflict (columns DF - DN), what specifically was the conflict? [short answer, with as much detail as possible]	Notes on what conflict (from the previous column "yes" answers) resulted in impacts to dredging operations.
If answered "Yes" to mitigation used in any conflict avoidance (columns DF - DN), what specifically was used to mitigate? [short answer, with as much detail as possible]	Notes on if/what mitigation strategies were used to mitigate dredging conflicts/issues indicated in previous columns (e.g., use of screens, changing dredging windows, etc.).
If answered "Yes" to dredge plan changing due to conflict avoidance (columns DF - DN), indicate buffer used [meters or range in meters]	Notes on if/how dredging plan was modified or re-designed due to one or more conflicts indicated in previous columns, and specifically the buffers used around the conflicts.
other factor(s) not listed that resulted in change in dredging plan or operations once started? [yes/no; add details in column DS]	Notes on any other factors that resulted in a change to planned dredging operations beyond what has been noted in previous columns.
details on other issues encountered, e.g., not finding what was expected in borrow areas, placed material didn't meet expectation, etc. [short answer]	Any other additional notes dredging OR placement operations not proceeding as expected based on the design plan. For example, not finding what was expected in borrow areas, placed material didn't meet expectation, etc.
Other Notes on Dredging (Dark Blue Columns) - e.g., was it redesigned after dredging started, mitigation impacted dredging efficiency, etc. [short answer]	Any other additional notes on dredging or placement operations beyond what was noted in the previous columns. For example, was the borrow area redesigned after dredging started, mitigation impacted dredging efficiency, etc.

The team next evaluated how feasible if would be to acquire this expanded list of parameters for used borrow areas through an assessment of available reports. APTIM and Water Institute team members searched online and on local servers for reports that might contain data to populate these parameters. The team was able to add information for seven of the borrow areas distributed across Louisiana, North Carolina, and Florida. For comparison, the full list of borrow areas within MMIS includes 63 sites from across the Gulf and Atlantic seaboard.

The project team was able to source additional information including prior or planned recurrent dredging and factors that constrained cut depths. In addition, the team was able to include information on planned and actual cut depths, sediment volumes, and sediment grain sizes. Information was also added on the type of dredge used, if overburden was present, and the contracting companies that conducted the design and dredging, as well as the need for and/or use of conflict mitigation in either borrow area design or in dredging practice.

However, there were still extensive gaps in the parameters even after an exhaustive review of available reports. For example, the team was only able to locate limited available information on sediment composition, lateral and basal bounding sediment character, and known or encountered conflicts in some cases. The team did not extend the pilot classification scheme approach to the updated classification parameter data table given that additional information could only be added for 7 of the 63 borrow areas and that substantial information was still missing across many of the classification scheme parameters.

The process of acquiring and entering this information was time-consuming: reviewing reports for additional data took approximately 8 hours per borrow area. In addition, many of the parameters could not be found within the reports, or the information within the reports was inconclusive. For example, a report failing to indicate that a borrow area was designed to avoid a pipeline could be because no pipeline was present, or that information may simply not have been noted in the report. However, the team determined that filling in the classification scheme parameters would take less time and could include additional information if a sediment resource user or BOEM populated the table at the time of borrow area design and/or dredging, given that most of the time spent on the data evaluation for this project was on locating and reviewing reports rather than on information logging.

DISCUSSION AND LESSONS LEARNED

The outcomes of the work to date include (1) development of a decision context and objectives for sediment resource classification; (2) identification of sediment parameters for defining classification scheme typologies, including an in-depth evaluation of available data; and (3) development of a classification scheme framework comprised of automated classification and subject-matter expert quality control, preliminarily applied to available borrow area data, that can be expanded to include more parameters and to consider risk when applied to sediment resources.

The Subtask 1B work supports classification scheme development in several ways. First, identification of sediment parameters forms the basis of creating typologies that are meaningful and useful to potential users of the classification scheme. Second, the in-depth evaluation of available data sources helped the team identify readily available data required for sediment classification scheme development, as well as data gaps inhibiting that development. Data gaps can be filled in the future through thoughtful adjustments to best practice in archiving information from sediment users when borrow areas are designed and dredged. Finally, the classification process developed for borrow areas in the pilot can be readily extended to incorporate new data and, in the long term, to sediment resources.

This work also yielded several early indicators of success for the long-term development and use of classification scheme applied to sediment resources:

- BOEM and APTIM team members, who are representative of priority users of the classification scheme, noted that the classification scheme parameter spreadsheet has high standalone utility for managing sediment resources. The information currently found in MMIS for borrow areas and sediment resources is useful, however, the expanded set of parameters provides significantly more information relevant to sediment resource users, particularly for borrow areas that may not be fully depleted when initially dredged.
- Building on the above, the deep dive to fill in the parameter spreadsheet using archived reports was time-intensive predominantly because of the retrospective nature of the work and the time required to locate reports. The team indicated that filling in the parameters when, or shortly after borrow area design or dredging work occurs would take significantly less time, and therefore the classification scheme parameter spreadsheet could be used to update best practice in data gathering and archiving for borrow areas and sediment resources. The time required to complete the table itself was minimal once information was available, approximately 10 minutes for each borrow area.
- The pilot application of the classification approach to borrow areas that have already been dredged illustrates a proof of concept for developing and applying typologies for a classification scheme. This initial application produced a key result, namely that data gaps are, unfortunately, one of the strongest common threads across used borrow areas. The use of machine learning for an initial classification allows the scheme to be readily applied as new data become available, sites are added, or parameters of interest to sediment users evolve.

The team determined that the highest priority is to update the classification scheme framework to incorporate screening data relevant to internal and external risk factors. The team has begun identifying these data types through elicitation of input from BOEM during small team calls and workshops, and includes:

- Distance to river discharges or other sources of sediment for infilling, and/or observations of sediment plumes from satellite imagery;
- Character of surficial geology and/or presence of surficial geologic features (e.g., sediment age, relief relative to seafloor, etc.);
- Character of subsurface geology and/or presence of subsurface geologic features (e.g., paleochannels);
- Oceanographic characteristics such as persistent current patterns or tidal asymmetry;

- Sediment or seafloor mobility and/or thresholds of seafloor stress exceedance;
- Shipwreck or other cultural resource information maps;
- Habitat and/or species information, such as essential fish habitat, aquaculture, and submerged aquatic vegetation;
- Proximity to areas potentially associated with unexploded ordinance (UXO) or munitions and explosives of concern (MEC), such as coastal restricted areas around military bases;
- Maps of pipelines, cables, oil and gas leasing areas, shipping lanes, or other potential conflicts with dredging; and
- Proximity or overlap with dredge disposal areas or other renewable sediment resources.

Each of these data sources is indirectly tied to sediment characteristics at a site (e.g., seafloor stress and sediment mobility are correlated to sediment grain size, where regions with more frequent and greater seafloor stress have coarser sediment due to winnowing of fine-grain material), and/or to the volume of sediment available for dredging (e.g., presence of pipelines limits the extractable sediment volume from a site). In the next stage, the team will document the conceptual linkages between these information sources and classification scheme parameters and will then conduct a review of readily available data associated with these information types. These data will then be used to expand the classification scheme parameter spreadsheet, which will then be reanalyzed using the classification scheme development framework (Figure 7).

The steps described above would result in the development of and application of classification scheme typologies that characterize used borrow areas based on the full suite of available information, including post-dredging data, site characterization, and screening data. Concurrently with the extension of the classification scheme to readily available screening data, BOEM can independently assess the feasibility of updating best practice in gathering information on borrow areas and sediment resources based on the classification scheme parameter spreadsheet. Together, these steps enable the development of a classification scheme that can be applied to sediment resources by advancing the classification scheme framework while simultaneously filing high priority data gaps.

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