



Rapid Soil Classification and Integration of Soil Characteristics for UXO Site Characterization and Risk Assessment

MR21-1265

Adrian Rodriguez-Marek

Virginia Tech

In-Progress Review Meeting

14 August 2024

Project Team



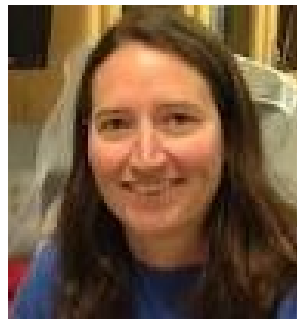
**Adrian
Rodriguez-
Marek**
*Virginia
Tech*



Nina Stark
*University of
Florida*



**Carl Friedrichs &
Grace Massey**
*Virginia Institute for
Marine Sciences*



**Kelly
Dorgan**
*University of
Texas Austin*

Bottom Line Up Front

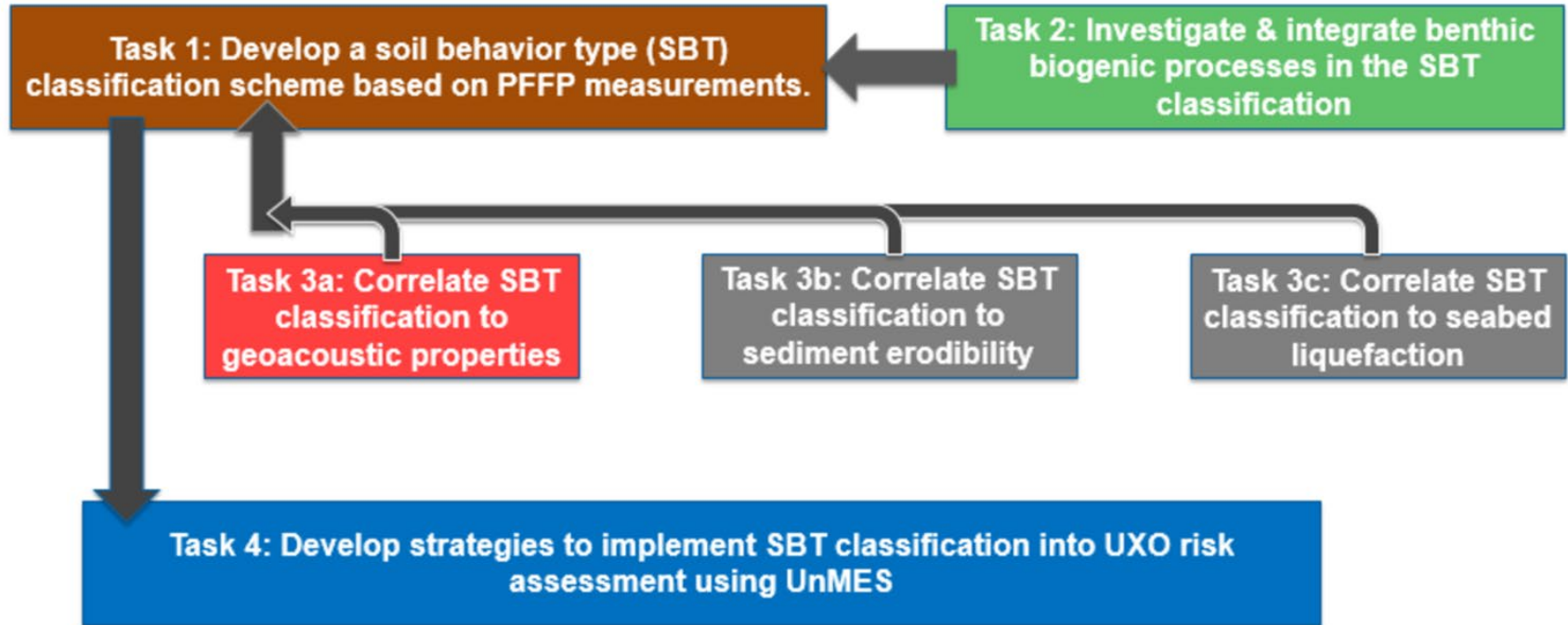
- An algorithm has been developed to rapidly classify seafloor sediments from portable free fall penetrometer (PFFP) testing.
- A machine learning algorithm (XGBoost) relates PFFP data to erodibility classes.
- Geoacoustic data from high-frequency side scan sonar and from low-frequency CHIRP sonar were inverted and correlated to geotechnical properties.
- Correlations between biogenic seabed activity and geotechnical properties as measured by PFFP are being advanced by three field data collection efforts focused on simultaneous and accurately co-located infauna characterization and PFFP deployments.

Technical Objective

Develop a rapid and integrative geotechnical site characterization strategy to assist with UXO detection, risk assessment, management, and remediation.

- Develop a soil behavior classification scheme based on portable free fall penetrometer measurements;
- Identify effects of benthic biogenic processes on geotechnical soil properties and integrate these effects in the soil classification scheme;
- Identify and quantify the impacts of the different soil classes on acoustic UXO detection and classification methods, on erodibility estimates, and on susceptibility to soil liquefaction processes;
- Develop strategies to implement the effects of soil classes into UXO risk assessment with UnMES.

Technical Approach



Results to Date

- Task 1: Develop a SBT classification scheme based on PFFP measurements.

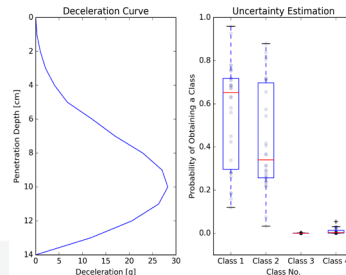


Date: 05/23/2025

Manuscript #: GTENG-13486R2

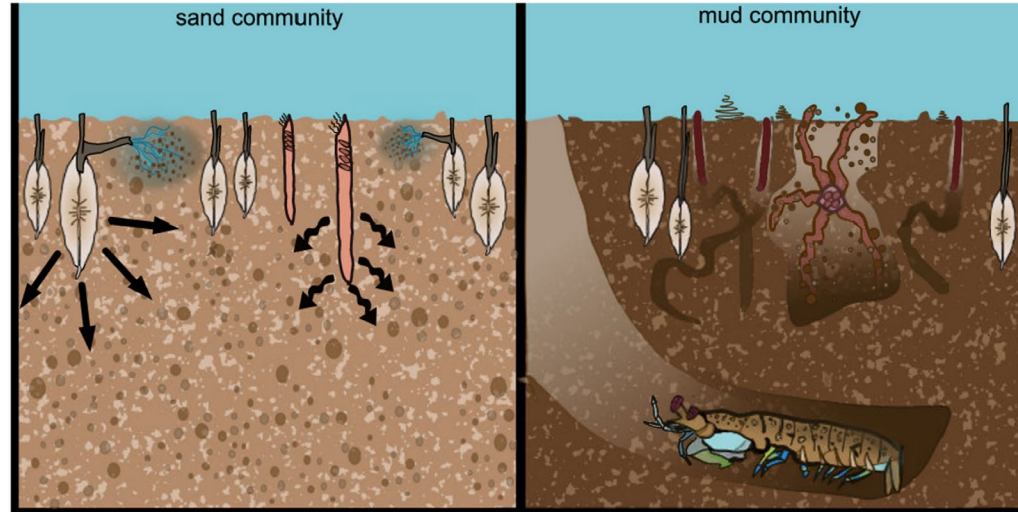
Manuscript Title: PROBABILISTIC CLASSIFICATION OF NEAR-SURFACE SHALLOW-WATER SEDIMENTS USING A PORTABLE FREE-FALL PENETROMETER

Authors: Md Rejwanur Rahman; Adrian Rodriguez-Marek; Nina Stark; Grace Massey; Carl Friedrichs; Kelly Dorgan



Results to Date

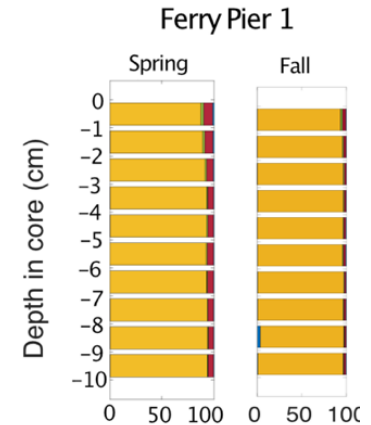
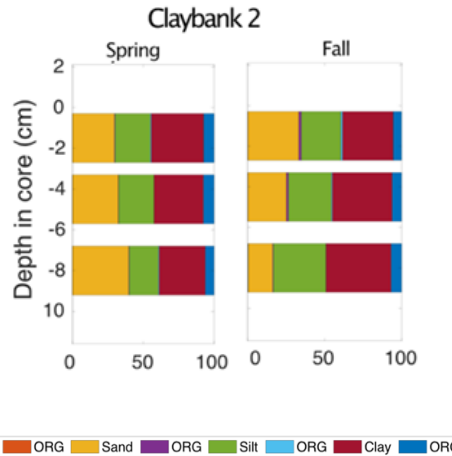
- Task 2: Investigate and integrate benthic biogenic processes in SBT classification.



Stark et al.
(2024)

Results to Date

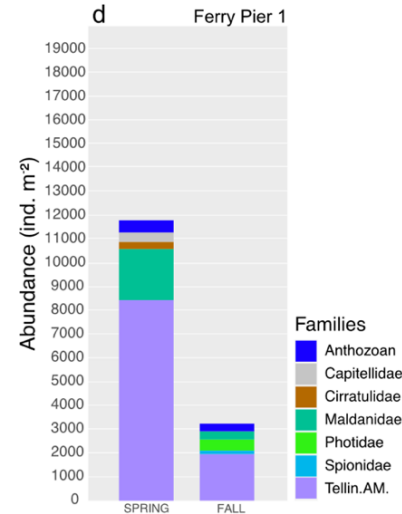
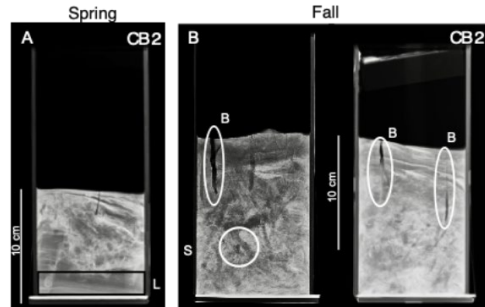
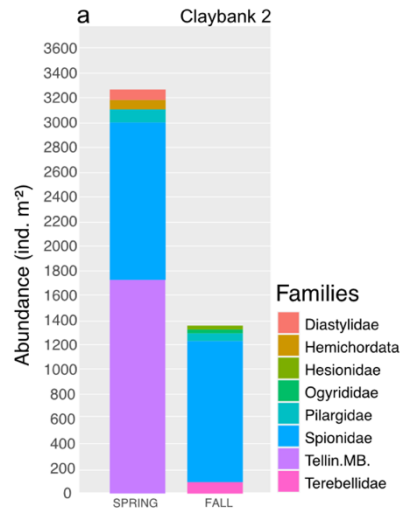
- Task 2: Investigate and integrate benthic biogenic processes in SBT classification – Data Collection 1: York River, VA



Cox et al. (*in review*)

Results to Date

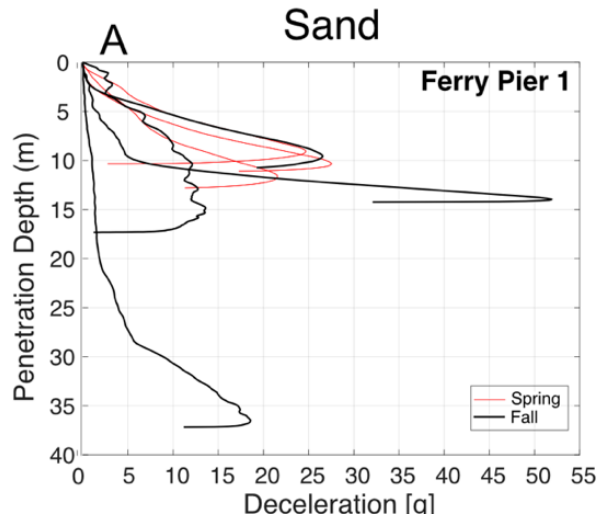
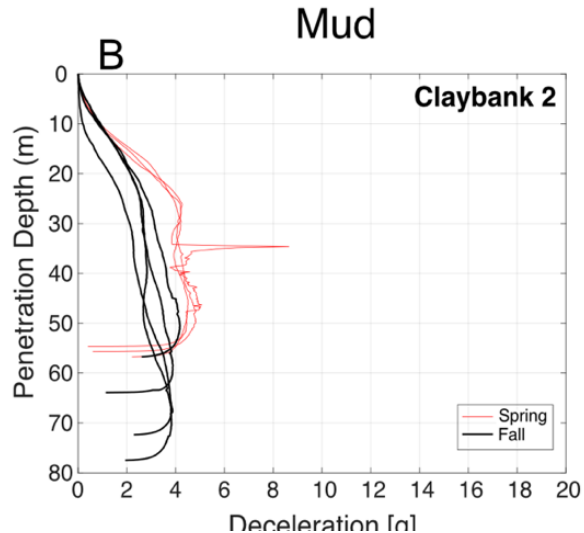
- Task 2: Investigate and integrate benthic biogenic processes in SBT classification – Data Collection 1: York River, VA



Cox et al. (*in review*)

Results to Date

- Task 2: Investigate and integrate benthic biogenic processes in SBT classification – Data Collection 1: York River, VA



Infauna abundance impacts on geomechanical properties: impact can be temporally offset and spatially sporadic.

Cox et al. (*in review*)

Results to Date

- Task 2: Investigate and integrate benthic biogenic processes in SBT classification – Data Collection 2: Sydney, NS, CAN

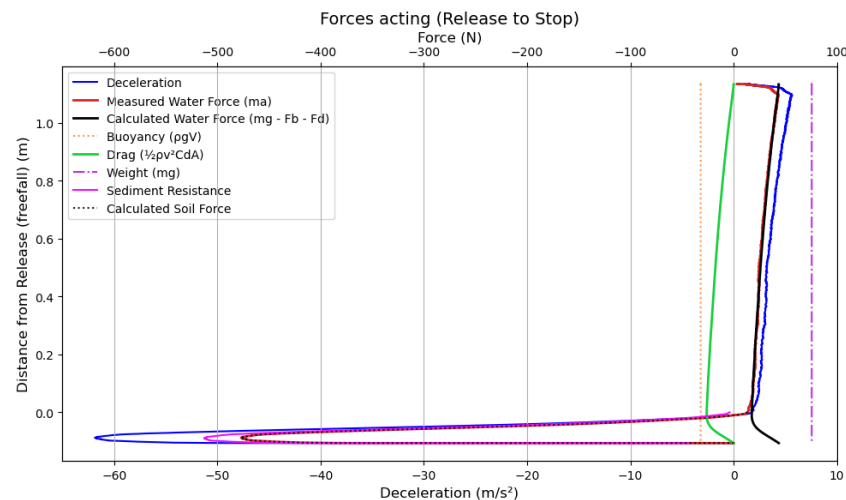


Tube-building
anemone
(*Cerianthus* sp.)

Results to Date

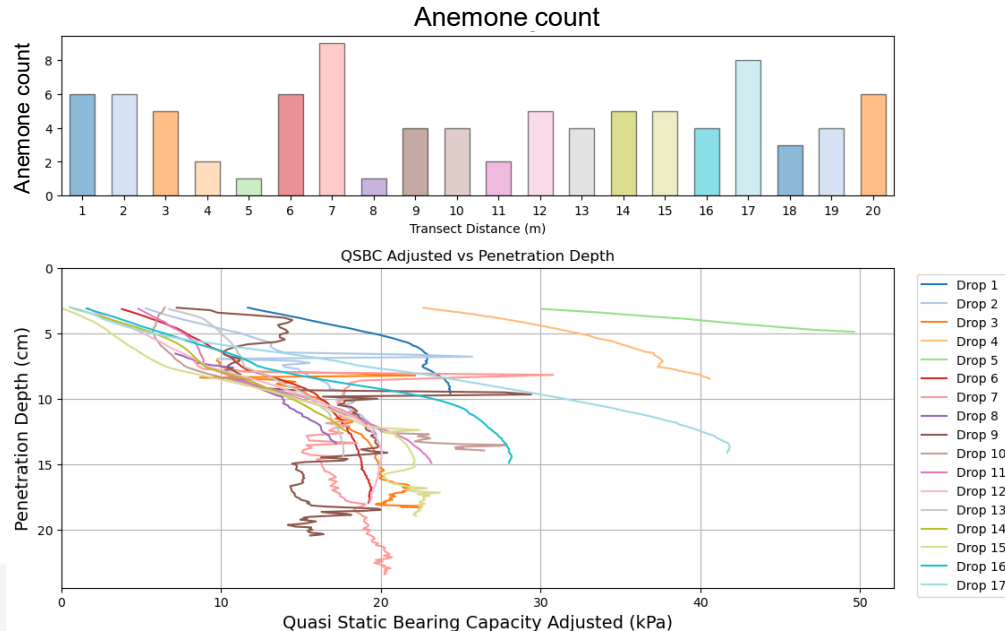
■ Task 2: Investigate and integrate benthic biogenic processes in SBT classification – Data Collection 2: Sydney, NS, CAN

- PFFP deployments and infauna counts/collects were performed by divers along co-located transects and simultaneously
- Data processing of diver deployments required additional data quality control and processing



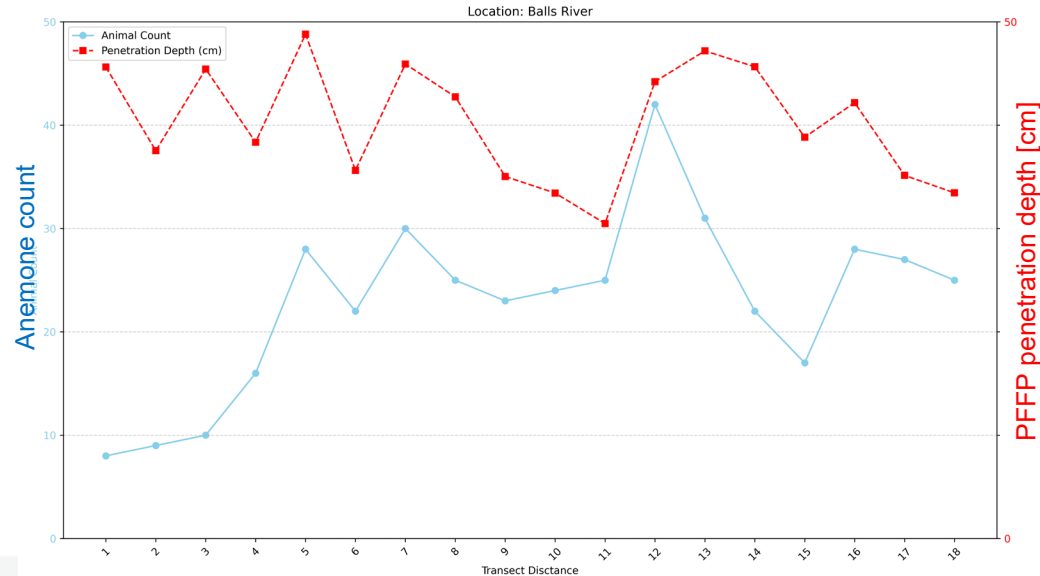
Results to Date

- Task 2: Investigate and integrate benthic biogenic processes in SBT classification – Data Collection 2: Sydney, NS, CAN



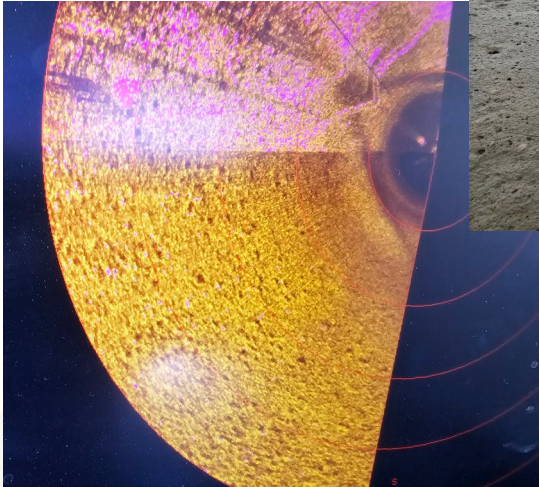
Results to Date

- Task 2: Investigate and integrate benthic biogenic processes in SBT classification – Data Collection 2: Sydney, NS, CAN



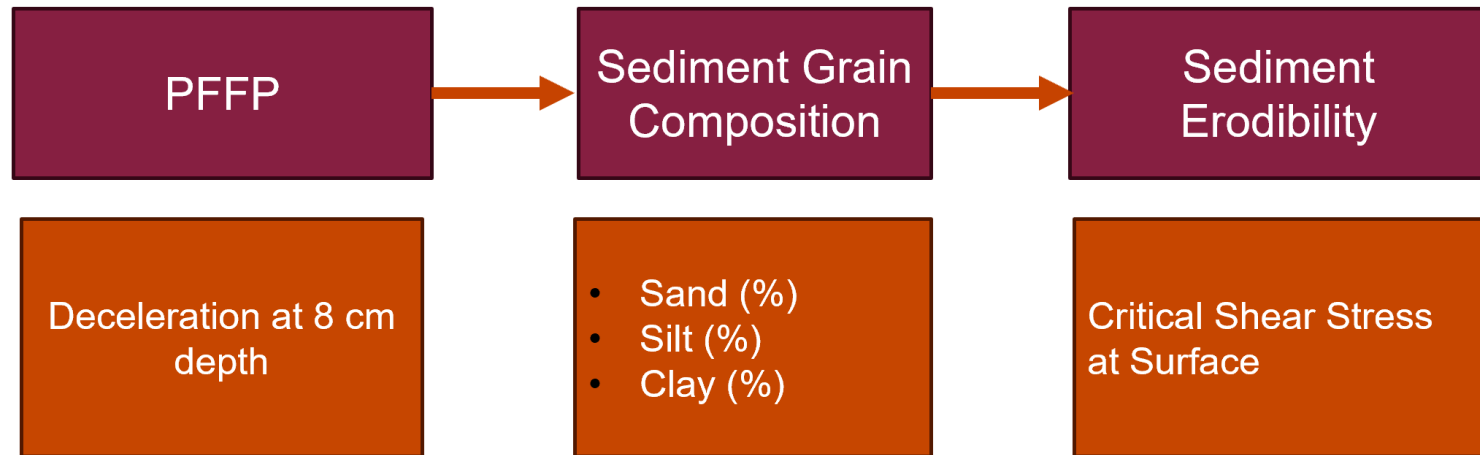
Results to Date

- Task 2: Investigate and integrate benthic biogenic processes in SBT classification – Data Collection 3: Cedar Key, FL



Results to Date

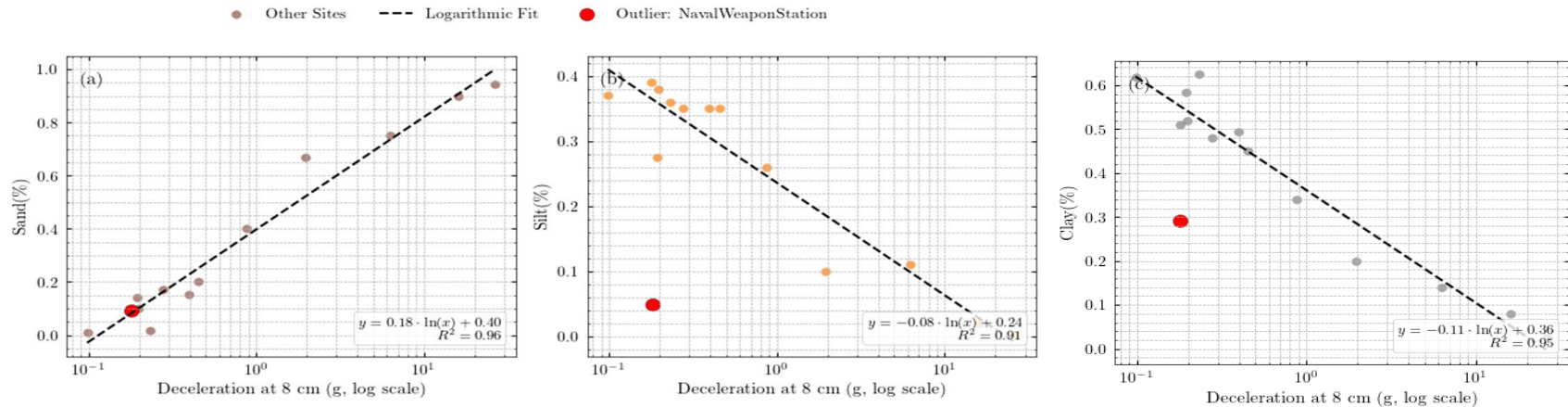
- Task 3: Correlate SBT classification to geoacoustic properties, sediment erodibility, and likelihood for seabed liquefaction



Rahman et al. (*in prep.*)

Results to Date

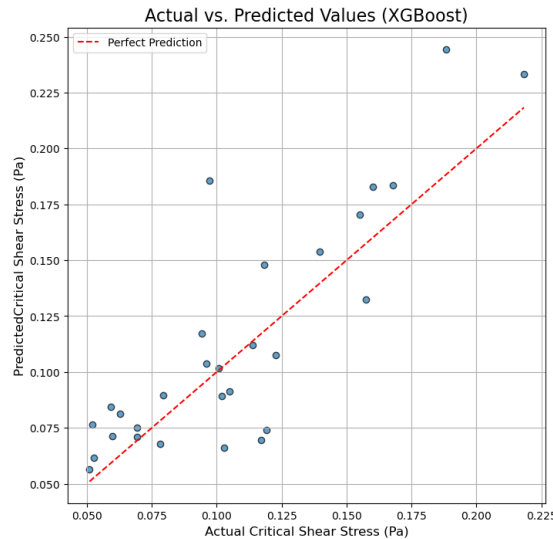
- Task 3: Correlate SBT classification to geoacoustic properties, sediment erodibility, and likelihood for seabed liquefaction



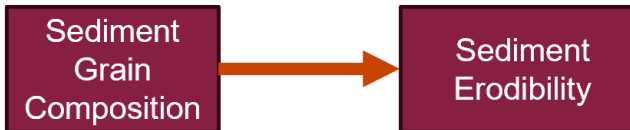
Rahman et al. (in prep.)

Results to Date

- Task 3: Correlate SBT classification to geoacoustic properties, sediment erodibility, and likelihood for seabed liquefaction



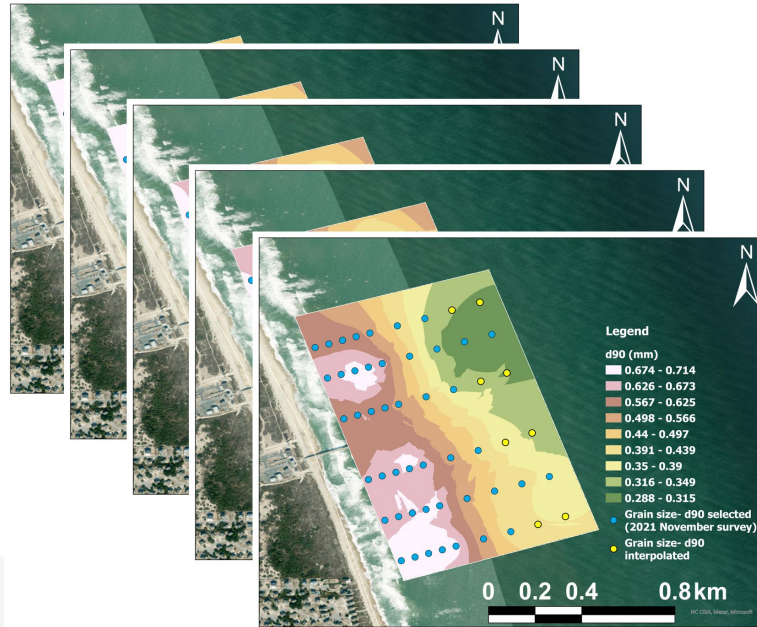
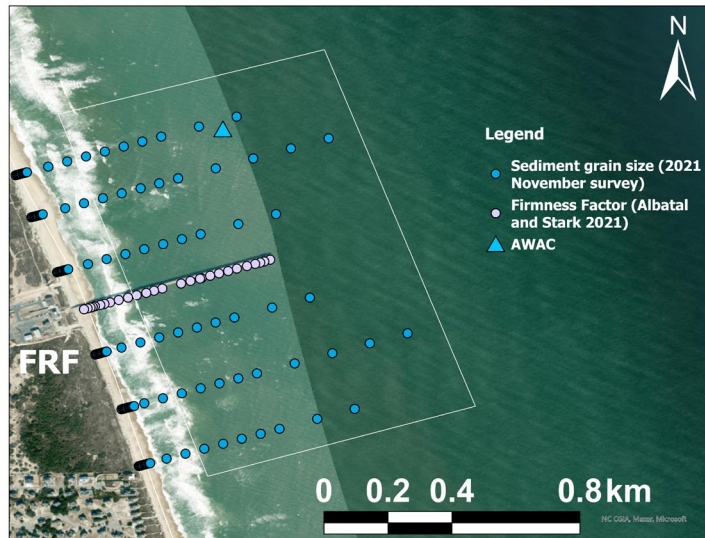
Comparison between Actual and Predicted Critical Shear Stress obtained using XGBoost



Rahman et al. (*in prep.*)

Results to Date

- Task 3: Correlate SBT classification to geoacoustic properties, sediment erodibility, and likelihood for seabed liquefaction



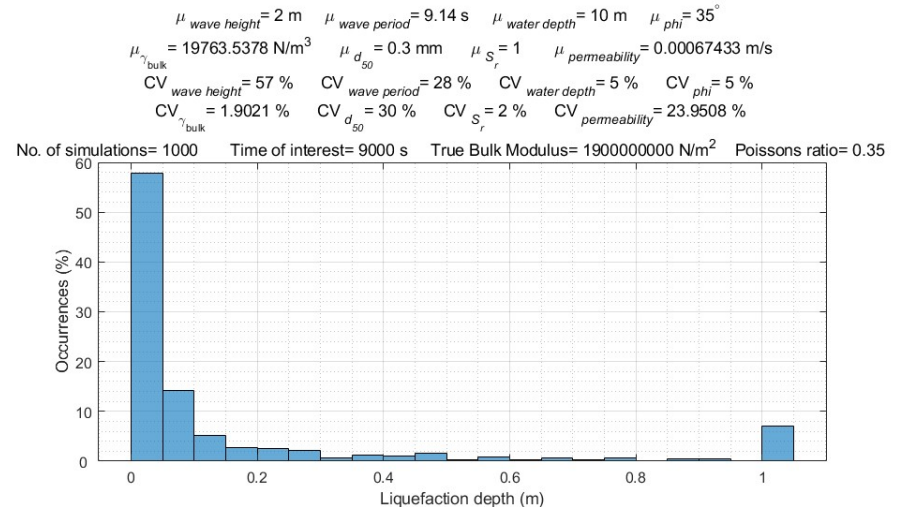
Shrestha et al. (in prep.)

Results to Date

- Task 3: Correlate SBT classification to geoacoustic properties, sediment erodibility, and likelihood for seabed liquefaction

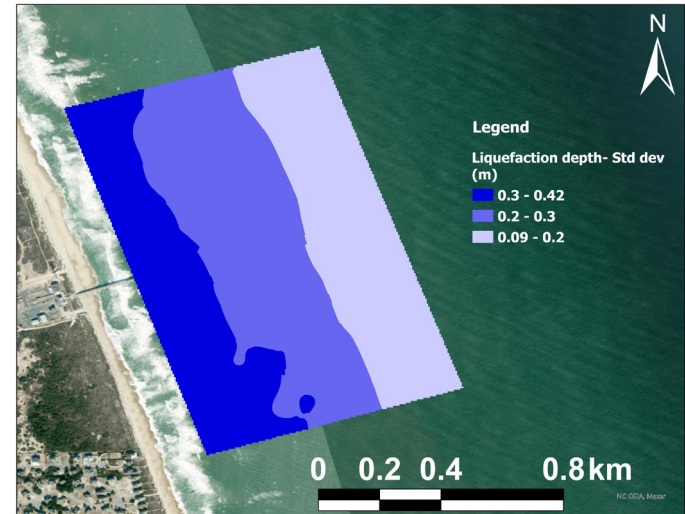
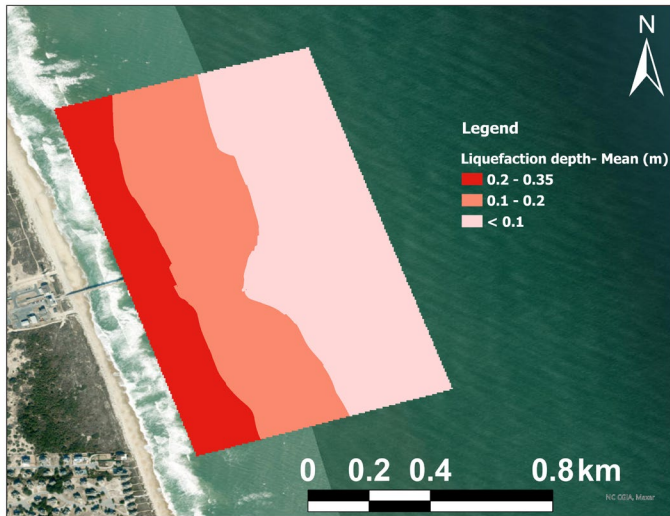
Study area	Statistics			
Parameters	μ	σ	CV	r
<i>Grain size</i>	-	-	30 %	NA
H_s	0.84 m	0.48 m	57.18 %	-0.134
T_p	9.14 s	2.58 s	28.27 %	
h	-	-	5.5 %	NA
S_r	1	0.02	2 %	NA

Histogram of predicted liquefaction depth



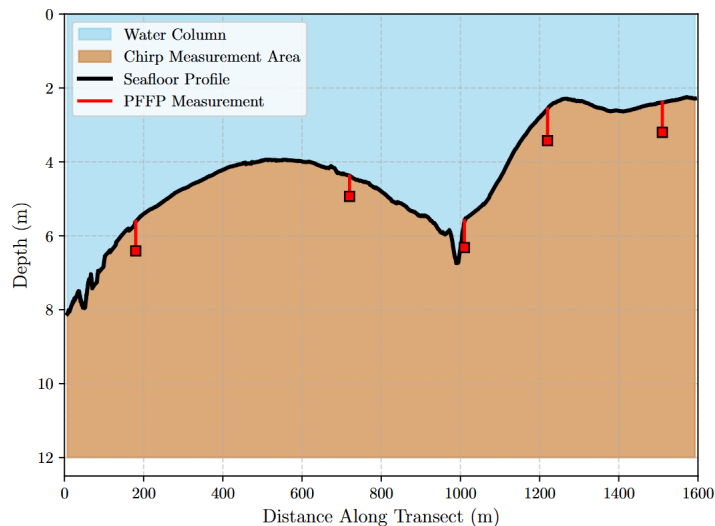
Results to Date

- Task 3: Correlate SBT classification to geoacoustic properties, sediment erodibility, and likelihood for seabed liquefaction

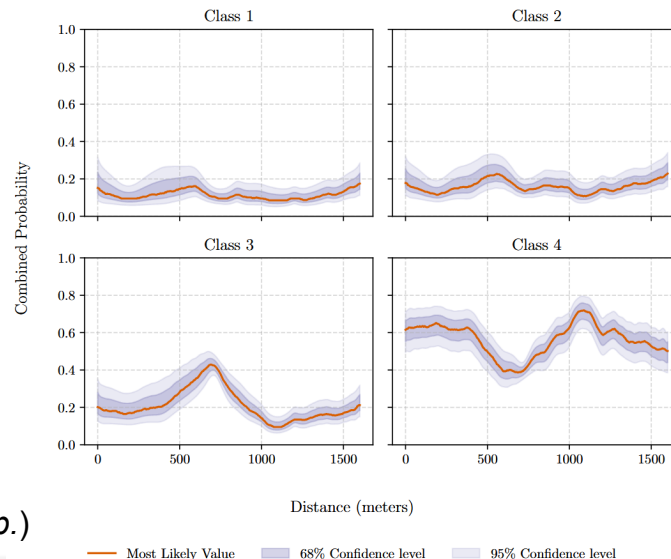


Results to Date

- Task 3: Correlate SBT classification to geoacoustic properties, sediment erodibility, and likelihood for seabed liquefaction



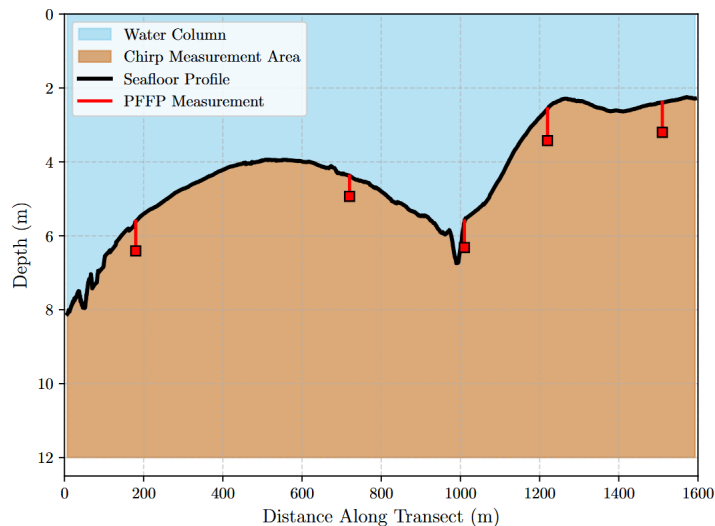
Inversion of
CHIRP sonar to
PFFP seabed
classes



Rahman et al. (in prep.)

Results to Date

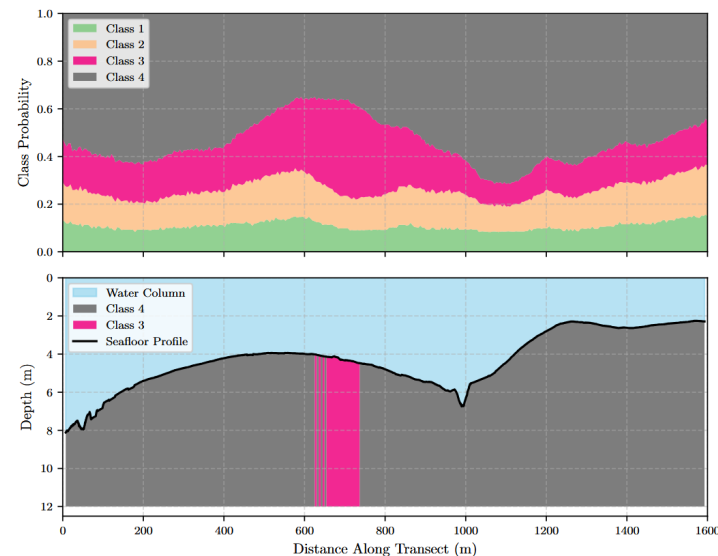
- Task 3: Correlate SBT classification to geoacoustic properties, sediment erodibility, and likelihood for seabed liquefaction



Inversion of
CHIRP sonar to
PFFP seabed
classes

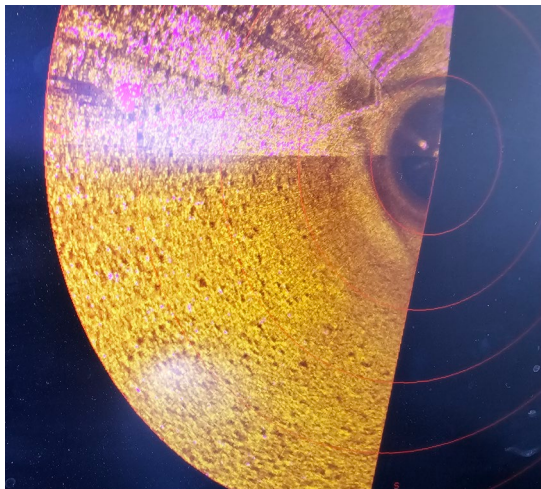


Rahman et al. (in prep.)



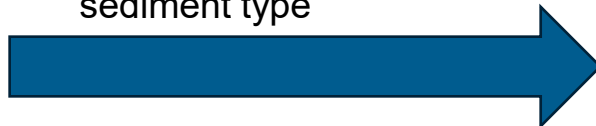
Results to Date

- Task 3: Correlate SBT classification to geoacoustic properties, sediment erodibility, and likelihood for seabed liquefaction

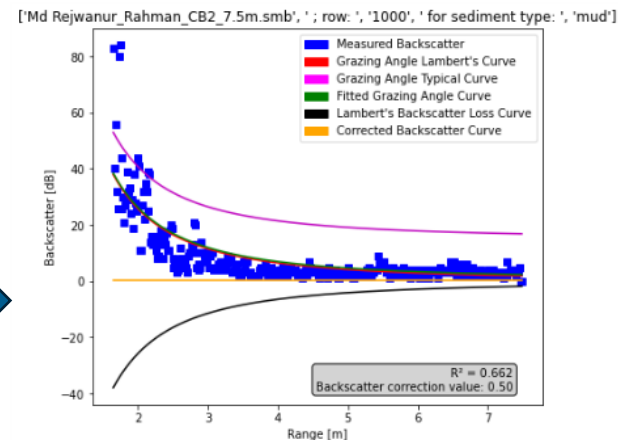


High-frequency side scan sonar

- Correct for range effects
- Extract deviations from an idealized Lambert's curve
- Relate those deviations to sediment type

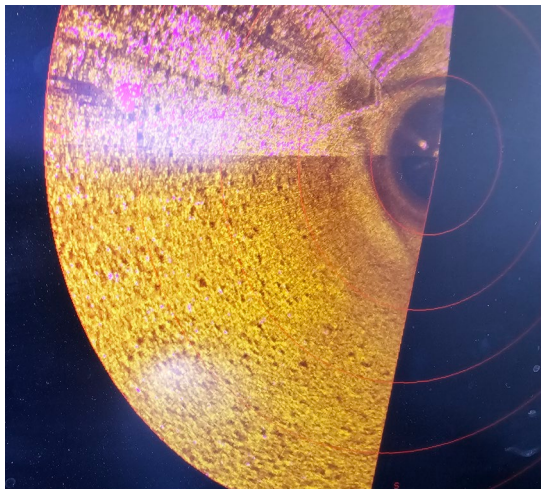


Clouse et al. (*in prep.*)



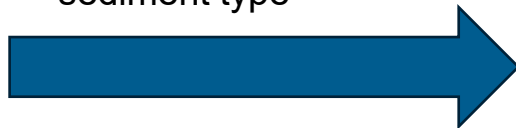
Results to Date

- Task 3: Correlate SBT classification to geoacoustic properties, sediment erodibility, and likelihood for seabed liquefaction

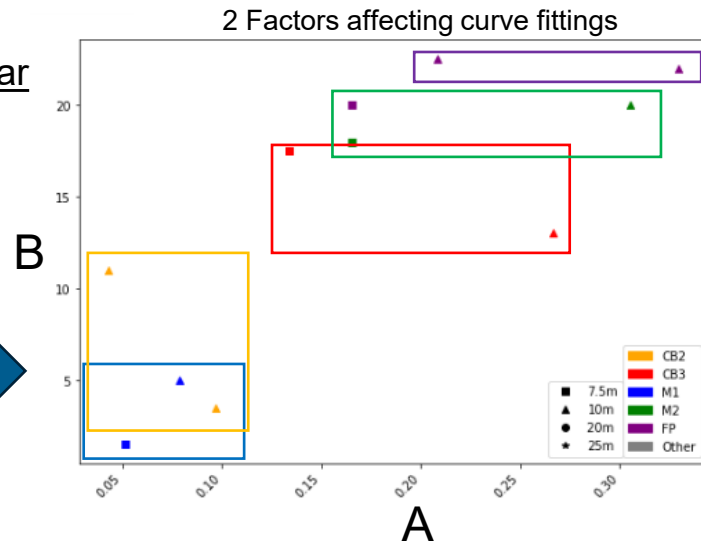


High-frequency side scan sonar

- Correct for range effects
- Extract deviations from an idealized Lambert's curve
- Relate those deviations to sediment type



Clouse et al. (*in prep.*)



Results to Date

- Task 4: Develop strategies to implement SBT classification into UXO risk assessment (using UnMES)
 - Deterministic vs. probabilistic approach: both demonstrated and possible
 - Probabilistic 4 (or more classes) approach provides soil behavior classification with soil behavior class ranges as well as uncertainty based on limited data requirements
 - Biological aspects can influence soil properties on relevant scale but are temporally complex and spatially to some degree “random”

Next Steps

- Complete data analysis from Cedar Key, FL experiment
- Complete synthesis, summary, and dissemination of results in tasks 2-3
- Complete task 4 - Develop pathway to integrate classification framework into UnMES (or other UXO risk assessment and management framework)
- SERDP Symposium 2025 poster
- Final Report

Technology Transfer

- Automated portable free fall penetrometer processing routine.
- Seabed classification framework including the major geomechanical processes affecting UXO risk assessment and management.
- Geotechnical data sets of different sites are available to other performers and managers.
- Modified approaches to relate geoacoustic data to geotechnical seabed properties
- Novel/modified to classify likelihood for seabed erodibility/liquefaction from rapid penetrometer testing
- SERDP webinar

Issues

- Delays which resulted from changes in personnel were solved and we have almost fully caught up with the project.
- A at no-cost extension was requested and approved with revised final report due date December 15, 2025.

BACKUP MATERIAL

These charts are required, but will only be briefed if questions arise.

21-1265: Rapid soil classification and integration of soil characteristics for UXO site characterization and risk assessment

Performers:

- Adrian Rodriguez-Marek (Virginia Tech)
- Nina Stark (University of Florida, previously: Virginia Tech)
- Grace Massey, Carl Friedrichs (Virginia Institute for Marine Sciences)
- Kelly Dorgan (Dauphin Island Sea Lab)

Technology Focus

- Seabed characterization and classification from portable free fall penetrometers with special attention to benthic biogenic processes, sediment dynamics, and impacts on geo-acoustics and UXO site management

Research Objectives

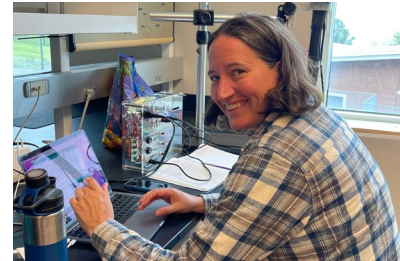
- Develop a soil behavior classification scheme based on portable free fall penetrometer measurements;
- Identify effects of benthic biogenic processes on geotechnical soil properties and integrate these effects in the soil classification scheme;
- Identify and quantify the impacts of the different soil classes on acoustic UXO detection and classification methods, on erodibility estimates, and on susceptibility to soil liquefaction processes;
- Develop strategies to implement the effects of soil classes into UXO risk assessment with UnMES.

Project Progress and Results

- Completion of the collection of field data sets (Sequim Bay; York River; Sydney, NS)
- Assembly of a “living” database
- Automation of portable free fall penetrometer processing and classification
- Relating of infaunal activity with geotechnical properties and portable free fall penetrometer readings

Technology Transition

- The soil behavior classification framework will be published and accessible to any potential user.
- The development of a pathway towards the integration into UnMES will be the first step to transition the soil behavior classification framework into application for UXO risk and site assessment.

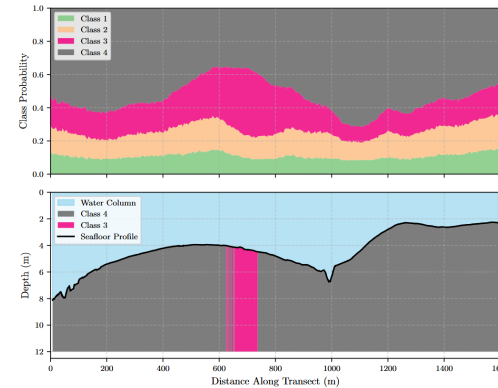


Plain Language Summary

- The detection, classification, and remediation of military munitions found at underwater sites of varying environmental conditions need innovative ideas and techniques for rapid site characterization.
- Portable free fall penetrometers (PFFP) are a recognized tool for rapid seabed site characterization, but more research is needed to relate these data to relevant geomechanical processes and simplify data interpretation.
- This project addresses this need by developing a user-friendly seabed classification framework with focus on PFFP data collection and relevant geomechanical processes.

Impact to DoD Mission

- Geomechanical seabed processes of significant concern to underwater UXO risk assessment and site management were related to four main seabed sediment classes.
- This simplifies and facilitates geotechnical site characterization for UXO management, decision making, and response.



Action Items

- Task 2.4: Laboratory testing – complete
- Task 2.5: Integration into soil classification – complete
- Task 3.3: Correlations to liquefaction – due Aug 31, 2025
- Task 3.4: Integration of correlations into classification – complete
- Task 4: Pathways to integration to risk assessment – due Oct 31, 2025
- Final report – due Dec 15, 2025

Publications

- Stark, N., Rodriguez-Marek, A., Massey, G., Friedrichs, C., and Dorgan, K. (2021). Rapid soil classification and integration of soil characteristics for UXO site characterization and risk assessment. Poster and oral presentation presented at *SERDP/ESTCP Symposium 2021*, virtual, Nov 29- Dec 3, 2021.
- Jaber, R., & Stark, N. (2022). Towards seabed penetrometer and chirp sonar measurements. *Cone Penetration Testing CPT'22*, Bologna, Italy, June 8-10, 2022.
- Hunstein, E., Stark, N., Massey, G., & Brill, N. (2022). *SERDP Sequim Bay Survey Report*. Internal report provided to SERDP MR leadership and collaborators
- Stark, N., Jaber, R., Smith, L., Massey, G., & Calantoni, J. (2022) Relating fine-grained sediment consolidation to acoustic seabed surveying. *Acoustical Society of America (ASA) meeting*, Denver, CO, May 23-27, 2022.
- Stark, N., Rodriguez-Marek, A., Massey, G., Friedrichs, C., and Dorgan, K. (2021). Rapid soil classification and integration of soil characteristics for UXO site characterization and risk assessment. Poster and oral presentation presented at *SERDP/ESTCP Symposium 2021*, Arlington, VA, Nov 29- Dec 2, 2023. **SERDP MR Project of the Year Award.**
- Moore, J., Stark N., Massey, G., Friedrichs, C., Dorgan, K., Rodriguez-Marek, A., Cox, C., Rahman, M.R., & Hunstein, E. (2023). Investigating the relationship between geotechnical seabed properties and erodibility. *Coastal Sediments 2023*, New Orleans, LA, April 11-15, 2023. **Student poster award**
- Cox, C., Dorgan, K., Stark, N., Massey, G., Friedrichs, C. (2023). Influence of biogenic processes on seabed properties in the York River Estuary, Chesapeake Bay. *Coastal Sediments 2023*, New Orleans, LA, April 11-15, 2023.
- Rahman, M.R., Hunstein, E., Rodriguez-Marek, A., Stark, N., Massey, G., Friedrichs, C., Dorgan, K., & Cox, C. Probabilistics Soil Characterization Based On Portable Free Fall Penetrometer Measurements. In *Coastal Sediments 2023: The Proceedings of the Coastal Sediments 2023*, 2398-2407, 2023.

Publications

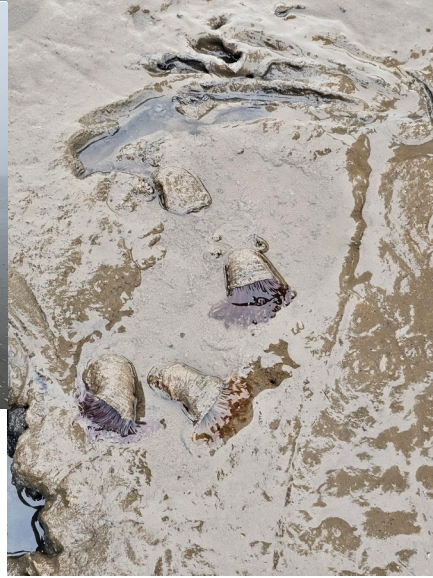
- Hunstein, E., Stark, N., & Rodriguez-Marek, A. Automatization of seabed impact selection for a portable free fall penetrometer. *ASCE Journal of Geotechnical and Geoenvironmental Engineering*, 149(12), 06023008, 2023. <https://doi.org/10.1061/JGGEFK.GTENG-1155>
- Jaber, R., & Stark, N. Geotechnical properties from portable free fall penetrometer in coastal environments. *ASCE Journal of Geotechnical and Geoenvironmental Engineering*, 149(12), 2023. <https://doi.org/10.1061/JGGEFK.GTENG-11013>
- Rahman, M.R., Rodriguez-Marek, A., & Stark, N. Probabilistic sediment characterization based on portable free fall penetrometer measurements using a Bayesian neural network. *9th International SUT Offshore Site Investigation and Geotechnics Conference 2023*, London, UK, September 12-14, 2023. **Student poster competition finalist**
- Cox, C. *Influence on infaunal community structure on surficial sediment properties*. **MS thesis** submitted to the University of Southern Alabama, 2023.
- Stark, N., Dorgan, K., Billi, N.C., & Frey, M.R. Observations of surficial seabed sediment strength and local infauna in sandy parts of Mobile Bay. *Acta Geotechnica, Special Issue on Bio-inspired Geotechnics*, 19, 1251-1265, 2024. <https://doi.org/10.1007/s11440-024-02241-y>
- Jaber, R., Stark, N., Sarlo, R., McNinch, J., & Massey G.M. Relating geotechnical sediment properties and low frequency chirp sonar measurements. *Remote Sensing*, 16(2), 241, 2024. <https://doi.org/10.3390/rs16020241>
- Rahman, M.R., Rodriguez-Marek, A., Stark, N., Massey, G., Friedrichs, C., & Dorgan, K., Probabilistic Classification of Near-surface Shallow-water Sediments using a Portable Free-Fall Penetrometer. In press for: *ASCE Journal of Geotechnical and Geoenvironmental Engineering*, 2025.
- Shrestha, S., Stark, N., Green, B., & Stilwell, D., A probabilistic approach for spatial scour burial prediction. In review with: *ASCE Journal of Waterway, Port, Coastal, and Ocean Engineering*.
- Cox, C.E., Dorgan, K.M., Stark, N., Rodriguez-Marek, A., Massey, G., Friedrichs, C., & Rahman, M.R. Influence of infaunal community structure on sediment physical properties. In review with: *Estuaries and Coasts*

Publications

- Four more journal publications and an abstract for the SERDP/ESTCP Symposium 2025 are in preparation

Literature Cited

Additional Slide(s) for High-Quality Photos



Acronym List

PFFP – Portable free fall penetrometer

UXO – unexploded ordnance