Project Summary Form

Louisiana Sea Grant

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Coastal Science Assistanship Program 2018

Project Number

Project Title

Comprehensive Sediment Balance of Marsh Creation Projects: From Hydraulic Dredging to Self-weight Consolidation

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Focus Areas

A COMPREHENSIVE SEDIMENT BALANCE OF MARSH CREATION PROJECTS: FROM HYDRAULIC DREDGING TO SELF-WEIGHT CONSOLIDATION

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INTRODUCTION: To combat the devastating wetland loss in coastal Louisiana, the 2017 Coastal Master Plan prioritized sediment diversions and marsh creation projects. These restoration efforts constitute the nation's largest investment, approximately $22.5 billion, allocated towards land building. The degree of success achieved in developing tidal marsh habitat for coastal restoration is influenced by many factors, e.g., water salinity, sediment supply, and hydrology (e.g., water levels, currents and, waves). However, marsh elevation is the most critical operational constraint because it dictates biological productivity of the established habitat and the volume of dredged fill, which constitutes the greatest expenditure (~60%) in marsh restoration projects. As a result, marsh creation projects must be designed to minimize the volume of dredged material while ensuring the surface elevation is within the narrow tidal inundation window for the project design life.

CPRA has utilized the expertise gained from the in-house design and construction of marsh creation projects, and the experience from construction contractors, field office engineers, engineering consultants, federal sponsors, and non-federal/local sponsors to develop design criteria for Louisiana marsh creation projects. The process of compiling this knowledge into a Design Manual is still in progress. *The objective of this CSAP is to reduce the knowledge gaps in the Design Manual so that CPRA provides state-of-practice guidelines to the industry.* In particular, this Design Manual provides only general guidance on dredged sediment calculations for sedimentation and self-weight consolidation processes, which is considered the greatest source of uncertainty in design and implementation phases. The U.S. Army Corps of Engineers Engineering Manual EM 110-2-5027 (USACE 1987) provides the sediment and consolidation theory underscoring confined dredged disposal, but the validation of design assumptions and laboratory tests is lacking for marsh creation projects because of the limited field monitoring data collection and analyses. Through discussions with CPRA and review of the Design Manual, we identified two research questions:

What is the spatial and temporal variation in particle size gradation of dredged sediments in the marsh creation area? Upon dredging from the borrow source to the containment area, sediments will settle according to their particle size gradation. The spatial variation in particle gradation is caused by plume driven flow and settling velocity. Coarser sediments are located at the dredge source (higher energy) and the average grain size decreases moving farther away (e.g., clay fines at lower energy). This leads to heterogeneity in the geotechnical properties, e.g., initial void ratio and density. The sediment size distribution is also important for predicting dredging efficiency. As fine clays are transported in suspension, a portion of them will leave the containment area as effluent. This becomes more pronounced as the marsh creation area decreases. Therefore, accurate representation of particle gradation in the containment area is important for operating the hydraulic dredge (e.g., optimal influent discharge and sediment concentration) and subsequent laboratory experiments to measure self-weight consolidation properties of the dredged fill.

What is the self-weight compressibility of the dredged fill? The void ratio at $\sigma'_v = 0$ represents the stage at which dredged sediments transition from zone settling to self-weight consolidation, i.e., the particles coalesce to form a coherent soil structure. Settling column tests are currently used to discern this parameter, but they are seldom verified in the field. For example, is the slurry concentration and particle gradation used in the settling column test representative of the effluent concentration from the dredge? Are the settling column test results still valid if the dredged concentration/gradation changes? These questions require integrated field monitoring and model-based estimations to identify the relationship between initial void ratio profile, slurry concentration, and particle gradation. This is important because the magnitude and time-rate self-weight consolidation of dredged fill influences the volume of dredged sediment (i.e., cut to fill ratio) predicted in the design phase.

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RESEARCH METHODOLOGY: The proposed research aims to develop guidelines for estimating the hydraulic efficiency and cut to fill ratio of dredged sediments for marsh creation projects. Fig. 1 describes the research plan to accomplish these two objectives. In particular, we will leverage ongoing marsh creation projects to collect field data for laboratory settling column tests and validation of numerical models (CDFATE and PSDDF). For example, grab samples in the diked area will be used to conduct settling column tests to explore how sediment concentrations, multiple-stage loading, and particle gradations affects the void ratio at $\sigma'_v = 0$. The settling column will also be instrumented to measure pore-water pressure at specific depth intervals and density along the column height using via X-ray detectors. This will yield the true low stress void ratio, compressibility, and permeability relationships of dredged fill, which will be used as a reference to develop and verify a standardized self-weight consolidation test for geotechnical testing laboratories. These relationships will be input into PSDDF to simulate self-weight consolidation and hence will provide an estimate of the cut to fill ratio across the site. In addition, the grab samples will reveal the in-situ particle gradation and concentration at the dredge source and containment area. This information will be used as input and validation of CDFATE, which simulates sediment plume hydrodynamics in containment areas. We will explore optimum hydraulic efficiency and how sediment particle gradation changes from the dredge source. This is important because future design guidelines can leverage CDFATE to predict the borrow area soil gradation for settling column tests.

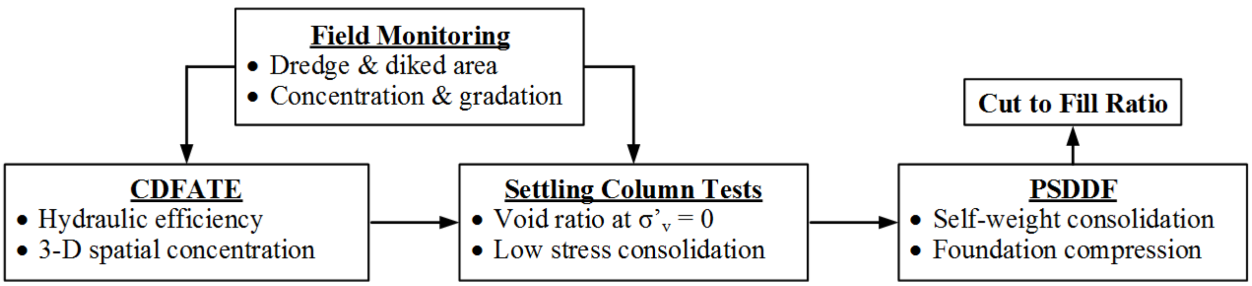

Figure 1. Overview of research plan

EXPECTED OUTCOMES AND SIGNIFICANCE:

Hydraulic dredging constitutes approximately 60% of the cost for marsh creation projects. More accurate estimates of dredged fill quantities will lead to reduced costs, increased efficiency, and successful ecological restoration. The outcome of this research will help realize these benefits (1) by providing guidelines for quantifying the hydraulic efficiency and cut to fill ratio of dredged fill; and (2) by codifying standardized methodologies for determining the self-weight consolidation of dredged fill. This will be documented in the CPRA Design Manual for future design and implementation of marsh creation projects. In addition, the settling column tests will be performed at the LSU Center for River Studies, which is located in the Water Campus next to CPRA. This close proximity will encourage collaboration and further research between CPRA and LSU beyond the CSAP internship hours.

Dr. Navid Jafari has previously assisted CPRA through their Coastal Science Assistantship Program, specifically on the development of a coastal Louisiana database of empirical correlations for predicting foundation settlement of coastal protection and restoration projects (Harris and Jafari 2017). He has also developed guidelines for performing settlement analyses using PSDDF and SETTLE^{3D} software (Jafari and Harris 2017). These projects resulted in monthly meetings with CPRA, which permitted Dr. Jafari to receive feedback on research needs and direction while also transferring research findings to CPRA. As a result, it is expected that the results from this CSAP will also benefit CPRA and practitioners involved in the design and construction of marsh restoration projects.

REFERENCES

Harris, B., and Jafari, N.H. (2017). "Long-term settlement of beach and dune restoration in coastal Louisiana I: Material Properties." Coastal Engineering, in submission.

Jafari, N.H., and Harris, B. (2017). "Long-term settlement of beach and dune restoration in coastal Louisiana II: Numerical Analysis." Coastal Engineering, in submission.