



Cooperative Agreement M21AC00010

Virginia Department of Energy

Analysis of Critical and Strategic Mineral Recovery from Sand Used for Beach Nourishment

Cooperative Agreement Summary Report Performance Period: July 01, 2021 – February 29, 2024

Lead Agency:

Virginia Department of Energy
Geology and Mineral Resources Program (GMRP)

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February 2024

Overview

Coastal shoreline loss has forced many local, state, and federal entities to prioritize the characterization of offshore sand resources needed for coastal resiliency projects. At the same time, evaluating these resources for domestic sources of economic minerals (i.e., heavy mineral sands with Ti, Zr, rare earth elements- REEs) is an important priority for the United States and is critical for our economy, national security, infrastructure, and energy needs. This study highlights the potential for an unconventional critical mineral resource and co-product of offshore sand used for beach re-nourishment.

The Virginia Department of Energy (VE) (formerly Department of Mines, Minerals and Energy) has worked with the United States Bureau of Ocean Energy Management (BOEM) and its predecessor (Minerals Management Service) since the 1980s to identify offshore areas suitable for supplying beach quality sand for coastal nourishment projects important to the Commonwealth. Alongside this work, total heavy mineral sand content and mineralogy has been conducted on marine core and bottom grab samples. A supplemental GIS geodatabase provides spatial data for heavy minerals offshore of Virginia and is available for download at <https://www.energy.virginia.gov/geology/ocssands.shtml>.

VE consulted with various entities throughout the project period, including regulatory authorities, state agencies, industry, non-profit stakeholders, academia, and coastal municipalities to gain insight into co-extraction feasibility. Specifically, the *Mid-Atlantic Marine Heavy Mineral Sands forum* organized in March 2022 gathered industry, regulatory, and environmental insights, and explored the viability and conceptual ideas of concentrating economic heavy minerals that contain critical commodities from offshore marine sands during beach nourishment. Detailed discussions and presentations from the forum are available in [Open-file report 2022-20](#). Further, information regarding state and federal regulations as they relate to co-extraction of heavy minerals or non-fuel mineral mining offshore of Virginia are summarized in the capacity assessment (Nelson et al., 2024).

A screening protocol utilizing a portable x-ray fluorescence (pXRF) instrument to measure elemental concentrations of Ti, Zr, and select REEs was developed as part of this Cooperative Agreement to aid in the identification of potential critical mineral commodities found within offshore sand resources. This procedure is intended to help the investigator prioritize sample targets for further laboratory analyses, utilizing both in-situ core scanning and simplified sample preparation methods. Lastly, recommendations for a pilot study have been outlined and can be used to test the feasibility of extracting heavy mineral sands alongside a beach nourishment project. These proposed next steps provide a roadmap for potential future endeavors.

Cooperative Agreement Outputs and Deliverables

Nelson, M.S., Hawkins, D.W., and Lassetter, W.L., 2024, A capacity assessment on the recovery of critical and economic minerals from sand used for coastal resilience projects: Virginia Department of Energy, Geology and Mineral Resources Program, Open-file report 2024-16, 76 p. and Appendices A-E.

Marine sand deposits containing critical minerals hold promise in fulfilling the objectives of Federal Executive Order 13817 (2017) aimed at securing the nation's vital materials for both security and economic prosperity. However, current understanding of offshore heavy mineral occurrences and co-extraction methods from marine sand deposits remains incomplete and untested. This capacity assessment serves as a comprehensive summary of investigations related to critical commodities found in marine heavy mineral sands offshore on Virginia's Outer Continental Shelf (OCS). Five main topics are covered:

1) forum presentations and proceedings, 2) existing regulations or lack thereof, 3) total heavy mineral sand occurrences and grade offshore of Virginia, 4) portable x-ray fluorescence (XRF) screening methods for critical commodities within marine sediment, and 5) what the next phase of this research would entail to test the feasibility.

Portable XRF units have proven to be an efficient screening tool for identifying heavy mineral-rich sands in large sand resource areas on the continental shelf. This rapid, non-destructive geochemical tool can identify critical commodities like Ti, Zr, and REEs in sediments while enhancing the evaluation of offshore sand resources. The capacity assessment and a related appendix outlines protocols for in-situ screening and minimally-processed samples from sediment cores (Figure 1). Recommendations for targeted sampling based on minimum-threshold elemental limits are provided. Analyses of newly collected OCS vibrocores revealed a heavy mineral sand content ranging from 0.4-1.4% in bulk samples, with ilmenite, zircon, and rutile identified as predominant economic heavy minerals. Based on reported sand volumes and heavy mineral percentages, the Sandbridge Shoal federal OCS lease areas offshore Virginia Beach contains an estimated 330,000 metric tons of economic heavy minerals, including critical commodities, with a calculated value of \$83.9 million at current commodity prices. These findings, along with the outlined protocols, recommendations, and regulatory summary, serve as a guide for fostering collaborative and economically beneficial relationships between marine and coastal resource users. The capacity assessment can be accessed via the project webpage at <https://energy.virginia.gov/geology/ocssands.shtml>.

Initial Considerations

- Confirm equipment calibration is up-to-date
- Determine adequate run time for sample (minimum 30 seconds per beam)
- Determine appropriate quality control measures
- Consider potential spectral interferences
- Utilize existing analytical data for validation

Note: detailed protocol available in associated report

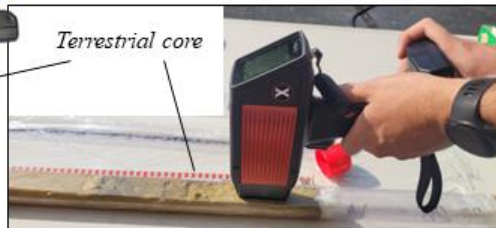
Marine core



In-situ Core Screening

- Determine the target interval
- Avoid H₂O-saturated zones
- Moisture content should be < 20%
- Analyzer should be in direct contact with surface (no gaps)
- Use protective film between window and sediment
- Use core stand or clamp to hold analyzer steady during run time

Terrestrial core



Ex-situ Sample Prep Screening

- Dry sample to remove moisture content
- Sieve to < 2 mm size fraction
- Homogenize material with splitter and mortar and pestle
- Ensure ≥ 10 mm thickness in the sample cup
- Repeat measurements for averaging (n ≥ 3)



Example of Sample Media

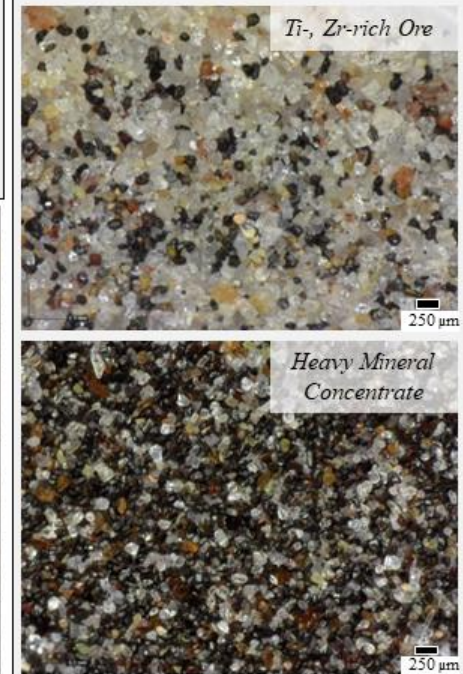


Figure 1. Generalized pXRF screening considerations for detecting critical commodities contained within offshore sand resources. Ex-situ sample pucks include packed sediment with a 4-micron thick prolene protective sheet.

Nelson, M.S., Hawkins, D.W., and Lassetter, W.L., 2024, M21AC00010_Geodatabase, Geodatabase: Virginia Department of Energy, Geology and Mineral Resources Program, <https://energy.virginia.gov/geology/ocssands.shtml>.

A GIS geodatabase was created for Cooperative Agreement M21AC00010 between VE and BOEM. This database provides an updated heavy mineral record of samples located offshore of Virginia (Figure 2). It consists of two separate point feature classes with total heavy mineral and modal mineralogy data on heavy minerals sands separated from offshore marine sand deposits, approximately > 2.9-3.2 g/cc. Each point feature class has a related non-spatial table that contains extensive geochemical data. The 'previous data' shapefile contains 620 grab and core sample points from decades of previous work showcasing heavy mineral sand content in marine deposits from the mouth of the Chesapeake Bay, Inner Continental Shelf (< 3 nautical miles from coastline) and the Outer Continental Shelf (OCS) (> 3 nautical miles from coastline). The 'M21AC00010 new data' shapefile represents data from cores collected in 2018 from Sandbridge Shoal and the Atlantic Ocean Federal Navigation Channel and sampled for heavy mineral analyses in 2022.

This digital database serves as a reconnaissance-level archive that may be queried for total heavy mineral content, mineral composition, and grade distribution patterns of heavy minerals in marine sediments offshore of Virginia. The polygon feature class contains the Sandbridge Borrow Lease Areas A and B which are managed by BOEM, and the Atlantic Ocean Federal Navigation Channel. Additional data, sources, and interpretations are presented in the capacity assessment. A potential use of this geodatabase would be to target locations for future critical mineral co-extraction operations during dredging for nourishment or navigational waterways that have high heavy mineral content. The geodatabase and detailed metadata are contained within a zip folder and can be downloaded at <https://energy.virginia.gov/geology/ocssands.shtml>.

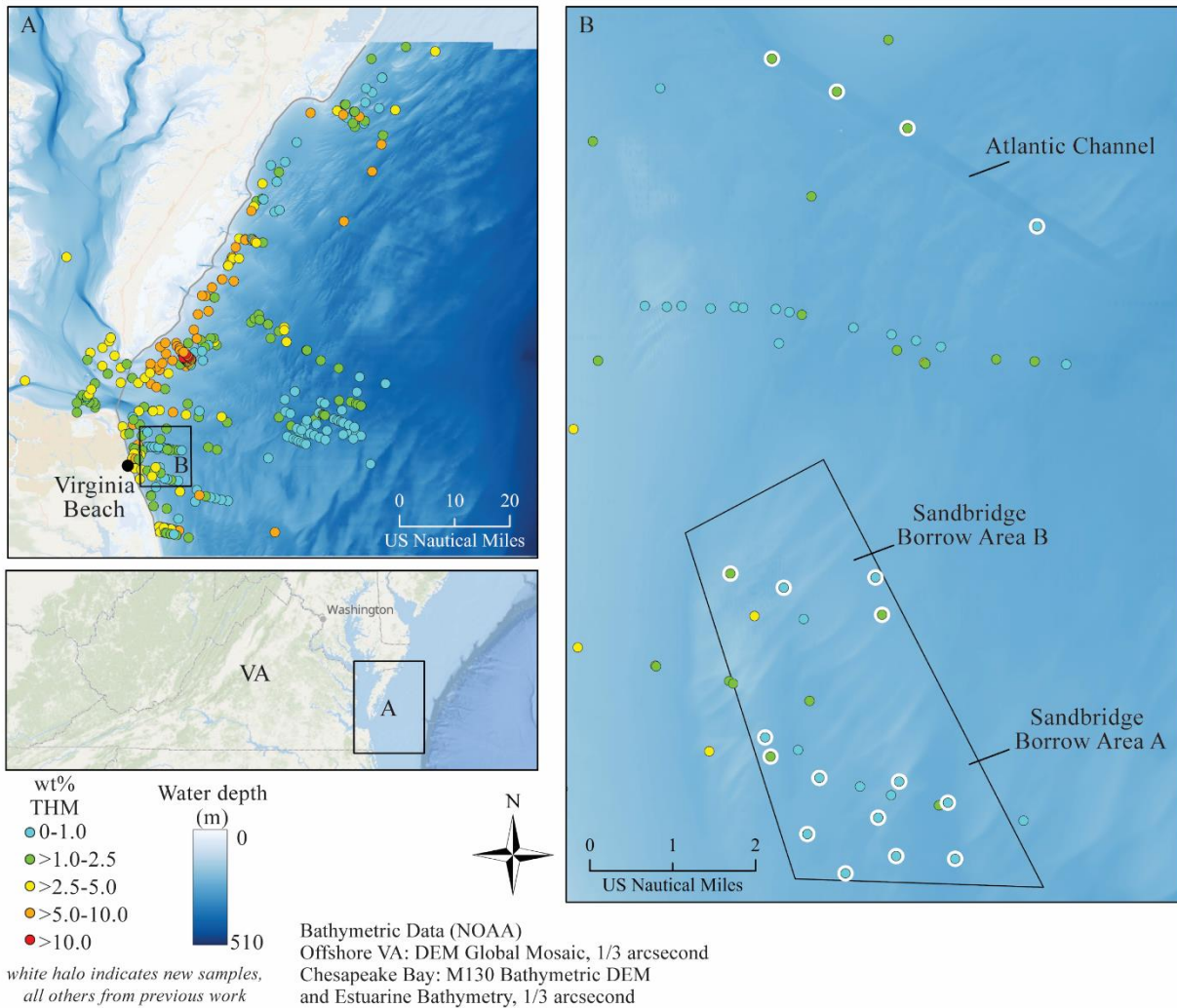


Figure 2. Heavy mineral geodatabase showing marine samples offshore of Virginia. Data is available for download at <https://www.energy.virginia.gov/geology/ocssands.shtml>. **A:** 620 samples with heavy mineral data from previous projects, symbol colors determined by the percent of total heavy minerals (THM) obtained through gravity spiral separation methods. **B:** M21AC00010 samples (indicated with white halo) from Sandbridge Shoal and Atlantic Channel vibracores for THM and mineralogical analyses.

Hawkins, D.W. and Lassetter, W.L., 2022, Proceedings of the 2022 Mid-Atlantic Marine Heavy Mineral Sands Forum, March 31, 2022, Virtual Forum, Charlottesville, Virginia: Virginia Department of Energy, Geology and Mineral Resources Program, Open-file report 2022-20, 21 p. and Appendices A-C.

On March 31, 2022, the *Mid-Atlantic Marine Heavy Mineral Sands forum* was convened to gather stakeholder and regulator insights regarding heavy mineral separation during beach sand nourishment. Results of the forum were collected in published proceedings (Hawkins and Lassetter, 2022). The purpose of this one-day virtual event was to bring together key maritime stakeholders, gather relevant information that would help assess the feasibility of extracting economic heavy minerals from marine sand deposits, the regulatory framework surrounding such a process, and who would be most affected. Nearly three-quarters of the 74 participants to the forum were from state and federal agencies. Environmental and mining consultants made up 12% of the forum participants, while mining companies, local municipalities, laboratory staff, academics, and fisheries experts made up less than 5% each.

Discussions identified inconsistencies and gaps in the existing federal, state, and local regulatory framework that address environmental concerns in onshore and offshore mining operations recovering non-fuel industrial minerals on the OCS. Additionally, sustained commitments between the sand mining industry and the government are essential for the feasibility of these projects. A review and synthesis of forum discussion points identified the following significant findings and recommendations:

1. Regulations need to be modified to differentiate between non-fuel minerals (excluding metals) and sand/gravel aggregate.
2. The National Environmental Policy Act (NEPA) process will need to address the transport, disposal, and handling of heavy mineral concentrates following beach nourishment.
3. Ownership rights to recovered heavy minerals from dredged material are ambiguous.
4. The mining industry has emphasized the necessity for long-term commitments from relevant government and/municipal partners to foster investment from industry.
5. These potential operations will need to leverage existing offshore analytical data and engineering expertise from onshore operations and reclamation.
6. Existing dredge spoil areas could be evaluated for heavy mineral potential.
7. The U.S. Army Corps of Engineers and the dredging community were absent from the forum, which represents a data gap in evaluating these regulatory and industry concerns. Additional conversations with these stakeholders should be solicited.

The forum proceedings can be downloaded from Virginia Energy's webstore ([Open-file report 2022-20](#)) and accessed via the project webpage at <https://energy.virginia.gov/geology/ocssands.shtml>.

Associated Cooperative Agreement Outputs

Presentations

Lassetter, W.L. and Hawkins, D.W., 2022. Marine Mineral Sands on Virginia's Outer Continental Shelf – The Case for Extracting Critical Minerals as Part of Beach Restoration Projects. Geological Society of America Abstracts with Programs. Vol. 54, No. 5. doi: [10.1130/abs/2022AM-381889](https://doi.org/10.1130/abs/2022AM-381889).

Hawkins, D.W. and Lassetter, W.L., 2023. Standardizing A Field Screening Protocol Using Portable X-Ray Fluorescence and Radiation Spectrometry to Assess Critical Mineral Commodities in Heavy

Mineral Placers: How Can We Better Streamline Decisions in The Field? Geological Society of America Abstracts with Programs. Vol. 55, No. 2. doi: [10.1130/abs/2023SE-385571](https://doi.org/10.1130/abs/2023SE-385571).

Nelson, M.S., Lassetter, W.L., and Hawkins, D.W., 2023. Heavy Mineral Sand Abundance and Mineralogy from Paleo-placer and Offshore Deposits in VA. 2023 Virginia Geological Research Symposium hosted by Virginia Department of Energy, Geology and Mineral Resources Program, Charlottesville, VA, April 21, 2023.

Nelson, M.S., Hawkins, D.W., and Lassetter, W.L., 2023. Economic Heavy Minerals in Sand Resources Offshore of Virginia: Geological Society of America Abstracts with Programs. Vol. 55, No. 6, 2023 doi: [10.1130/abs/2023AM-395679](https://doi.org/10.1130/abs/2023AM-395679).

Other Related Virginia OCS Reports

Berquist, C.R., Jr. and C.H. Hobbs, III, 1986, Assessment of economic heavy minerals of the Virginia inner shelf: Virginia Division of Mineral Resources [Open-file report 86-1](#). 13 p. and Appendices.

Berquist, C.R., Jr. and C.H. Hobbs, III, 1988, Study of economic heavy minerals of the Virginia inner continental shelf: Virginia Division of Mineral Resources [Open-file report 88-4](#), 23 p. and Appendices.

Berquist, C.R., Jr., [ed.], 1990, Heavy-mineral studies – Virginia inner continental shelf, Virginia Division of Mineral Resources [Publication 103](#), 39 p. and Appendices.

Berquist, C.R., Jr., [ed.], 2012, Heavy-mineral analysis of five samples: Addendum to sand resource evaluation on Virginia’s outer continental shelf coastal plain – Final technical report: Prepared for U.S. Bureau of Ocean Energy Management, [Cooperative Agreement M10AC20021 for the performance period Sept 14, 2010, to Oct 31, 2011](#), 2 p. and Appendices.

Berquist, C.R., Jr., Lassetter, W.L., and Goodwyn, M.H., 2016, Grain size distribution and heavy mineral content of marine sands in Federal waters offshore of Virginia: Virginia Division of Geology and Mineral Resources [Open-file report 2016-01](#), 22 p. and Appendices.

Berquist, C.R., Jr. and Boon, J.D., 2019, Heavy mineral distributions in offshore sediments using Q-mode factor analysis: Virginia Division of Mineral Resources [Open-file report 2019-04](#), 35 p.

Blanchette, J.S. and Lassetter, W.L., 2019, Assessment of offshore sand resources for beach remediation in Virginia: Virginia Division of Geology and Mineral Resources [Open-file report 2019-02](#), 24 p. and Appendices.

DMME (Department of Mines, Minerals and Energy), 2012, Sand resource evaluation on Virginia’s outer continental shelf – Final Technical Report: Prepared for U.S. Bureau of Ocean Energy Management, [Cooperative Agreement M10AC20021 for the performance period Sept 14, 2010 to Oct 31, 2011](#), 19 p.

DMME (Department of Mines, Minerals and Energy), 2020, Annual Production data reported to the Division of Mineral Mining, <https://energy.virginia.gov/mineral-mining/mineralmining.shtml>.

- Goodwyn, M.H., Enomoto, M.R., Lassetter, W.L., and Kuehl, S.A., 2016, GIS compilation of geophysical data on Virginia's Outer Continental Shelf: Division of Geology and Mineral Resources [Open-file report 2016-02](#), 10 p. and Appendices.
- Hawkins, D.W., and Lassetter, W.L., 2022, Proceedings of the 2022 Mid-Atlantic Marine Heavy Mineral Sands Forum: Virginia Geology and Mineral Resources Program [Open-file report 2022-20](#), 21 p. and Appendices.
- Lassetter, W.L., and Blanchette, J.S., 2019, Economic heavy minerals on the continental shelf offshore of Virginia - new insights into the mineralogy, particle sizes, and critical element chemistry: Virginia Division of Geology and Mineral Resources [Open-file report 2019-03](#), 33 pp and Appendices.
- Milligan, D.A., Kuehl, S.A., and Hardaway, C.S., 2016, Digital conversion of geologic core data, quality control, and preliminary assessment of sand resource area on Virginia's Outer Continental Shelf: [Virginia Institute of Marine Science](#), 14 p.