Texas General Land Office Upper Outer Continental Shelf Sand Banks Reconnaissance Geotechnical Survey

Final: June 2025

U.S. Department of the Interior
Bureau of Ocean Energy Management
Headquarters, Sterling, VA

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Contributing Authors: Beau Suthard (Aptim Environmental & Infrastructure, LLC [APTIM]) was the Project Manager for this survey and the primary author of this report. He was responsible for project formulation and execution, including data analyses, interpretations, and report preparation. Mr. Suthard was supported by Jeffrey Andrews, CH and APTIM's Geophysical and Geologic Survey teams with data collection, analysis, and interpretation. Beth Forrest, Ph.D., PG, (APTIM) provided support throughout the study, oversaw geotechnical data processing, and contributed with written sections of the report. Additional report writing was conducted by Patrick Bryce, PG, Chris Dvorscak, MA, RPA, Alexandra Valente, Alexsandra Henes, Liam Fry, Sarah Finkle, Thomas Shahan, Ryan Stiglbauer, Rob Hollis (TWI), Maricel Beltran Burgos (TWI), John Swartz, Ph.D., (TWI), Mike Miner, Ph.D., (TWI).

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Acronyms and Abbreviations

%	percent
~	approximately
APTIM	Aptim Environmental & Infrastructure, LLC
ASTM	American Society for Testing and Materials
BCM	billion cubic meters
BCY	billion cubic yards
BOEM	Bureau of Ocean Energy Management
cm	centimeter
CORS	Continually Operating Reference System
CPE	Coastal Protection Engineering LLC
DGPS	Differential Global Positioning System
ft	feet (foot)
GLO	General Land Office
GPS	Global Positioning System
Hz	Hertz
km	kilometer
LNM	Local Notice to Mariners
m	meters
MCM	million cubic meters
MCY	million cubic yards
mm	millimeters
NAD	North American Datum
NAVD	North American Vertical Datum
NOAA	National Oceanic and Atmospheric Administration
OCS	Outer Continental Shelf
QMA	Qualified Marine Archaeologist
TWI	The Water Institute
USACE	U. S. Army Corps of Engineers
USCG	U. S. Coast Guard
USCS	Unified Soil Classification System
USEPA	U. S. Environmental Protection Agency

Executive Summary

The Texas General Land Office (GLO) and the Bureau of Ocean Energy Management (BOEM) contracted Aptim Environmental & Infrastructure, LLC (APTIM) with its team member The Water Institute (TWI) under the GLO Contract Number No. 22-004-003 (Work Order No. E274) to conduct geotechnical sampling to assist the GLO and BOEM with identifying and delineating sediment resources along the Texas Continental Shelf. The goal of the project is to assist in a multi-agency response to categorizing sediment resources offshore for development of policies and inventories for coastal restoration and determine the location of sediment deposits for their restoration efforts aimed at mitigating the beach erosion caused by storms and currents. This project continues investigation efforts initially conducted by APTIM and TWI, in a report titled *Texas GLO Offshore Sediment Resource Inventory: Geological and Geophysical Data Collection and Processing for Identification of Outer Continental Shelf Mineral Resources Offshore of Texas* (2022). That investigation consisted of the collection of 1,133 nautical miles (2,098.3 kilometers) of full-suite geophysical (seismic sub-bottom, sidescan sonar, and magnetometer) and hydrographic (single beam bathymetry) data, interpretation, and identification of major regional stratigraphic features. The investigation conducted in 2022 identified major subsurface geologic systems representing a cumulative gross volume of ~2.1 billion cubic yards (BCY) (~1.6 billion cubic meters [BCM]) with overburden of varying sediment lithologies and an overlying surficial Seismic Unit Q1, which represents a gross volume of ~5.9 BCY (~4.5 BCM). Additionally, as part of the previous investigation, 74 vibracore sites were identified for future data collection to ground-truth the deposits and further characterize their properties.

In 2023, the GLO and BOEM contracted APTIM with its team member TWI to collect the previously identified 74 vibracores and evaluate the usability and geotechnical properties of the deposits identified in 2022. Before collecting the geotechnical data, APTIM’s Qualified Marine Archaeologist conducted a site clearance for all proposed sites to ensure they were clear of any archaeological artifacts. Once sites were cleared and the archaeological clearance letter was approved by BOEM, APTIM began geotechnical survey operations. Between June 28 and August 6, 2024, the APTIM crew conducted day-time survey efforts and collected 74 vibracores along Sabine, Heald, and Shepard Bank (and adjacent areas) in support of the GLO Sediment Management Plan Surveys on the federal Outer Continental Shelf (OCS).

Upon the completion of the reconnaissance geotechnical survey, APTIM and TWI correlated the geophysical and geotechnical data to further evaluate the targeted localized features and major regional stratigraphic features on the Sabine, Heald, and Shepard Bank and adjacent sand banks. From the re-evaluation of the geophysical data, APTIM and TWI were able to further constrain where sand resources are within the major depositional units and identify ~2.8 BCY (~2.1 BCM) of surficial sand resources (with sand quality varying from less than 5 percent fines to the threshold of 30 percent fines) within the Q1 unit and 102.7 million cubic yards (MCY) (78.5 million cubic meters [MCM]) of sand resources within previously identified channel belts and terraces.

1 Introduction

The Texas General Land Office (GLO) and the Bureau of Ocean Energy Management (BOEM) contracted Aptim Environmental & Infrastructure, LLC (APTIM) with its team member The Water Institute (TWI) under GLO Contract Number No. 22-004-003 (Work Order No. E274). Under this contract, APTIM and TWI conducted geotechnical sampling to assist the GLO and BOEM with identifying and delineating sediment resources along the Texas Outer Continental Shelf (OCS). The goal of the project is to assist in a multi-agency response to categorizing offshore sediment resources. This work will contribute to the development of policies and inventories for coastal restoration and determining the location of sediment deposits for their restoration efforts aimed at mitigating the beach erosion caused by storms and currents.

This project builds on the investigation conducted by APTIM and TWI, which is detailed in *Texas General Land Office Offshore Sediment Resource Inventory: Geological and Geophysical Data Collection and Processing for Identification of Outer Continental Shelf Mineral Resources Offshore of Texas* (2022) The 2022 investigation aimed to identify any potential sand resources associated with Sabine, Heald, Shepard Bank and adjacent banks and consisted of the collection of 1,133 nautical miles (nm) (2,098.3 kilometers [km]) of full-suite geophysical data (seismic sub-bottom, sidescan sonar, and magnetometer) and hydrographic data (single beam bathymetry), followed by data interpretation, and identification of major regional stratigraphic features that could be a potential sand resource. The investigation identified major subsurface geologic systems representing a cumulative gross volume of ~2.1 billion cubic yards (BCY) (~1.6 billion cubic meters [BCM]) without overburden of varying sediment lithologies and an overlying surficial Seismic Unit Q1 which represents a gross volume of ~5.9 BCY (~4.5 BCM). Additionally, as part of the previous investigation, 74 vibracore sites were identified for future data collection to ground-truth the deposits and further characterize their properties.

In 2023, the GLO and BOEM contracted APTIM with its team member TWI to continue the investigation previously conducted in 2022 (APTIM and TWI 2022). The work completed as part of this investigation consisted of collecting the previously identified 74 vibracores and evaluating the usability and geotechnical properties of the deposits identified in 2022. In order to effectively coordinate this investigation, GLO, BOEM, and APTIM developed a four-phase project approach. Task 1 consisted of project planning, activity review, permitting, and benthic habitat and cultural resource clearance in the form of a geological sampling plan. During Task 1, APTIM reviewed the previously identified 74 vibracore sites, detailed in APTIM and TWI (2022) and removed or moved any sites that were affected by culturally significant areas or sensitive benthic habitats. Upon completion of this review, APTIM submitted to the GLO and BOEM a Benthic Habitat and Cultural Resource geological sampling plan. Once the sampling plan was approved, APTIM moved to Task 2, which consisted of a reconnaissance-level geotechnical data collection effort. Task 2 took place between June 28, 2024, and August 6, 2024, during which APTIM collected 74 vibracores offshore western Louisiana and eastern Texas along Sabine, Heald, and Shepard Bank and adjacent sand banks (Figure 1 and Figure 2). Upon completion of the geotechnical data collection, APTIM began processing the vibracores under Task 3. During Task 4, mechanical sieve and composition analysis data were obtained to provide additional information on the overall geologic framework of the area and compared to the information gathered during the 2022 geophysical survey to assist with revising the previous conclusions on the geologic framework of the area and the usability of the deposits identified.

Figure 1. As-built vibracore locations on Heald and Shepard Bank.

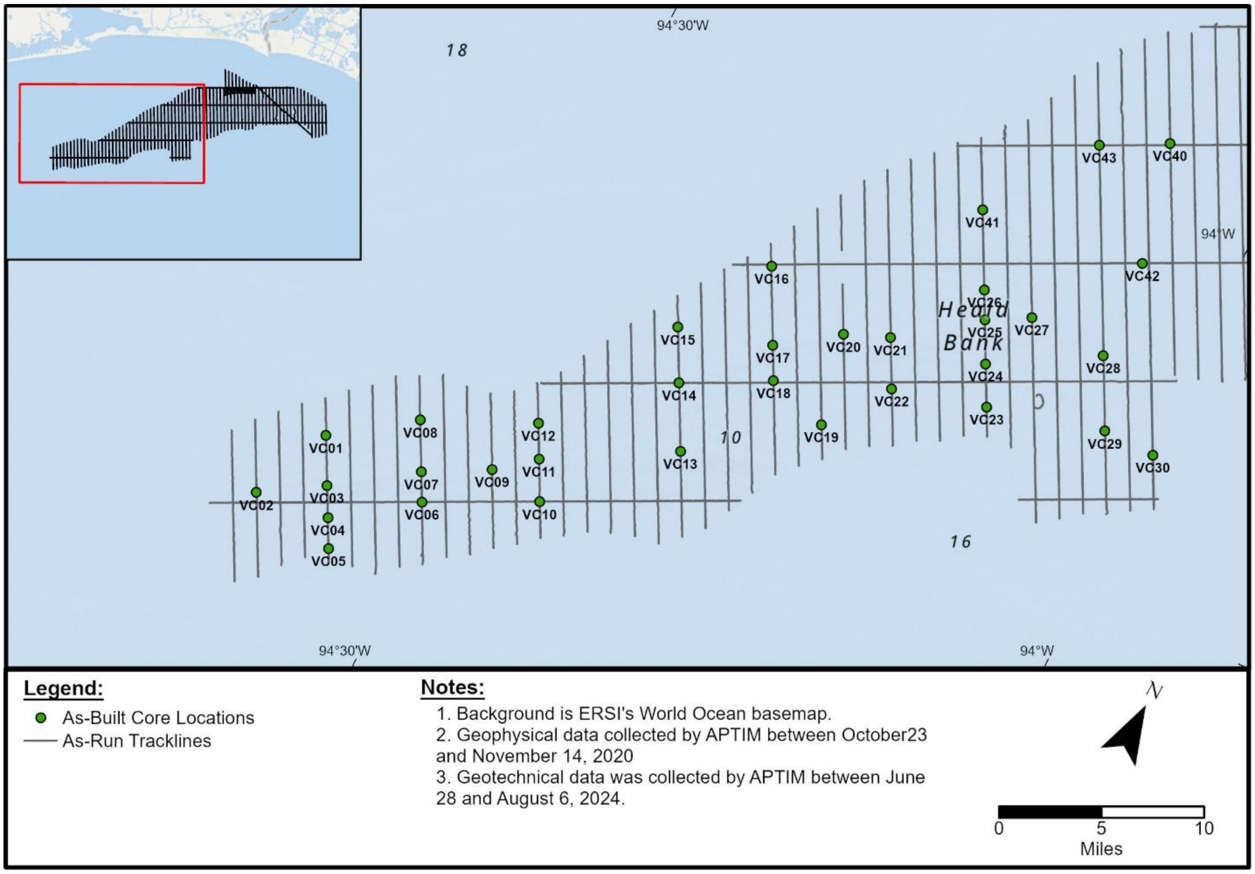
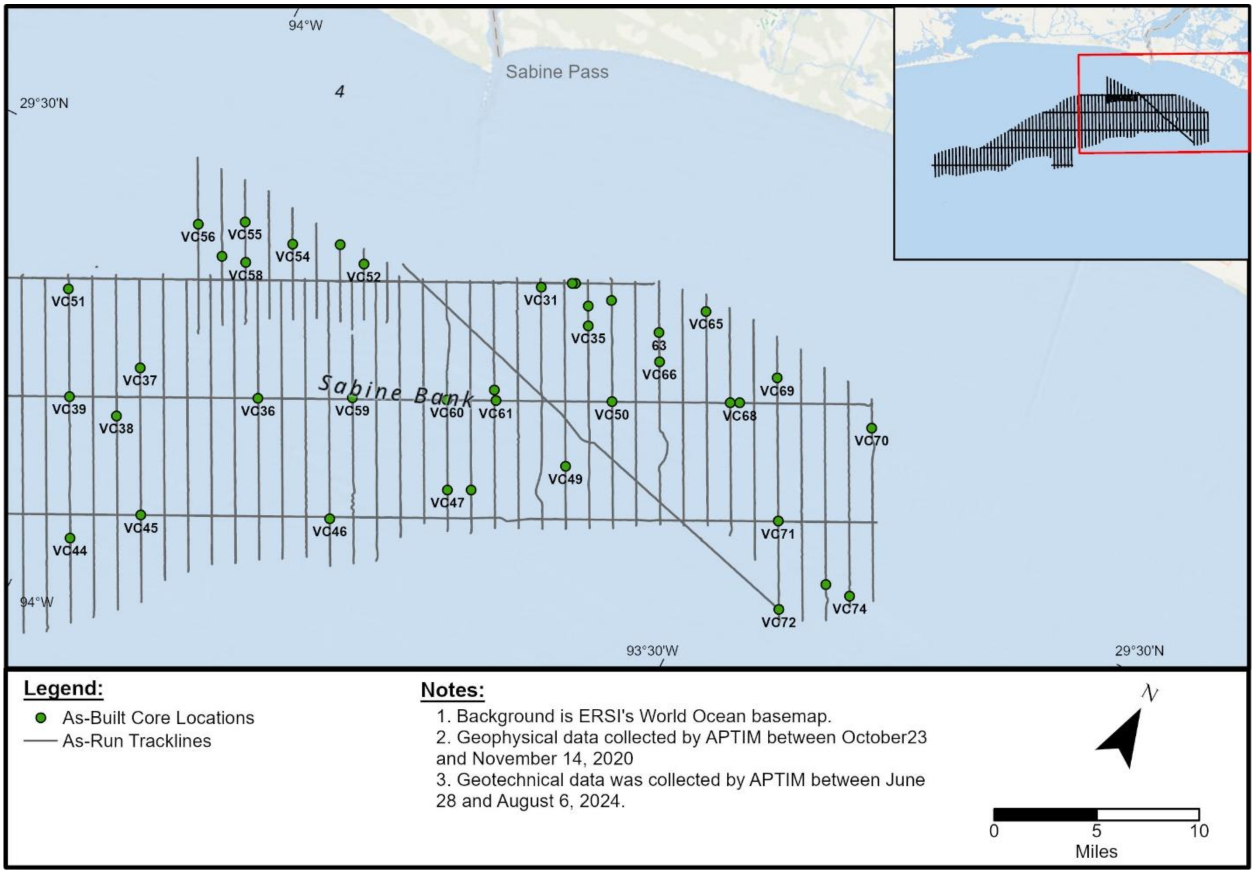


Figure 2. As-built vibracore locations on Sabine Bank.



2 Task 1: Project Planning, Activity Review, Permitting, Benthic Habitat and Cultural Resource Clearance and Geological Sampling Plan

The collection of geologic samples from appropriate sites is essential in any effort to qualify and quantify a potential sand resource, calculate the available sediment volume, and determine sedimentological characteristics such as grain size, color, carbonate content, and shell content. As such, the GLO contracted APTIM and TWI in 2021 to conduct geophysical surveys across Sabine, Heald, Shepard, and adjacent banks (APTIM and TWI 2022). With the data collected from these surveys, APTIM identified geologic sampling sites that could provide pertinent information regarding the usability of identified resources within the region. Targeted sedimentological characteristics were limited to the upper 20 feet (6.1 meters) of sediment due to maximum vibracore length as stipulated in BOEM's *Final Environmental Assessment for Sand Survey Activities for BOEM's Marine Minerals Program, Atlantic and Gulf of Mexico* (2019) A total of 74 sites were identified for the collection of geologic samples. The locations of these sites are presented in Figure 3 and their vibracore unique identifier, seismic line, targeted feature, and site description are presented in Table 1. Prior to collecting geotechnical data, APTIM coordinated with the GLO and BOEM to conduct the necessary activity review, which included cultural resource and benthic habitat clearance as well as the submittal of a geologic sampling plan (GSP) for review.

Figure 3: Proposed vibracore sites identified during Upper OCS geophysical survey.

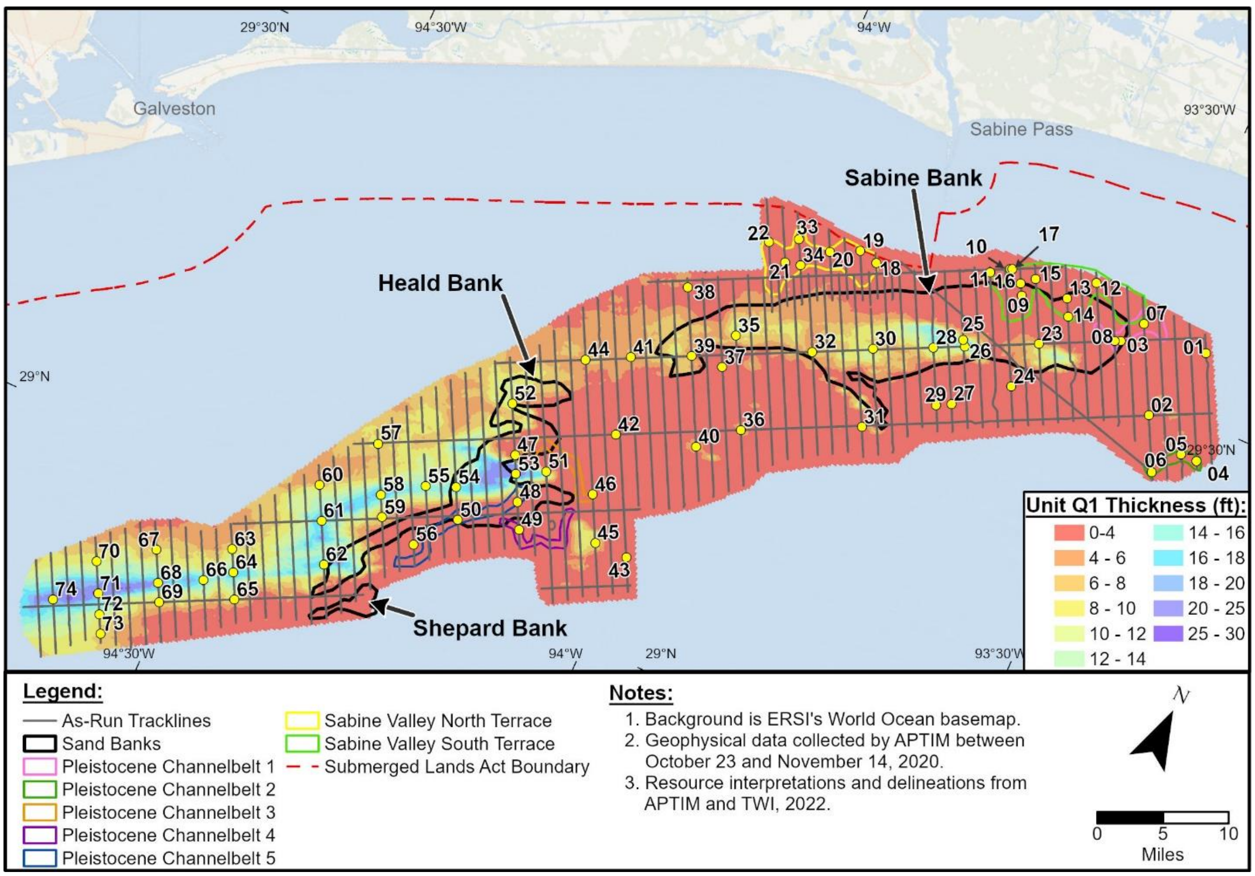


Table 1. Vibracore locations and general description of targeted stratigraphy
(Modified from APTIM and TWI 2022).

Site No.	Vibracore Name	Seismic Line	Targeting Feature	Comments/Targeting Features/Site Description
1	GLO-UPOCS-VC-24-70	Line_001	Localized Feature	Channel with prograding stratigraphy and acoustic blanking
2	GLO-UPOCS-VC-24-71	Line_005	Localized Feature	Incised deposit with some prograding stratigraphy and acoustic blanking at bottom
3	GLO-UPOCS-VC-24-68	Line_101	Localized Feature	Incised deposit with prograding stratigraphy, some acoustic blanking and chaotic deposition at the bottom
4	GLO-UPOCS-VC-24-74	Line_003	Pleistocene Channel Belt 2	Incised channel with acoustic blanking and some prograding stratigraphy at edge
5	GLO-UPOCS-VC-24-73	Line_004	Pleistocene Channel Belt 2	Incised channel with prograding stratigraphy overlaying an acoustically transparent layer
6	GLO-UPOCS-VC-24-72	Line_209.002	Pleistocene Channel Belt 2	Incised channel with acoustic transparency and some angular deposit patterns
7	GLO-UPOCS-VC-24-69	Line_005	Pleistocene Channel Belt 1	Channel with some mixed stratigraphy overlaying an acoustically transparent unit
8	GLO-UPOCS-VC-24-67	Line_101	Pleistocene Channel Belt 1	Incised channel system with some acoustic blanking and prograding stratigraphy
9	GLO-UPOCS-VC-24-35	Line_013	Localized Feature	incised unit with acoustic transparency and somewhat chaotic deposit
10	GLO-UPOCS-VC-24-33	Line_100.002	Localized Feature	Incised deposit with prograding angular deposits overlaid by 10ft of overburden
11	GLO-UPOCS-VC-24-31	Line_015	Localized Feature	Incised deposit with some acoustic transparency, prograding stratigraphy and some chaotic deposition at bottom
12	GLO-UPOCS-VC-24-65	Line_008	Sabine South Terrace	Portion of incised deposit with angular stratigraphy
13	GLO-UPOCS-VC-24-63	Line_010	Sabine South Terrace	Deposit with some acoustic blanking and angular deposits
14	GLO-UPOCS-VC-24-66	Line_010	Sabine South Terrace	Terrace unit with prograding angular stratigraphy and some acoustic blanking
15	GLO-UPOCS-VC-24-64	Line_012	Sabine South Terrace	Unit with acoustic blanking and some angular deposits
16	GLO-UPOCS-VC-24-34	Line_013	Sabine South Terrace	Acoustically transparent unit with some chaotic portions
17	GLO-UPOCS-VC-24-32	Line_100.002	Sabine South Terrace	Unit with acoustic blanking
18	GLO-UPOCS-VC-24-52	Line_201	Sabine North Terrace	Unit with acoustic blanking and some angular deposits, with 10–15 ft of overburden
19	GLO-UPOCS-VC-24-53	Line_202	Sabine North Terrace	Acoustically transparent unit with some angular surface deposits
20	GLO-UPOCS-VC-24-54	Line_204	Sabine North Terrace	Acoustically transparent unit with some angular bottom deposits
21	GLO-UPOCS-VC-24-57	Line_207	Sabine North Terrace	Acoustically transparent unit with 10–15 ft of overburden
22	GLO-UPOCS-VC-24-56	Line_208	Sabine North Terrace	Acoustically transparent surface unit with some angular point-bar like deposits at the bottom
23	GLO-UPOCS-VC-24-50	Line_013	Shoal	Surface unit with some laminated stratigraphy and acoustic transparency
24	GLO-UPOCS-VC-24-49	Line_014	Localized Feature	Incised deposit with prograding stratigraphy and some chaotic deposition
25	GLO-UPOCS-VC-24-62	Line_017	Shoal	Shoal edge, with surface mixed sediment deposit overlaying laminated strata
26	GLO-UPOCS-VC-24-61	Line_101	Shoal	Mixed sediment shoal/acoustic transparency and laminated surface deposit overlaying laminated strata

Site No.	Vibracore Name	Seismic Line	Targeting Feature	Comments/Targeting Features/Site Description
27	GLO-UPOCS-VC-24-48	Line_018	Localized Feature	Portion of incised channel that is acoustically transparent
28	GLO-UPOCS-VC-24-60	Line_101	Shoal	Mixed sediment shoal/acoustic transparency and laminated surface deposit overlaying laminated strata
29	GLO-UPOCS-VC-24-47	Line_019	Localized Feature	Channel edge with prograding stratigraphy/fluvial point bar and acoustic blanking
30	GLO-UPOCS-VC-24-59	Line_023	Shoal	Mixed sediment wedge/chaotic deposition overlaying laminated strata
31	GLO-UPOCS-VC-24-46	Line_024	Shoal	Mixed sediment wedge/chaotic deposition overlaying laminated strata
32	GLO-UPOCS-VC-24-36	Line_027	Shoal	Mixed sediment wedge/chaotic deposition overlaying laminated strata
33	GLO-UPOCS-VC-24-55	Line_206	Localized Feature	Localized deposit with some acoustic transparency and prograding deposits
34	GLO-UPOCS-VC-24-58	Line_206	Localized Feature	Localized deposit with some acoustic transparency at the surface and angular point-bar like deposits at the bottom, with 10 ft of overburden
35	GLO-UPOCS-VC-24-37	Line_032	Shoal	Mixed sediment wedge/chaotic deposition overlaying laminated strata
36	GLO-UPOCS-VC-24-45	Line_102	Shoal	Mixed sediment shoal/acoustic transparency and laminated surface deposit overlaying laminated strata
37	GLO-UPOCS-VC-24-38	Line_033	Shoal	Mixed sediment shoal/chaotic deposition overlaying laminated strata
38	GLO-UPOCS-VC-24-51	Line_035	Localized Feature	Incised deposit with prograding angular deposits overlaid by 10–15 ft of overburden
39	GLO-UPOCS-VC-24-39	Line_035	Shoal	Mixed sediment wedge/chaotic deposition overlaying laminated strata
40	GLO-UPOCS-VC-24-44	Line_035	Shoal	Mixed sediment wedge/chaotic deposition overlaying laminated strata
41	GLO-UPOCS-VC-24-40	Line_039	Shoal	Mixed sediment wedge/chaotic deposition overlaying laminated strata
42	GLO-UPOCS-VC-24-42	Line_102	Localized Feature	Incised deposit with prograding stratigraphy and acoustic blanking, with 10–15 ft of overburden
43	GLO-UPOCS-VC-24-30	Line_040.003	Localized Feature	Incised channel deposit with point-bar like prograding stratigraphy and acoustic transparency
44	GLO-UPOCS-VC-24-43	Line_042	Shoal	Mixed sediment wedge/chaotic deposition overlaying laminated strata
45	GLO-UPOCS-VC-24-29	Line_042	Shoal	Mixed sediment shoal/chaotic deposition overlaying laminated strata
46	GLO-UPOCS-VC-24-28	Line_042	Pleistocene Channel Belt 3	Incised deposit with prograding angular deposits overlaid by 10–15 ft of overburden
47	GLO-UPOCS-VC-24-26	Line_047.002	Pleistocene Channel Belt 3	Incised deposit with prograding angular deposits overlaid by 10–15 ft of overburden
48	GLO-UPOCS-VC-24-24	Line_047.002	Pleistocene Channel Belt 5	Incised deposit with prograding angular deposits overlaid by 10–15 ft of overburden
49	GLO-UPOCS-VC-24-23	Line_047.002	Pleistocene Channel Belt 4	Incised deposit with prograding angular deposits overlaid by 10–15 ft of overburden
50	GLO-UPOCS-VC-24-22	Line_051	Pleistocene Channel Belt 5	incised acoustically transparent unit with some stratigraphy at edges, overlaid with 10–12 ft of overburden
51	GLO-UPOCS-VC-24-27	Line_045.001	Shoal	Mixed sediment shoal edge/chaotic deposition overlaying laminated strata
52	GLO-UPOCS-VC-24-41	Line_047.002	Shoal	Mixed sediment shoal/chaotic deposition overlaying laminated strata
53	GLO-UPOCS-VC-24-25	Line_047.002	Shoal	Mixed sediment shoal/chaotic deposition overlaying laminated strata

Site No.	Vibracore Name	Seismic Line	Targeting Feature	Comments/Targeting Features/Site Description
54	GLO-UPOCS-VC-24-21	Line_051	Shoal	Mixed sediment shoal/chaotic deposition overlaying laminated strata
55	GLO-UPOCS-VC-24-20	Line_053	Shoal	Mixed sediment shoal/chaotic deposition overlaying laminated strata
56	GLO-UPOCS-VC-24-19	Line_054.002	Channel	Bottom of channel/channel edge with some prograding stratigraphy and acoustic transparency overlaid by 10 ft of overburden
57	GLO-UPOCS-VC-24-16	Line_056	Shoal	Mixed sediment wedge/acoustic transparency overlaying laminated strata
58	GLO-UPOCS-VC-24-17	Line_056	Shoal	Mixed sediment shoal/chaotic deposition overlaying laminated strata
59	GLO-UPOCS-VC-24-18	Line_056	Shoal	Mixed sediment wedge/acoustic transparency overlaying laminated strata
60	GLO-UPOCS-VC-24-15	Line_060	Shoal	Mixed sediment wedge/acoustic transparency overlaying laminated strata
61	GLO-UPOCS-VC-24-14	Line_060	Shoal	Mixed sediment wedge/acoustic transparency and chaotic surface deposit overlaying laminated strata
62	GLO-UPOCS-VC-24-13	Line_060	Shoal	Mixed sediment shoal/acoustic transparency and chaotic surface deposit overlaying laminated strata
63	GLO-UPOCS-VC-24-12	Line_066	Shoal	Mixed sediment wedge/acoustic transparency and chaotic surface deposit overlaying laminated strata
64	GLO-UPOCS-VC-24-11	Line_066	Shoal	Mixed sediment wedge/acoustic transparency overlaying laminated strata
65	GLO-UPOCS-VC-24-10	Line_066	Shoal	Mixed sediment wedge/acoustic transparency and chaotic surface deposit overlaying laminated strata
66	GLO-UPOCS-VC-24-09	Line_068	Shoal	Mixed sediment wedge/acoustic transparency overlaying laminated strata
67	GLO-UPOCS-VC-24-08	Line_071.002	Shoal	Mixed sediment wedge/acoustic transparency deposit overlaying laminated strata
68	GLO-UPOCS-VC-24-07	Line_071.002	Shoal	Mixed sediment shoal/acoustic transparency overlaying laminated strata
69	GLO-UPOCS-VC-24-06	Line_071.002	Shoal	Mixed sediment wedge/acoustic transparency and chaotic surface deposit overlaying laminated strata
70	GLO-UPOCS-VC-24-01	Line_076	Shoal	Mixed sediment wedge/acoustic transparency and laminated surface deposit overlaying laminated strata
71	GLO-UPOCS-VC-24-03	Line_076	Shoal	Mixed sediment shoal/acoustic transparency and laminated surface deposit overlaying laminated strata
72	GLO-UPOCS-VC-24-04	Line_076	Shoal	Mixed sediment wedge/acoustic transparency and laminated surface deposit overlaying laminated strata
73	GLO-UPOCS-VC-24-05	Line_076	Shoal	Mixed sediment wedge/acoustic transparency deposit overlaying laminated strata
74	GLO-UPOCS-VC-24-02	Line_078	Shoal	Mixed sediment shoal/acoustic transparency and laminated surface deposit overlaying laminated strata

2.1 Activity Review and Mitigation

To meet the environmental mitigation measures required by the GLO and BOEM, APTIM conducted an archaeological and benthic clearance of all proposed sites. The documentation of these clearance reviews was compiled in a GSP and submitted to BOEM for review. As part of the archaeological clearance process, APTIM's qualified marine archaeologist (QMA) evaluated the collected geophysical data in conjunction with information gathered as part of the desktop study and background research. Through this evaluation, the QMA was able to determine if there were any targets or features of archaeological interest present in regards to the pre-contact and maritime history of the area and/or its historical military use. Benthic habitat assessment consisted of reviewing the sidescan sonar data collected as part of the previous investigation,(APTIM and TWI 2022) as well as environmental databases (NOAA, BOEM), to ensure that geotechnical sampling procedures would not adversely impact the seafloor or any habitats. Vibracores were limited in depth to near surface sand deposits with a seafloor disturbance footprint of less than 21.5 square feet per sample (2 square meters). All geological sampling avoided archaeological resources by a minimum of 328 feet (100 meters). In the unlikely event that an archaeological resource was discovered during operations, operations would be halted immediately, the discovery would be reported to BOEM within 24 hours, and the QMA would provide a statement documenting the extent of the impacts on the resource, if any, to BOEM.

2.1.1 Sensitive Benthic Habitat and Communities Avoidance Requirements

Prior to commencing geological operations APTIM took the necessary precautions to avoid munitions and ordnances, including unexploded shells and depth charges, which may be present in military operating areas, ordnance disposal areas, or historical firing fans, collocated with the authorized area. APTIM avoided anchoring, geological sampling, and any other seafloor-disturbing activities in the vicinity of sensitive benthic habitat and associated communities, including live/hard bottom, topographic features, rippled scour depressions, cobbled seafloor, reef tract, and Habitat Areas of Particular Concern by at least 500 feet (152 meters). APTIM avoided geological sampling near archaeological resources by a minimum of 328 feet (100 meters). All associated anchoring, if any, avoided archaeological resources by 328 feet (100 meters).

APTIM utilized live boating during sampling operations to avoid unnecessary seafloor anchoring and disturbance. If unavoidable, APTIM only anchored in emergency situations or unexpected field situations and utilized a minimum-sized anchor/anchor array and was restricted to an area cleared, previously or in real-time, of sensitive habitat, cultural resources, and shallow hazards.

3 Task 2: Geotechnical Data Collection

On June 21, 2024, APTIM mobilized equipment and personnel to Patterson, Louisiana where the APTIM crew prepared the R/V *Rachel K. Goodwin* survey vessel for geotechnical data collection. From June 28 through August 6, 2024, APTIM conducted geotechnical sample collection offshore western Louisiana and in eastern Texas along Sabine, Heald and Shepard Banks. APTIM conducted this survey aboard the R/V *Rachel K. Goodwin* from 30 minutes before sunrise to 30 minutes after sunset during favorable weather conditions. Over the course of 13 operational days, APTIM collected a total of 74 vibracores (Appendix B Map 1) averaging a total of 5 cores a day.

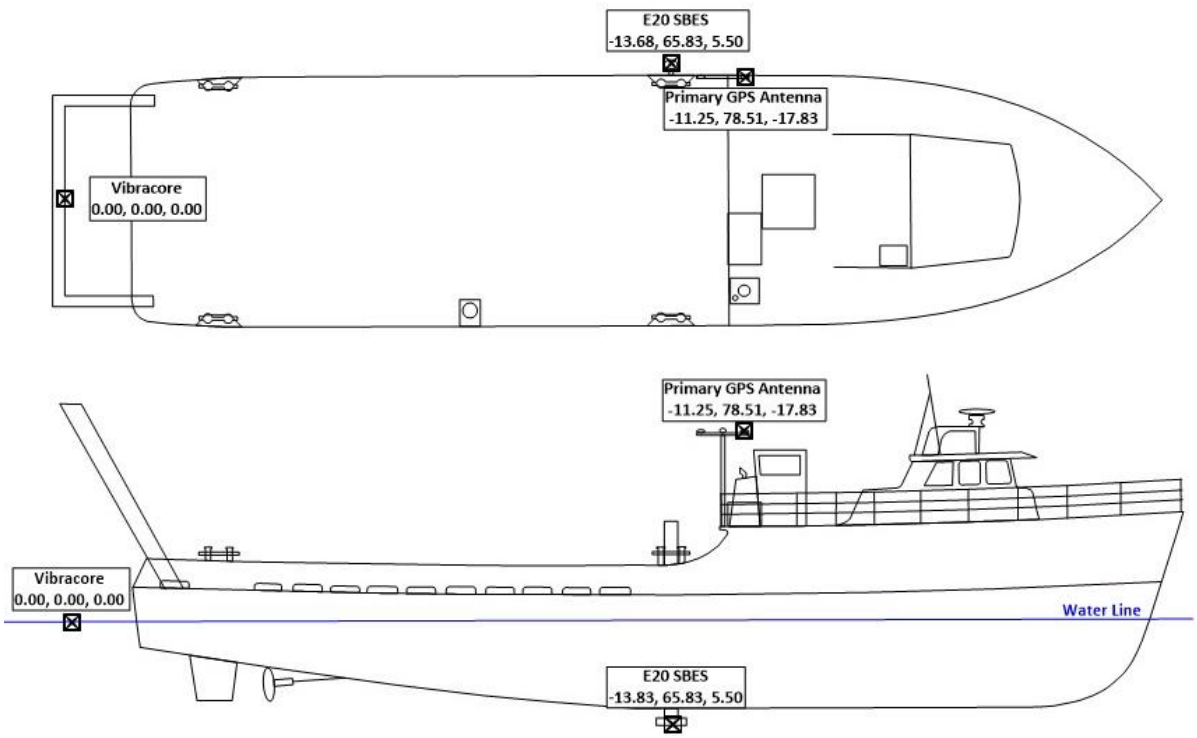
On the morning of June 28, 2024, the crew transited to the first core site, which was located at the southern end of the investigation area and began operations. Core collection continued without incident until June 30, 2024, when the vibracore system suffered a breakdown and the APTIM crew docked in Galveston, Texas so that repairs could be made. On July 1, 2024, the vessel transited back to the investigation area where operations continued without incident. On July 3, 2023, a scheduled crew change took place, and the following day operations resumed until the vibracore system was rendered inoperable again. The vessel transited back to dock in Galveston, Texas for repairs and geotechnical operations were halted from July 4 to 21, 2024. On July 22, 2024, the APTIM crew arrived back on site after sunset and continued geotechnical operations the following morning. Operations continued without incident until July 25, 2024, when a critical piece of survey equipment broke, forcing the vessel to dock in Sabine Pass, Texas for repairs. Operations were halted for 8 days while equipment was repaired. On August 2, 2024, the APTIM crew remobilized to Galveston, Texas and transited to the investigation area in the evening.

On the morning of August 3, 2024, geotechnical operations resumed and continued smoothly until the survey was completed on August 5, 2024. In total, field operations were halted for 25 days due to equipment malfunctions.

3.1 Systems and Equipment

Between June 28 and August 6, 2024, APTIM collected 74 vibracores using the R/V *Rachel K. Goodwin* with survey equipment mounted to the vessel as shown in Figure 4.

Figure 4: R/V *Rachel K. Goodwin* vessel diagram.



3.1.1 Geologic Survey Vessel Characteristics

The R/V *Rachel K Goodwin* is a 110-foot (33.5-meter) steel-hulled vessel that is outfitted for the sole purpose of geophysical, geotechnical, and biological surveys. It is equipped with a 10-ton capacity 27-foot (8.23-meter) hydraulic A-frame, twin 1692 Detroit diesel main engines, twin 471 Detroit diesel generators (40 Amp), one 18,000 pound capacity deck winch, and a 4-inch (10.16-centimeter) down pole with variable mounting brackets. The R/V *Rachel K Goodwin* has crew and client quarters as well as a full galley with two heads including showers. As a U.S. Coast Guard (USCG)-inspected vessel, the R/V *Rachel K Goodwin's* safety features include fire extinguishers, life vests/survival suits, a 50-man life raft, first aid kits, radar, very high frequency radios, and an emergency position-indicating radiobeacon (EPIRB). These safety features and the level of experience and expertise of the captain and crew allows the R/V *Rachel K Goodwin* to operate safely and efficiently throughout geotechnical survey operations.

3.1.2 Vibracore System Characteristics

APTIM used the SEAS VC-700 Vibracoring System, configured to collect undisturbed 20-foot (6.1 meters) sediment cores. The VC-700 is a single core electric vibracoring system, operational to depths of 3,281 feet (1,000 meters). The electric vibracore is the most versatile of vibracore systems, with the ability to retrieve deep core samples with no pressure constraints as found with pneumatic vibracores. The self-contained, free-standing electronically operated vibracore unit contains a VC-700 vibrator head (4.4 kilowatts) configured to 415 VAC or 220 VAC 3-phase power, which enables a user to operate the vibracorer at fluctuating vibration frequencies to penetrate through otherwise unyielding strata. A 688-foot (210-meter) long 4-core Hydrofirm sea cable provides power to the drive unit of the vibracore from the surface control system, located aboard the vessel.

The vibracore unit was winch and A-frame deployed and retrieved from the R/V *Rachel K Goodwin*. The vibracore unit's lightweight modular construction allowed for safe and efficient deployment and retrieval to and from the survey vessel. The vessel "live boated" at all geologic sample locations to minimize bottom disturbance.

As part of the geotechnical operations, APTIM used an underwater camera with lights installed on the vibracore frame to enable the operator to determine/adjust the proper vibrating frequency to preserve the integrity of the sample, as well as observe what was happening with the vibracore sample during operations. APTIM also utilized a penetrometer, which provided information on the rate/speed of penetration. When recovery was less than 80 percent of the expected penetration, the liner was removed, a new liner inserted, and a second and third attempt was performed as needed. Upon collection of the vibracores and removal of the liner, APTIM geologists measured, marked, and cut the liner of each vibracore into 5-foot (1.52-meter) sections to prepare the cores for transport. The vibracores were then transported to APTIM's accredited geotechnical laboratory in Boca Raton, Florida, where they were processed according to the American Society for Testing and Materials (ASTM) standards.

3.1.3 Navigation

The navigation and positioning system deployed for this survey was a Trimble SPS461 dual antenna Global Navigation Satellite System interfaced to Hypack Inc.'s Hypack 2024® (referred to herein as Hypack). Hypack is a state-of-the-art navigation and hydrographic surveying system. The SPS461 receiver automatically acquired and simultaneously tracked Satellite-Based Augmentation System satellites while receiving precisely measured code phase and doppler phase shifts that enabled the receiver to compute the position and velocity of the vessel. The receiver then determined the time, latitude, longitude, height, and velocity at 5 hertz.

All coordinates presented in this report are in U.S. Survey Feet, relative to the North American Datum (NAD) 1983, Texas State Plane Coordinate System, South Central. Elevations are presented in U.S. Survey Feet, relative to the North American Vertical Datum (NAVD) 1988.

APTIM's navigation and depth sounder systems were interfaced with an onboard computer and the data were integrated in real time using Hypack software. The location of the transducer mount A-frame block, at which the vibracore was deployed, was measured in relation to the center of mass of the vessel and the Differential Global Positioning System (DGPS). Vertical and horizontal measurements were recorded and entered into Hypack. Online screen graphic displays included the pre-plotted vibracore sites, the updated boat track across the survey area, as well as other positioning information such as boat speed and quality of fix measured by Position Dilution of Precision.

When the survey vessel was within the 100-foot (328-meter) buffer, data from Hypack and the E20 were recorded to ensure that accurate top of core measurements were captured. Once the vibracore was deployed and contacted the seafloor, a target in Hypack was taken. The digital data were merged with the positioning data DGPS, video displayed, and recorded to the acquisition computer's hard disk for post processing and/or replay.

The Odom Hydrographic Systems, Inc.'s ECHOTRAC E20 is a single frequency portable hydrographic echo sounder that was used to perform the bathymetric survey. The ECHOTRAC E20 is a digital, survey-grade sounder that operates at frequencies between 10 and 250 kilohertz. A 200 kilohertz, 4 degree transducer was used for the bathymetric survey during vibracore collection. Soundings were collected at maximum ping rates to provide an accurate depiction of the seafloor. Sounder calibration was performed periodically throughout the survey. The sounder was calibrated via bar-checks and a sound velocity probe.

Valeport's SwiFT Sound Velocity Profiler was used to measure the speed of sound through the water column with the average speed used to calibrate the ECHOTRAC E20. Bar checks were performed from a depth of 5 to 25 feet (1.5 to 7.6 meters) to verify the transducer draft and speed of sound. Echogram data showing the results of the bar check calibration were displayed in the sounder's user interface during descent of the bar.

3.2 Environmental Mitigations

While impacts on marine mammals were not expected, the following mitigation protocols were implemented to reduce the small risk that the geotechnical survey could impact marine mammals. These protocols reflected the most recent federal regulatory coordination document to address mitigation measures, as required for all BOEM Marine Mineral Program (MMP) Geophysical & Geological investigations resulting from the programmatic Sand Survey Environmental Assessment. Additional information on the environmental mitigation set forth by BOEM are detailed below.

3.2.1 Vessel Strike Avoidance Protocol

During survey operations all efforts were made by the vessel operators and crew to avoid striking any protected species. A visual observer (e.g., captain) aboard the vessel monitored a vessel strike avoidance zone around the vessel to ensure the potential for strike was minimized. Vessel speeds would have been reduced to 10 knots or less if the visual observer identified any mother/calf pairs, pods, or large assemblages of any marine mammals seen within the avoidance zone. The vessel would have maintained a minimum separation distance of 328 feet (100 meters) from sperm whales, and 1,640 feet (500 meters) from any baleen whale to specifically protect the Gulf of America Bryde's whale. The vessel maintained a minimum separation distance of 164 feet (50 meters) from all other aquatic protected species, including sea turtles, with an exception made for those animals that approached the vessel. If aquatic protected species were sighted while the vessel was underway, the vessel acted as necessary to avoid violating the appropriate required separation distance. If aquatic protected species were to have been sighted within relevant separation distance, the vessel would have reduced speed, the engine would have been shifted to neutral, and the engines would not have been re-engaged until animals were clear of the area. The requirements stated above would not have been applied in any case where compliance would create imminent and serious threat to a person or vessel or to the extent that the vessel was restricted in its ability to maneuver and, because of the restriction, was unable to comply. No protected species were observed during this operation.

Any injured or dead aquatic protected species, regardless of whether the injury or death was caused by the survey vessel, would have been reported to the proper authorities specified in the Marine Mammals Protection Act (MMPA). No injured or dead aquatic protected species were observed.

3.2.2 Sea Turtle and Smalltooth Sawfish "Construction" Conditions

All APTIM personnel were alerted to the potential presence of and need to avoid sea turtles and smalltooth sawfish, as well as the fact that there are penalties for harming, harassing, or killing these species. All vessels operated at "no wake/idle" speeds at all times while in water depths where the draft of the vessel provides less than a 4 feet (1.2 meters) clearance from the bottom. No sawfish or sea turtles were observed during the survey, however if sea turtles or smalltooth sawfish had been encountered within the acoustic exclusion zone of an active sound source or vibracore or 164 feet (50 meters) of a moving vessel, APTIM would have implemented protections consistent with protected species observer shutdown requirements and would have stayed at least 164 feet (50 meters) away from sea turtles or other protected species whenever possible. APTIM would not have re-engaged engines until the protected species were clear of the 164 feet (50 meters) exclusion area.

3.2.3 Marine Pollution Control Plan

APTIM conducted all activities under a Marine Pollution Control Plan, which addresses the marine debris awareness requirements described below. APTIM prepared for and took all necessary precautions to prevent discharges of waste or hazardous materials that may impair water quality.

Under the Marine Pollution Control Plan all vessels must have sufficient fuel spill response equipment and supplies available onboard to contain and recover the maximum scenario fuel spill keyed to the proposed operations and disclosed in the marine pollution control plan. To reduce the likelihood of accidental fuel spills, APTIM fueled all vessels in port at a docking facility only; no at-sea cross-vessel fueling was conducted. All vessel operations were compliant with USCG regulations and the U.S. Environmental Protection Agency's (USEPA) Vessel General Permit, as applicable.

3.2.4 Marine Debris Awareness Program

All survey participants were educated on marine trash and debris awareness elimination. During survey operations all APTIM employees and subcontractors were aware of the environmental and socioeconomic impacts associated with marine trash and debris and their responsibilities for ensuring that trash and debris were not intentionally or accidentally discharged into the marine environment. Intentional marine littering is subject to strict laws such as the International Convention for the Prevention of Pollution from Ships Annex V and the Marine Plastic Pollution Research and Control Act, as well as regulations imposed by various agencies such as the USCG and the USEPA.

The deliberate discharge of containers and other similar materials (i.e., trash and debris) into the marine environment is prohibited. APTIM employees were required to identify equipment, tools, containers (especially drums), and other materials with durable markings. During survey operations no trash or debris were intentionally or accidentally discharged into the marine environment.

3.2.5 Navigation and Commercial Fisheries Operations Conflict Minimization Requirements

To ensure consistency with applicable USCG regulations for vessels great than 65 feet (20 meters) the R/V *Rachel K. Goodwin* vessel was, regardless of operational status, equipped with Automatic

Information System to broadcast the vessel's identity, type, position, course, speed, and navigational status during surveying activities. During geotechnical operations the vessel displayed the appropriate USCG-approved day shapes (mast head signals used to communicate with other vessels) and displayed the appropriate lighting during daylight operations to designate that the vessel has limited maneuverability. Prior to commencing survey operations, the operator traversed or visually scanned the general survey area, or used other effective methods, to determine the presence of deployed fishing gear to minimize any interactions with fishing gear that may be present in the authorized area. Observed fishing gear was avoided by a minimum of 100 feet (30 meters). Fishing gear was not relocated or otherwise disturbed during this investigation.

3.2.6 Advanced Notification of Survey Activities

APTIM contacted the USCG Marine Safety District 8 Office in Texas City, Texas on July 17, 2024, 14 days prior to the commencement of surveying to record upcoming activities and arrange for project notification to be published in the Local Notice to Mariners (LNM) (Figure 5). Information provided to the USCG for the LNM includes: project start date; approximate end date; nature of the work to be performed; and precautions that nearby mariners should exercise.

Figure 5. Local Notice to Mariners.

LA/TX - GULF OF MEXICO - Vibracore Sampling and Survey Operations
Continuing through July 19, 2024, geotechnical survey and vibracore sampling operations are taking place in the Gulf of Mexico, in the Outer Continental Shelf waters off the coasts of Louisiana and Texas. The survey area will be bound by the following approximate positions:
29-35-50N 093-19-18W,
29-40-10N 094-38-12W,
28-47-26N 093-21-49W and
28-46-25N 094-41-16W.
Operations will be conducted during daylight hours only. On-scene research vessels will be restricted in their ability to maneuver and will monitor VHF-FM Channel 16. Mariners are requested to maintain a 0.5 nautical mile closest point of approach to reduce impacts to survey data quality and should proceed with caution.
Charts: 1117A 11300 LNM: 27-24

3.2.7 Vibracore Sampling Protocol

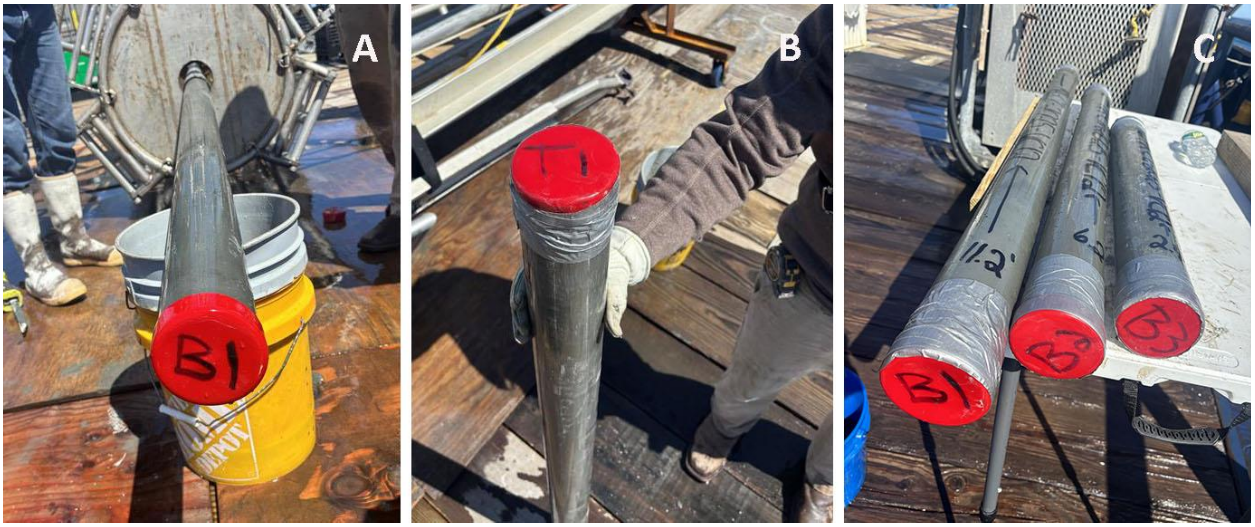
During geotechnical operations, APTIM did not operate the vibrahead during deployment until the vibracore platform contacted the seabed and the core barrel contacted the seafloor to minimize disturbance caused by loud vibrations. The vibrahead was not operated when the vibracore platform was being retrieved.

All seafloor sampling occurred within the effective coverage of geophysical data and did not occur within the nadir or other gaps of sidescan sonar survey data. During vibracoring, vibracore penetration rates were monitored to help ensure that minimum sampling was conducted in geologic units that were not indicative of surface sands or may be host to prehistoric or other cultural resources. During operations, no geologic or other information of archaeological interest were identified and noted/photographed.

4 Task 3: Geotechnical Processing and Analysis

Upon collection of the vibracores and removal of the vibracore tube (Figure 6 panel A), APTIM geologists measured, marked, and cut each vibracore into 5-foot (1.52 meter) sections to prepare the vibracores for transportation (Figure 6 panel B). Each 5-foot section was capped with bottom and top caps labeled with B or T respectively and numbered 1–4, with 1 being the first removed section (bottom of core), and 4 being the last section (top of core). Each vibracore section was then labeled onboard the vessel (Figure 6 panel C) with the sample identifier and the top and bottom measurements. After geotechnical survey operations were completed, all vibracore sections were transported to APTIM's accredited geotechnical laboratory in Boca Raton, Florida. APTIM geologists split each vibracore lengthwise and logged them in detail. These logs included descriptions of sedimentary properties by layer in terms of layer thickness, wet Munsell color, texture (grain size), composition and presence of clay, silt, gravel, and any other identifying features. The vibracores were logged in accordance with the ASTM Standard Materials Designation D2488-17e1 for the description and identification of soils using the visual-manual procedure. Wet Munsell colors were determined from the methodology described in the Munsell Soil Color Book. Logging was consistent with USACE ENG Form 1836.

Figure 6: Vibracore processing upon completion of sample collection.



Sediment subsamples were extracted from the vibracore sample halves at irregular intervals based on distinct stratigraphic layers and sediment quality. Strata with apparent high fines content were typically avoided for sieve analysis and Field Vane Shear tests were performed instead when applicable (detailed in Section 4.2 below). Layers that consisted predominately of clay with little to no sand or silt were sampled as a shear vane test and are categorized as Undistributed Samples within the vibracore logs. All physical samples extracted for grain size analysis are categorized as Distributed Samples and have sample data associated with them. Table 2 presents a breakdown of sampling and testing efforts for each vibracore. The subsample collection depths were noted on the logs, and the subsamples were stored in labeled plastic bags. The archived (unsampled) halves and sampled halves of the vibracore sections were then placed in labeled plastic sleeves and stored at APTIM to be available for additional review and sampling as needed. Archived vibracore halves were wrapped with plastic wrap prior to placement in the plastic sleeves, so as to reduce shifting of the sediments during storage and future transfer. The vibracore log descriptions were entered into the gINT® software program.

Table 2: Sampling conducted as part of geotechnical data analysis.

Vibracore Name	Number of Sieve Samples	Number of Field Vane Test
GLO-UPOCS-VC-24-01	1	3
GLO-UPOCS-VC-24-02	3	0
GLO-UPOCS-VC-24-03	5	0
GLO-UPOCS-VC-24-04	0	4
GLO-UPOCS-VC-24-05	0	7
GLO-UPOCS-VC-24-06	1	6
GLO-UPOCS-VC-24-07	5	0
GLO-UPOCS-VC-24-08	3	1
GLO-UPOCS-VC-24-09	2	2

Vibracore Name	Number of Sieve Samples	Number of Field Vane Test
GLO-UPOCS-VC-24-10	5	0
GLO-UPOCS-VC-24-11	5	0
GLO-UPOCS-VC-24-12	4	1
GLO-UPOCS-VC-24-13	5	0
GLO-UPOCS-VC-24-14	3	0
GLO-UPOCS-VC-24-15	1	3
GLO-UPOCS-VC-24-16	3	3
GLO-UPOCS-VC-24-17	7	0
GLO-UPOCS-VC-24-18	1	2
GLO-UPOCS-VC-24-19	0	5
GLO-UPOCS-VC-24-20	4	0
GLO-UPOCS-VC-24-21	4	1
GLO-UPOCS-VC-24-22	0	4
GLO-UPOCS-VC-24-23	0	6
GLO-UPOCS-VC-24-24	2	5
GLO-UPOCS-VC-24-25	5	0
GLO-UPOCS-VC-24-26	1	8
GLO-UPOCS-VC-24-27	3	2
GLO-UPOCS-VC-24-28	0	3
GLO-UPOCS-VC-24-29	5	1
GLO-UPOCS-VC-24-30	0	4
GLO-UPOCS-VC-24-31	0	4
GLO-UPOCS-VC-24-32	0	6
GLO-UPOCS-VC-24-33	0	7
GLO-UPOCS-VC-24-34	5	0
GLO-UPOCS-VC-24-35	0	4
GLO-UPOCS-VC-24-36	3	0
GLO-UPOCS-VC-24-37	2	3
GLO-UPOCS-VC-24-38	0	4
GLO-UPOCS-VC-24-39	0	4
GLO-UPOCS-VC-24-40	3	1
GLO-UPOCS-VC-24-41	3	3
GLO-UPOCS-VC-24-42	1	7
GLO-UPOCS-VC-24-43	0	3
GLO-UPOCS-VC-24-44	3	1
GLO-UPOCS-VC-24-45	4	1
GLO-UPOCS-VC-24-46	2	2
GLO-UPOCS-VC-24-47	1	4
GLO-UPOCS-VC-24-48	5	0
GLO-UPOCS-VC-24-49	2	3
GLO-UPOCS-VC-24-50	3	2
GLO-UPOCS-VC-24-51	0	4
GLO-UPOCS-VC-24-52	0	3
GLO-UPOCS-VC-24-53	0	5
GLO-UPOCS-VC-24-54	0	4
GLO-UPOCS-VC-24-55	0	3
GLO-UPOCS-VC-24-56	0	5
GLO-UPOCS-VC-24-57	0	3
GLO-UPOCS-VC-24-58	0	3
GLO-UPOCS-VC-24-59	3	1
GLO-UPOCS-VC-24-60	4	1
GLO-UPOCS-VC-24-61	4	0
GLO-UPOCS-VC-24-62	4	0
GLO-UPOCS-VC-24-63	0	4

Vibracore Name	Number of Sieve Samples	Number of Field Vane Test
GLO-UPOCS-VC-24-64	1	5
GLO-UPOCS-VC-24-65	2	5
GLO-UPOCS-VC-24-66	0	5
GLO-UPOCS-VC-24-67	0	6
GLO-UPOCS-VC-24-68	0	4
GLO-UPOCS-VC-24-69	5	0
GLO-UPOCS-VC-24-70	0	4
GLO-UPOCS-VC-24-71	0	4
GLO-UPOCS-VC-24-72	3	2
GLO-UPOCS-VC-24-73	3	0
GLO-UPOCS-VC-24-74	4	0

The split vibracores were photographed in 2-foot (0.6 meters) intervals using a Ricoh WG-6 20-megapixel digital camera that was mounted on a frame directly above the vibracores. The photographs were taken using the normal image compression mode (shooting at "Normal" quality), full spectrum overhead lighting, and an 18 percent gray background. This background provides a known reference color and is the standard reference value against which all camera light meters are calibrated. Each photograph included the relevant project name, vibracore name, depth interval, and scale. Photograph procedures were determined from the methodology described in the Florida Department of Environmental Protection's Offshore Sand Search Guidelines. The photographs were downloaded from the camera as .jpgs, formatted for consistency, and then exported into the finalized .pdf format. Vibracore photographs, logs, curves, and torvane results are presented in Appendix C (both attached to the report and provided digitally) and as-builts are provided in Appendix D.

4.1 Mechanical Sieve Analysis

The sediment subsamples were analyzed to determine color and grain size distribution. During sieve analysis the wet, dry, and washed Munsell colors were noted. Dry and washed Munsell colors were determined from the methodology described in the Munsell Soil Color Book. Grain size was determined through sieve analysis in accordance with ASTM Standard Materials Designation D6913/D6913M-17 for particle size analysis of soils. This method covers the quantitative determination of the distribution of sand particles. Sediment finer than the no. 200 sieve (3.75 phi) was analyzed following ASTM Standard Materials Designation D1140-17. Mechanical sieving was accomplished using calibrated sieves with a gradation of half-phi intervals. Additional sieves were included to represent key ASTM sediment classification boundaries, and the weights retained on each sieve were recorded cumulatively. The sieve stack used for mechanical analysis is provided in Table 3. Grain size results were entered into the gINT® software program, which computes the mean and median grain size, sorting, and fines (silt/clay) percentages for each sample using the moment method. Grain size results are displayed on the granulometric reports, grain size distribution curves, and logs (Appendix C).

Table 3: Granulometric analysis mesh sizes by Unified Soil Classification System (USCS) based on the ASTM D2487/2488 standards.

Sieve Number	Sieve Size (phi)	Sieve Size (mm)
Coarse Gravel	Coarse Gravel	Coarse Gravel
3/4	-4.25	19.03
Fine Gravel	Fine Gravel	Fine Gravel
5/8	-4.00	16.00
7/16	-3.50	11.20
5/16	-3.00	8.00

Sieve Number	Sieve Size (phi)	Sieve Size (mm)
3 ½	-2.50	5.60
4	-2.25	4.75
Coarse Sand	Coarse Sand	Coarse Sand
5	-2.00	4.00
7	-1.50	2.80
10	-1.00	2.00
Medium Sand	Medium Sand	Medium Sand
14	-0.50	1.40
18	0.00	1.00
25	0.50	0.71
35	1.00	0.50
Fine Sand	Fine Sand	Fine Sand
45	1.50	0.36
60	2.00	0.25
80	2.50	0.18
120	3.00	0.13
170	3.50	0.09
200	3.75	0.08
Silty/Clay	Silty/Clay	Silty/Clay
230	4.00	0.06

4.2 Field Vane Shear Tests

Field vane shear tests were conducted during vibracore logging in accordance with ASTM Standard Test Methods of Laboratory Miniature Vane Shear Test for Saturated Fine-Grained Clayey Soil (D4648/D4648M-16). These tests were used when possible to characterize the clay material in the vibracores as outlined in Table 2. Clay layers with higher silt, sand, and/or shell content were avoided for testing as the presence of these sediment types tends to skew the results of the miniature vane shear test. The results presented in this report represent miniature vane shear test results.

5 Task 4: Geophysical and Geotechnical Data Interpretation

The geotechnical results of this study were integrated with the geophysical interpretations detailed in APTIM and TWI (2022). Combined geophysical and geotechnical analysis allowed for detailed assessments of sand resource volumes, geotechnical properties, overburden or accessibility constraints, and their likely geologic origin and evolution. The geotechnical analysis provides necessary testing of the previously identified and interpreted geophysical acoustic facies and identification of specific lithologic occurrences. The following sections provide specifics of the data-correlation methodology, updated results and geologic interpretation of sedimentary deposits located within the Upper OCS and provide the foundation for new sediment resource quantification and geologic framework creation detailed in Section 5.2 and Section 5.3. A key finding of these results is the scale of surficial sand resources associated with Heald and Shepard Banks, where potentially beach-compatible sands occur in thicknesses greater than 15 feet (4.6 meters) and with greater extent than the more commonly studied Sabine Bank.

5.1 Seismic and Geotechnical Data Correlation

During the previous geophysical investigation, APTIM and TWI initially delineated potential sand bearing geologic features within the Upper OCS using chirp sub-bottom data (APTIM and TWI 2022). In order to calculate preliminary sediment volume estimates of these geologic features, upper and lower bounding reflectors of a deposit were mapped regionally using SonarWiz. The thickness between these surfaces were exported (thickness as xyz) from SonarWiz, imported into Surfer 23, and gridded using a kriging interpolation method to create a sediment isopach. Sediment volume estimates were calculated using ArcPro's surface volume tool.

The preliminary sediment volume estimates and interpretations from the 2022 geophysical investigation were refined by integrating vibracore data collected during the current geotechnical investigation. After each vibracore was collected, processed, and analyzed as part of tasks 2 and 3, they were integrated to the chirp sub-bottom profiles in SonarWiz. The chirp sub-bottom stratigraphy was re-interpreted using the new vibracore information. Stratigraphic reflectors correlating to sandy portions of previously identified geologic features were digitized within SonarWiz to create a new color-coded boundary. These boundaries appear on the subsequent chirp sub-bottom imagery to allow for an easy, visual reference for the boundary representing the bottom of the sand unit. If the sandy portions of geologic features were interpreted as thicker than the maximum sample depth of the vibracores, the lower boundary of sand was delineated using sub-bottom data. These new upper and lower boundaries were used to compute the thickness of sand units, and later, sand isopachs using the same methodology as the geophysical investigation. Sand volumes were calculated from the interpolated sand isopach in ArcPro. Chirp seismic profiles with new and previous interpretations/digitization and color-coded vibracores are included in the Seismic Web Project digital appendix as part of the non-508 submittal for this study. Additionally, maps in Appendix B (Map 2A and 2B) as well as Figure 23, Figure 24, Figure 25, Figure 26, and Figure 27 show the lateral extent of the sandy portions of each of the deposits as well as the vibracores used to evaluate their gross sand composition.

To meet the project goals, APTIM developed a project-specific color-coding scheme for the sediment layers within each vibracore to aid in the assessment of potential sediment resources (Table 4). The color-coding scheme is based largely on grain size/fines and the eligibility of sand-containing sediments for future use in beach restoration using a green, yellow, orange, and red color scheme, with eligibility decreasing down this ranking as the percentage of fines increase. Clay-containing sediments were based on a blue-purple color scale, with dark blue representing a fatter, stiffer clay and light blue representing a leaner clay. Fat clays are also known as expansive clays because they can absorb large amounts of water that lead to significant volume changes when wet. Fat clays are cohesive, compressible, and have high plasticity, such that they pose the risk of clogging dredge machinery. Lean clays absorb smaller amounts of water and experience minimal volume changes when wet. They have low to medium plasticity due to a relatively higher content of silt or sand. The geotechnical properties of clays need to be considered during sand resource design and project design since they can have an impact on the outcome of marsh and/or habitat restoration projects. Sediment layers containing mostly clay or silt but also a small amount of sand was represented with light or dark purple respectively.

Table 4: Vibracore color-coding scheme based on fine content or sediment type

Color	Description
Green	Sand with less than 10% fines
Yellow	Sand with 10% to 20% fines
Orange	Sand with 20% to 30% fines
Red	Sand with more than 30% fines, Sand with shells/shell hash
Blue	Clay, fat
Light Blue	Clay, lean
Light Purple	Clay, little or some sand
Dark Purple	Silt, little or some sand

5.1.1 Seismic Unit Quaternary 1 (Q1)

The reconnaissance geophysical survey detailed in APTIM and TWI (2022) identified a large surficial sedimentary unit, Seismic Unit Quaternary 1 (Q1), that extends across the majority of the investigation area. This unit is more expansive than other identified shoals that have previously been defined or modeled solely from bathymetry, encompassing the previously identified Sabine, Heald, and Shepard Banks (Rodriguez et al. 2004; Dellapenna et al. 2009) as well as smaller transgressive shelf shoals on the upper Texas Shelf (Suter and Berryhill, Jr. 1985; Flocks et al. 2023) (Figure 7). Previously characterized bank facies and lithologic units consisting of marine shoal, relict coastal shoreface or tidal deposits, and estuarine deposits were identified based on archival geologic cores with paleo-environmental analysis (Rodriguez et al. 2004). The suggested Texas Banks coastal shoal evolution model was interpreted as overtopped, drowned, and subsequently reworked barrier islands (Rodriguez et al. 2004). Recent work using the geophysical survey data collected as part of this investigation hypothesized that Heald Bank is a post-transgressive marine shoal, while Sabine Bank contains preserved subaqueous barrier island facies (Miller, Goff, Gulick, and Lowery 2024; Miller, Goff, Gulick, Wallace, et al. 2024).

The Q1 unit was delineated as the uppermost surficial unit overlying the transgressive ravinement surface, and is generally eroded seaward of the larger banks, where the transgressive ravinement surface coincides with the modern seafloor except where the smaller shoals exist. The generic Q1 designation does not imply or specify an environment of deposition or geological interpretation, rather, the designation is used to refer to the uppermost regionally mappable seismic unit. The unit is broadly described as being Quaternary in age based on its position overlying previously dated Pleistocene and Holocene age units (e.g., Rodriguez et al. 2004). The variable internal acoustic seismic characteristics include chaotic, hazy, transparent, and laminated acoustic units. The mapped Q1 unit was estimated to contain over 5.9 BCY (4.5 BCM) of gross sediment (Figure 8), estimated to contain a range of 20–100 percent sand based on archival cores (APTIM and TWI 2022). The current geotechnical phase of the investigation integrated 74 newly collected vibracores to ground-truth textural properties of seismic facies and refine the resource sand potential of certain surficial and subsurface geologic features (Figure 7). The gross sediment volumes reported in the geophysical report (APTIM and TWI 2022) were refined to better constrain the sand content and boundaries based on newly collected vibracores where possible. A summary table and detailed findings from each of the Sabine, Heald, Shepard, and smaller shoals are presented below.

Figure 7. Extent of offshore survey tracklines, as-built core locations, and distribution of shoals.

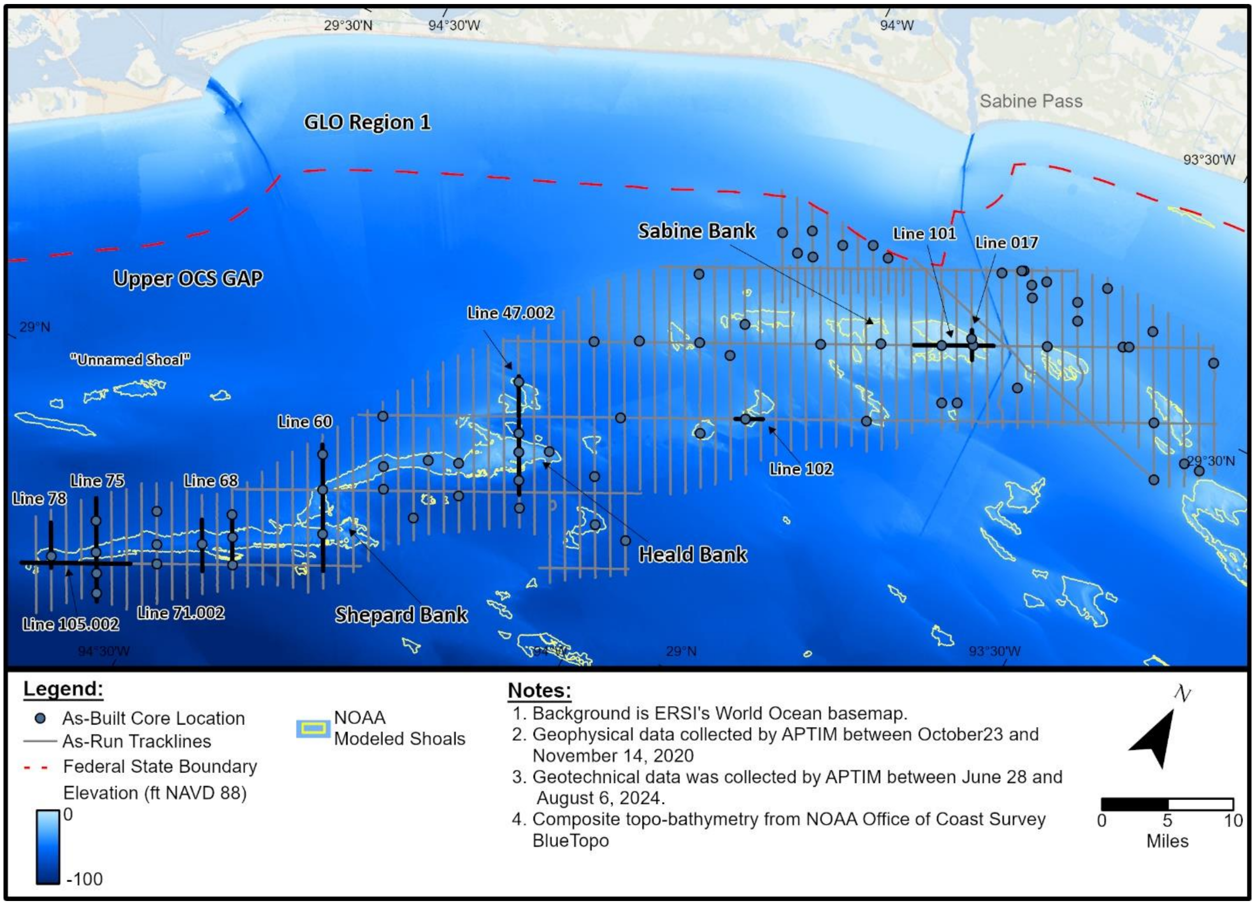


Figure 8. Map of Seismic Unit Quaternary 1 gross sediment isopach from APTIM and TWI (2022).

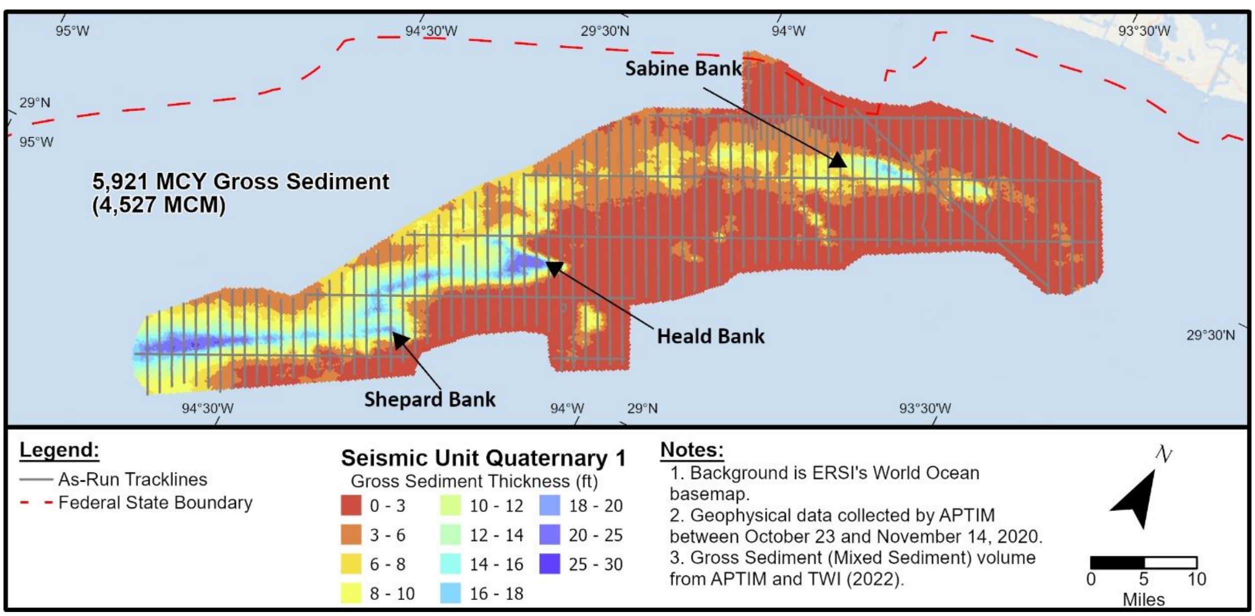
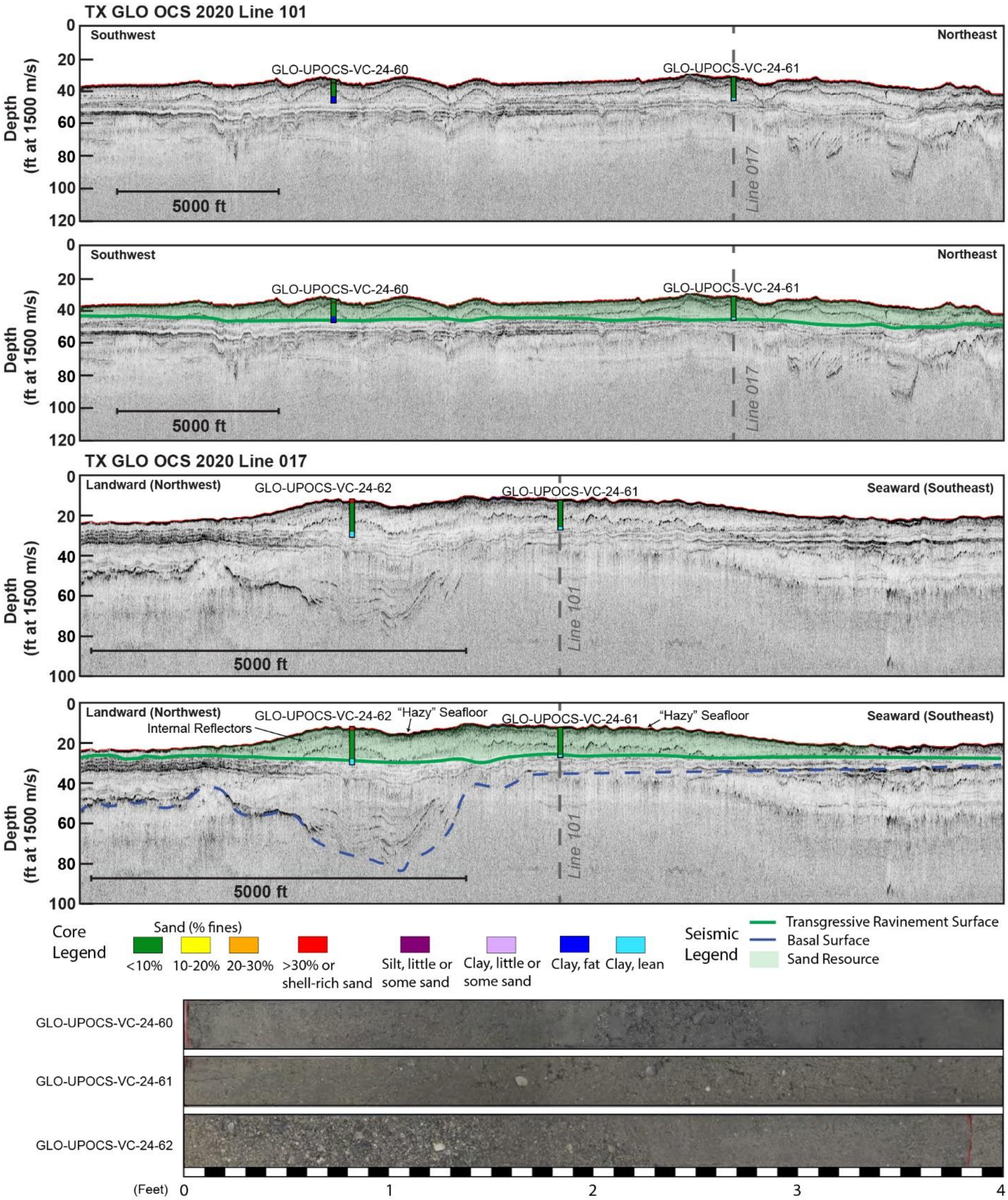


Table 5. Summary characteristics of Q1 sub-features including Sabine, Heald, Shepard Banks and the smaller shoals.

Q1 Sub-Feature	Internal Seismic Architecture	Vibracore Sampling Q1 Sand (GLO-UPOCS-VC#)	Average Sand thickness (ft)	Average Sand Percentage	Notes
Sabine Bank	Transparent to faint landward-dipping reflectors	36, 37, 40, 50, 59, 60, 61, 62	8.2	85.6	Sand content/thickness decreases to the southwest
Heald Bank	Transparent to faint landward-dipping reflectors	14, 15, 16,17,18, 20, 21, 25, 27, 41	10.2	81.8	Large footprint of 10ft or more sand thickness along Bank Crest
Shepard Bank	Horizontal internal packages of transparent subunits	1, 2, 3, 7, 8, 9, 11, 12, 13	11.1	76.7	Large footprint of 10ft or more sand thickness along Bank Crest. Variable sediment composition of transparent facies
Smaller Shoals	Chaotic/hazy unit	29, 44, 45, 46	9.7	93.6	Generally overlies Pleistocene sediment/ drainage tributaries

The Sabine Bank generally overlies the Sabine Incised Valley Fill, but some of the thickest portions of the bank overlie shallow Pleistocene stratigraphy. Sabine Bank has been the focus of investigations for decades and is the site of previously defined borrow areas (CPE 2002; Bermudez and Carter 2009; Ocean Surveys, Inc. 2023). Sabine Bank's internal seismic signature includes transparent to faint, landward-dipping reflectors. Vibracores in this area (GLO-UPOCS-VC-24-60 through 62) sample up to 16 feet (4.9 meters) of gray to dark gray sand (1 to 4 percent fines) with shell hash horizons and whole shells, corresponding to transparent seismic facies with diminished acoustic imaging below (Figure 9). Other sand resource investigations exploring Sabine Bank found similar sand content of less than 10 percent fines and thicknesses up to 25 feet (7.6 meters) in early investigations (Morton and Gibeaut 1995; Dellapenna et al. 2009) with more recent detailed borrow site design level surveys estimating sand up to 20 feet (6.1 meters) thick (Ocean Surveys, Inc. 2022; Ocean Surveys, Inc. 2023). Sand thickness and composition decrease to the southwest along the trend of Sabine Bank, with the thickest sands along the main bank crest. Hazy shallow seismic reflectors correlated to dense shell hash units in vibracores where sampled (GLO-UPOCS-VC-24-62 Figure 9). The upper hazy acoustic package likely correlates to the actively reworked shoal facies of Rodriguez et. al. (2004) consisting of interbedded shell hash and sand as a result of modern oceanographic processes. The northeastern portion of Sabine Bank has the highest sand resource potential of thickest and cleanest sands out of the previously mapped Q1 unit in APTIM and TWI (2022).

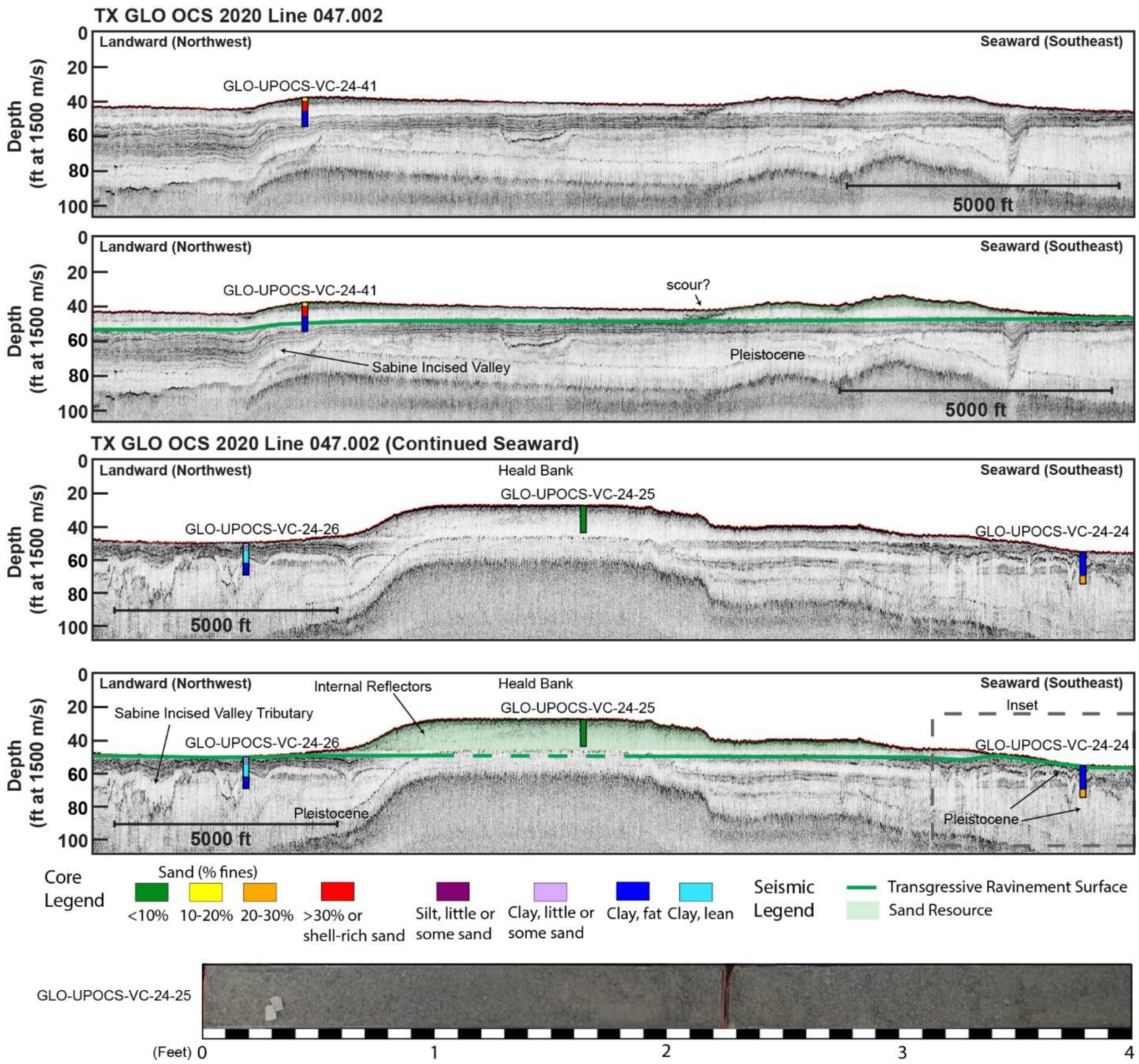
Figure 9. Example sub-bottom profiler data across Sabine Bank. See Figure 7 for location.
Note: Vibracore photographs in greater scale and detail are included in Appendix C.



Heald Bank is an overall lunate-shaped shoal, with the thickest portion located at the central crest and tapering on its flanks. Transects of vibracores obtained through the central bank crest and the flanks detail its sand resource potential and variable composition. The central portion of Heald Bank contains over 15 feet (4.6 meters) of gray sand (1 to 3 percent fines) with shell hash, whole bivalve shells, and trace organics (GLO-UPOCS-VC-24-25) corresponding to a transparent unit grading to faint landward dipping reflectors in seismic (Figure 10). The total sand thickness inferred from the sub-bottom data indicates up to 20 feet (6.1 meters) of potential resources. The homogenous transparent facies on the southern portion of Heald Bank and the generally massive, uniform sand verified in the geotechnical data indicate that this region could be a high-quality sand resource. Landward and seaward of the Heald Bank crest, the seafloor appears to be erosional or non-depositional, as the seafloor coincides with the transgressive ravinement surface. Seaward of the bank, there are oxidized Pleistocene floodplain and fluvial deposits underlying a thin modern marine unit. Landward of the Heald Bank crest are soft, laminated clays and sands with trace shells and an organic horizon overlying stiff sediment below. Regionally, Heald Bank is situated above shallow Pleistocene sediment and partially overlies a tributary to the larger Sabine Incised Valley. A radiocarbon dated peat horizon at a proximal location and similar depth horizon was estimated to be 11,700 years old, supporting the northern Sabine Incised Valley tributary fill succession (Rodriguez et al. 2004). Further landward, the smaller flanks of the crescent shape shoal are verified to have 2 to 8 feet (0.6 to 2.4 meters) of sand (19 to 31 percent fines), overlying thick estuarine fill of the main Sabine Incised Valley (Figure 10; GLO-UPOCS-VC-24-41). These smaller shoal flanks are transparent with a faint upper unit separated by a weak amplitude reflector. The landward toe of the shoals displays small incisional features at their base that could be related to reworking by oceanographic processes as the shoals migrate. Of the original mapped Q1 unit, there appears to be higher occurrence of muddy sands ranging from 30 to 70 percent sand correlating to transparent units landward of the Heald Bank crest, with the crest itself containing nearly all high-quality sand.

Figure 10. Example sub-bottom data across Heald Bank and its smaller flanking shoals. See Figure 7 for location.

Note: Vibracore photographs in greater scale and detail are included in Appendix C.



Generally, Shepard Bank and the smaller flanking shoals consist of an overall transparent seismic unit with some horizontal internal architecture grading to more laminated seismic facies landward. Shepard Bank crest consists of up to 18 feet (5.5 meters) of gray to greenish gray sand (2 to 18 percent fines) with shell hash layers (GLO-UPOCS-VC-24-14). Several secondary shoals or bedforms consisting of internal reflectors form the uppermost unit of the overall transparent Shepard Bank (Figure 11). Sub-bottom lines within a few miles of each other have very similar seismic signatures but have different sediment compositions (Figure 12). The transparent seismic unit of the shoal crest consists of firm, fat clay with trace shell hash and organics (GLO-UPOCS-VC-24-09) to the northeast and dark greenish gray sand, with some silt and clay, and trace shell hash (GLO-UPOCS-VC-24-07) to the southwest. The bathymetric expression of Shepard Bank's flank diminishes along the southwest portion of the investigation area, which appears to correlate to the decreasing surficial sand content and thickness. However, the broader Q1 unit (the uppermost unit above the transgressive ravinement) is ~15 feet (4.6 meters) at the investigation area boundary and likely extends beyond it (Figure 13). This southwest portion of the shoal is verified to contain sand resources, as well as potentially sand-rich Pleistocene deposits at depth. Oxidized sediment, interpreted as Pleistocene subaerially exposed floodplain, correlates to a change in transparent to faintly dipping clinoforms. These units are subsequently overlain by horizontally laminated estuarine to recent marine sediments. This area is outside the main Sabine Incised Valley, where Pleistocene deposits are within the upper ~15 feet (~4.6 meters) and could contain other fluvial channel belt sediment resources upon further geotechnical sampling. Several sub-bottom profiles of the larger Shepard Bank features display a "hazy" seafloor signature at the seaward "toe" of the shoal that could be related to active reworking of the shoal; seaward of the shoal toe consists of fine-grained sediment at the seafloor and a thin sand sheet landward of the shoal (Figure 11 and Figure 12).

Figure 11. Example sub-bottom data across Shepard Bank. See Figure 7 for location.

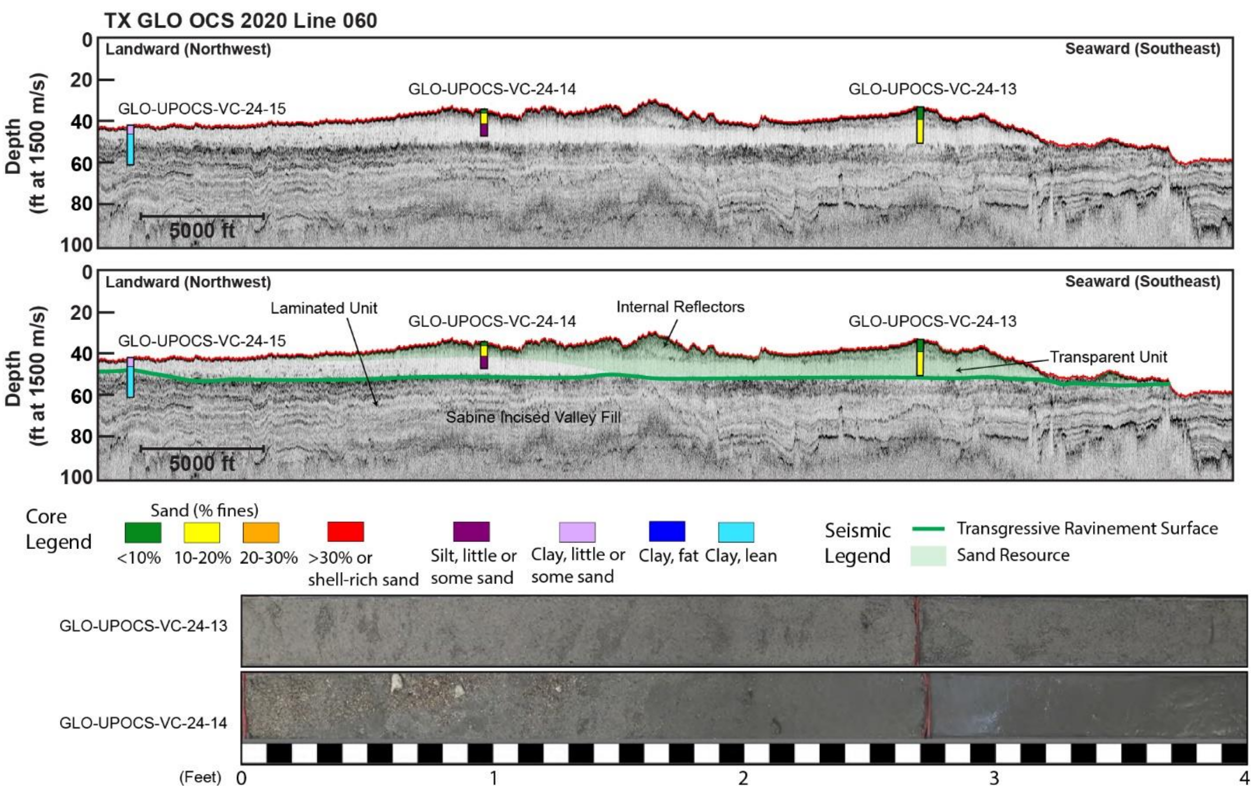


Figure 12. Example sub-bottom data across Shepard Bank flank displaying the sediment composition variability of similar transparent seismic facies. See Figure 7 for location.

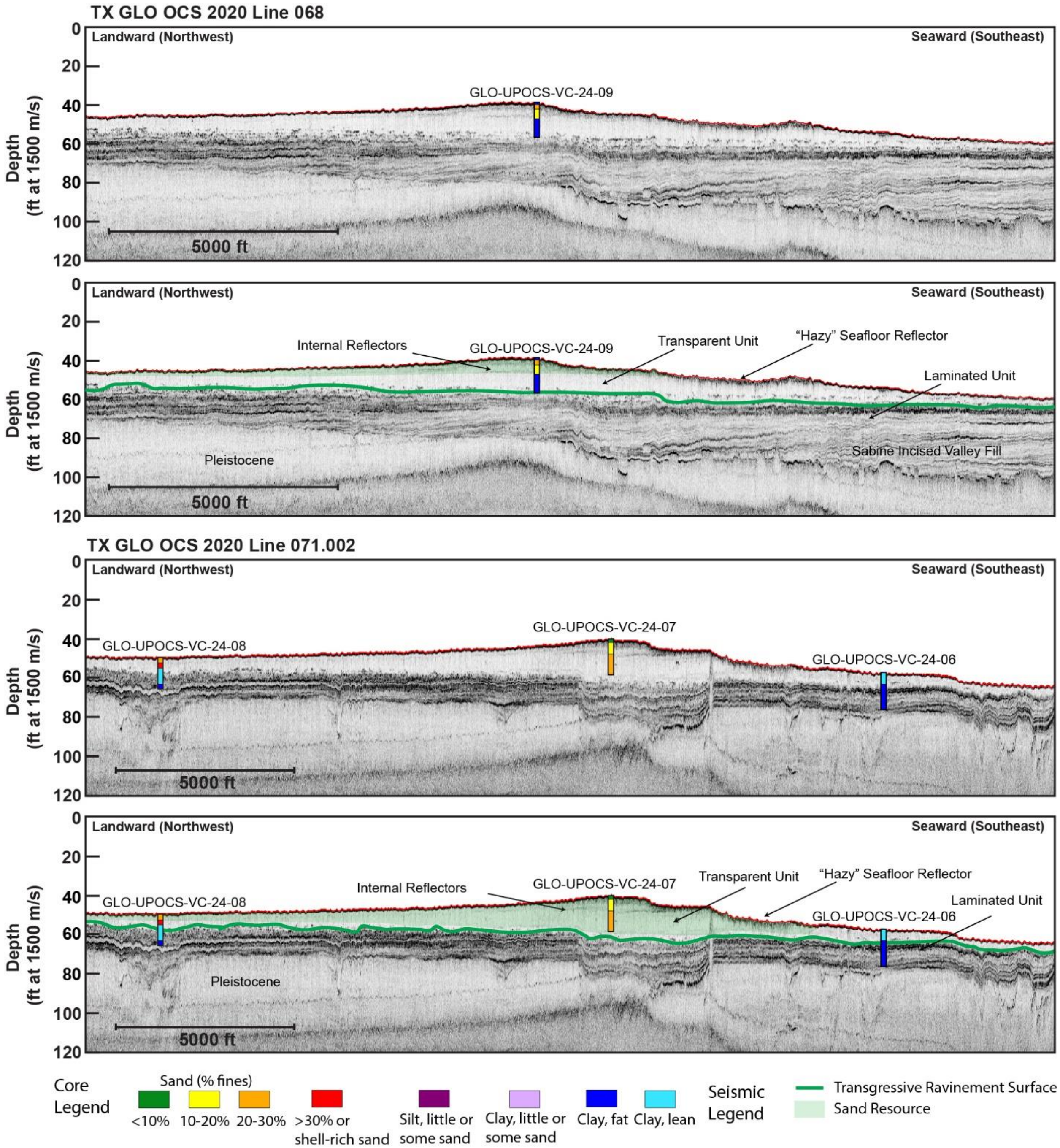
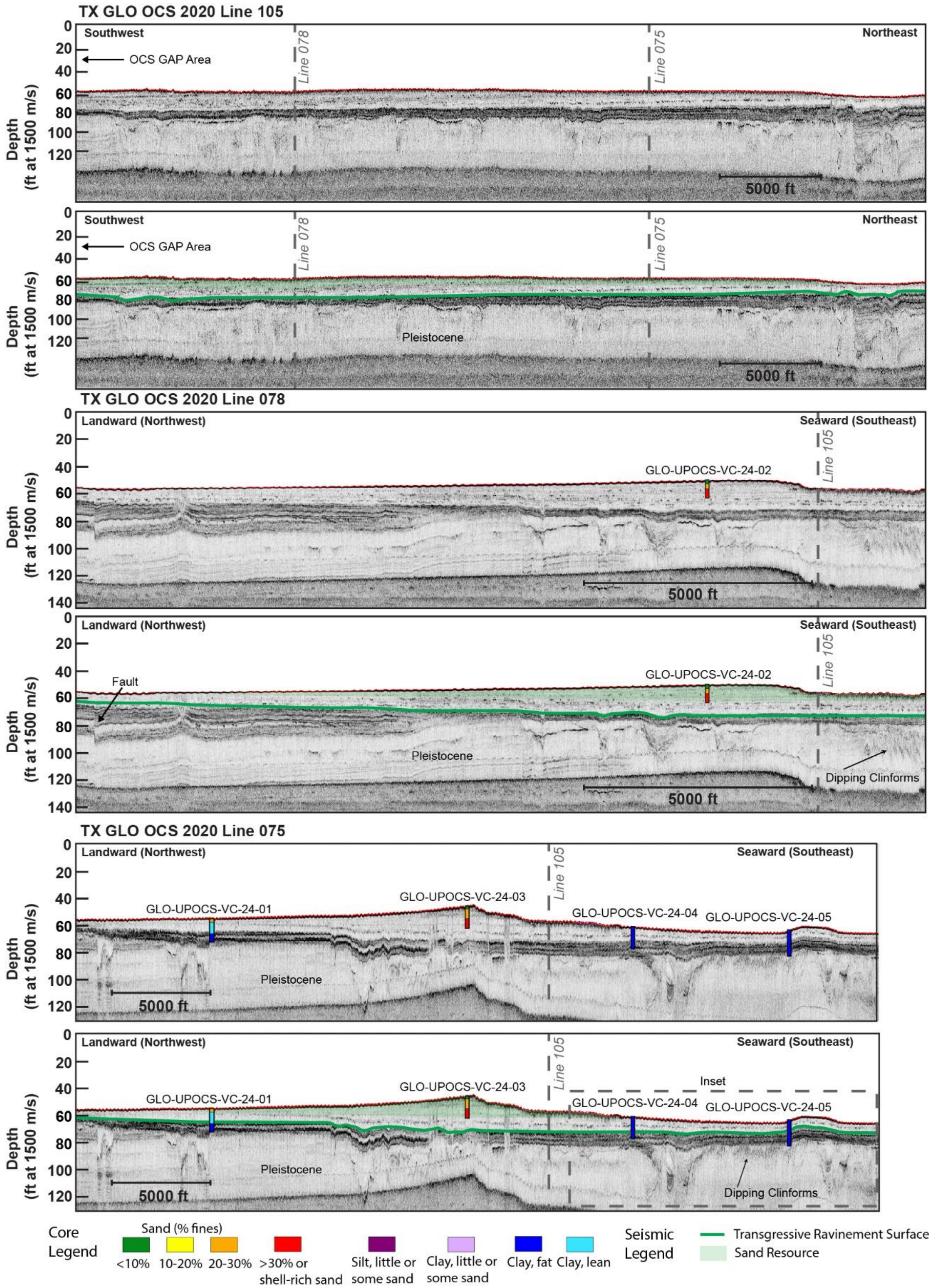
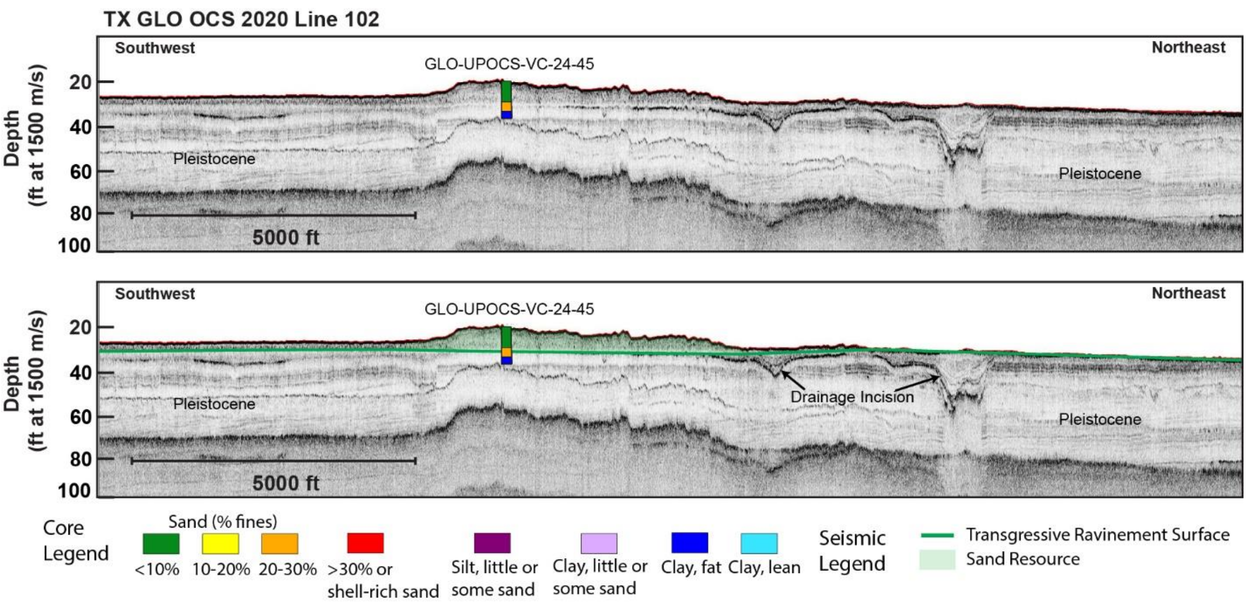


Figure 13. Example sub-bottom data across the Shepard Bank flanking shoals, demonstrating the thickness of Q1 surficial sand deposits likely extending beyond the investigation area. See Figure 7 for location. Inset Figure 33 shown in Localized Feature section.



Several smaller shoals exist within the investigation area as identified in composite bathymetry data sets (Figure 7) and are part of the general Q1 unit. Geotechnical sampling during this reconnaissance investigation verified a few of the many smaller shoals as containing potential sand resources, some up to ~15 feet (~4.6 meters; GLO-UPOCS-24-45). This particular unnamed shoal is composed of a chaotic to hazy acoustic unit. The larger shoals not associated with named banks are generally located outside the incised valleys, overlying Pleistocene sediment exposed at or very near the seafloor and may be associated with incisional topography created by smaller tributary drainages (Figure 14). The unnamed shoals, some of which were verified to contain significant sand resources in this investigation, have a much larger spatial extent in the bathymetry than what is delineated by the NOAA-modeled shoals.

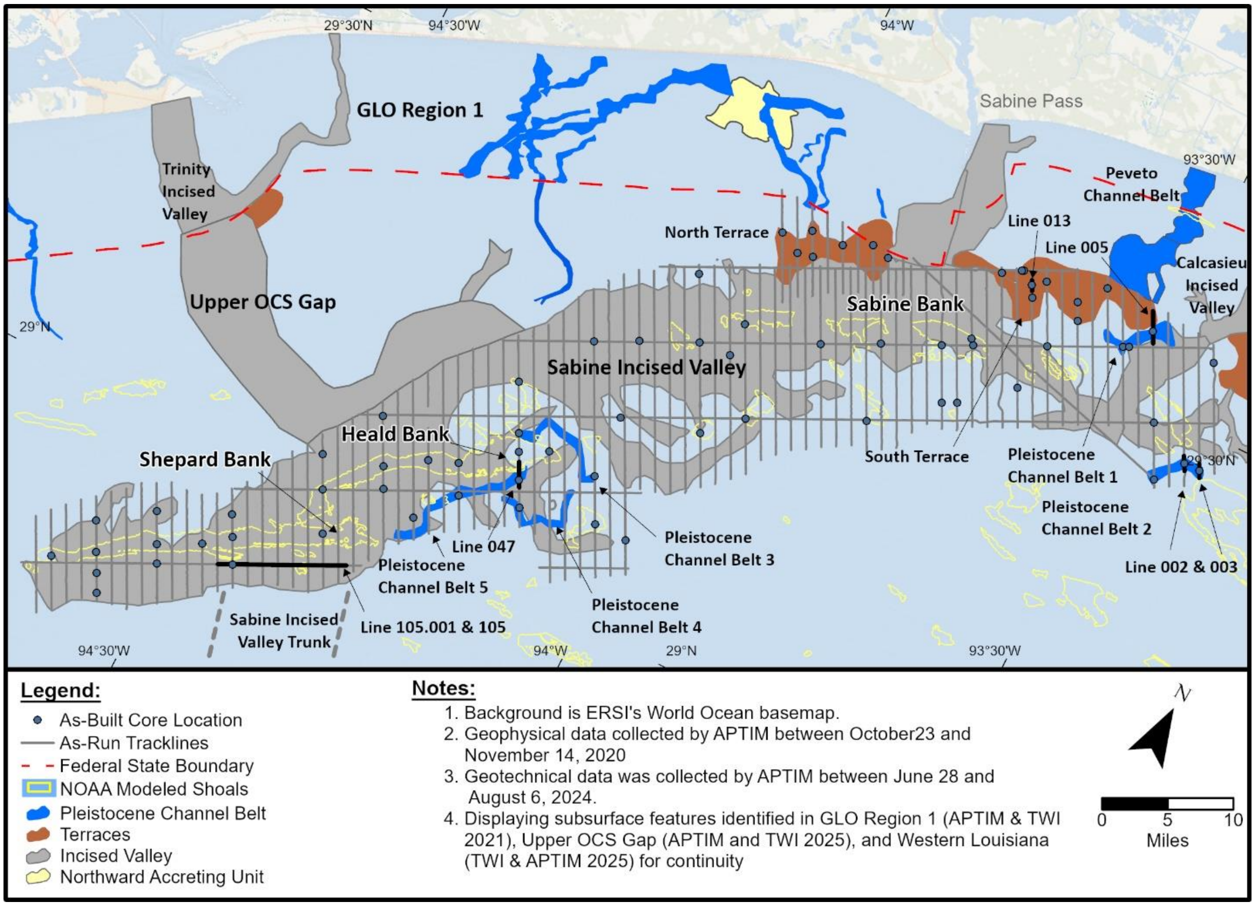
Figure 14. Example sub-bottom data across smaller shelf shoal and its relation to antecedent incisional topography. See Figure 7 for location.



5.1.2 Pleistocene Fluvial Channel Belts

Of the five Pleistocene channel belts mapped in the first phase geophysical investigation (APTIM and TWI 2022) (Figure 15), three were verified to contain significant sand resources with the current geotechnical investigation. These channel belts were unmapped in prior research (Rodriguez et al. 2004; Miller, Goff, Gulick, Wallace, et al. 2024). The verified sand-rich seismic facies, which consisted of a transparent to faintly dipping reflector package, were expanded with the available survey data for resource quantification. The verified seismic facies had a strong, hazy top reflector with loss of acoustic imaging below the package compared to the surrounding laminated strata at depth. Other facies within the larger Pleistocene channel belt include high frequency, dipping reflector sets of variable amplitude that likely contained mixed-sediment resources.

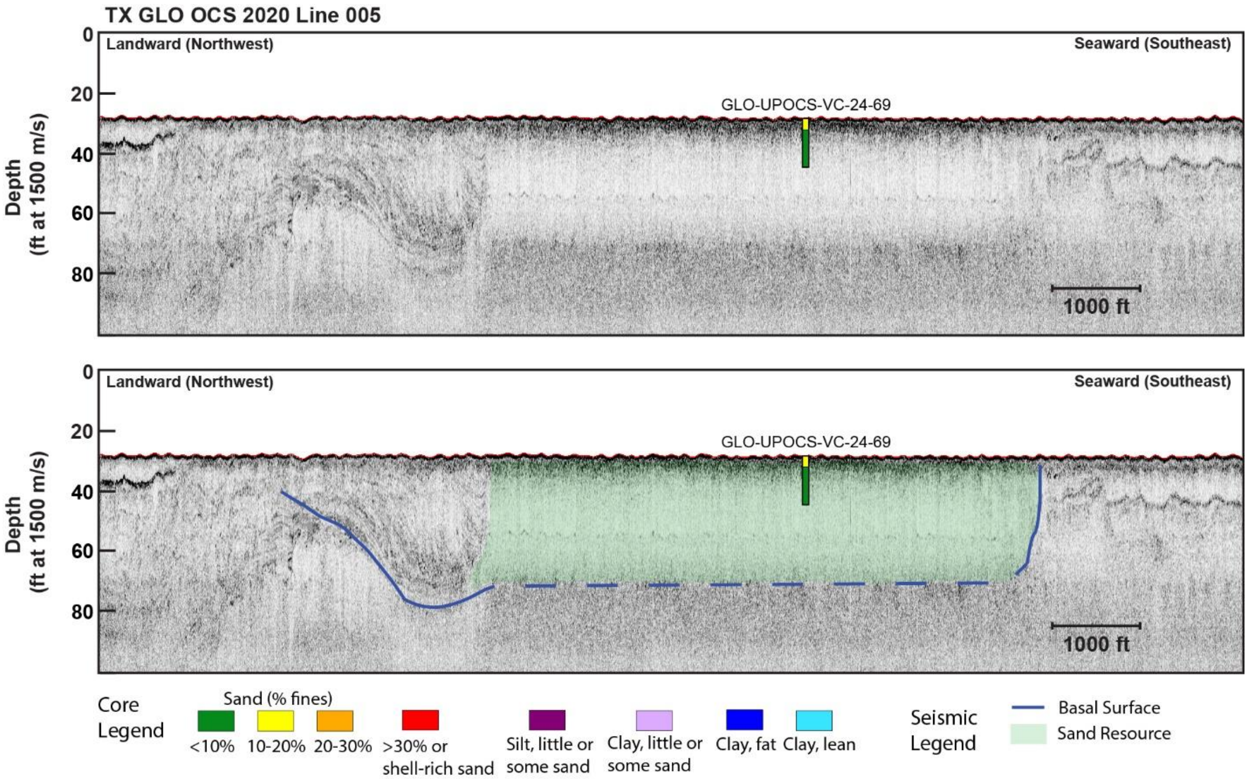
Figure 15. Mapped sub-surface geologic features.



5.1.2.1 Pleistocene Channel Belt 1

Pleistocene Channel Belt 1 was identified in APTIM and TWI (2022), and is described as an incisional feature within Beaumont Pleistocene stratigraphy located on the interfluve areas outside the main Sabine Incised Valley. This Pleistocene Channel Belt is cross-cut by a younger incisional drainage in the eastern portion that is likely a tributary to the main Sabine Incised Valley trunk. Three vibracores sampled various facies of the larger channel belt unit (GLO-UPOCS-VC-24-67 through 69), verifying each textural composition. The channel infill, consisting of finely laminated draping to slightly prograding reflector sets, is verified as dominantly fine-grained clays with trace organics and sand pockets, which is similar to other channel fill findings (APTIM and TWI Forthcoming; TWI and APTIM Forthcoming). Vibracore GLO-UPOCS-VC-24-69 sampled over 16 feet (4.9 meters) of brownish gray fine- to medium-sand containing trace organics. This correlated to a transparent seismic facies grading vertically into a strong amplitude hazy seafloor reflector (Figure 16). There is a loss of acoustic signal below this target facies. The channel belt deposit is estimated to contain a unit of up to 40 feet (12.2 meters) thick of sand-rich sediment inferred from sub-bottom data from the base of the channel thalweg. Portions of the larger verified Pleistocene Channel Belt contain significant sand resources with minimal overburden in some areas. This feature may be an extension of sand-rich channel belt features mapped offshore western Louisiana (TWI and APTIM Forthcoming) which would significantly increase the quantity and confidence of sand resource quality if correlated as the same system.

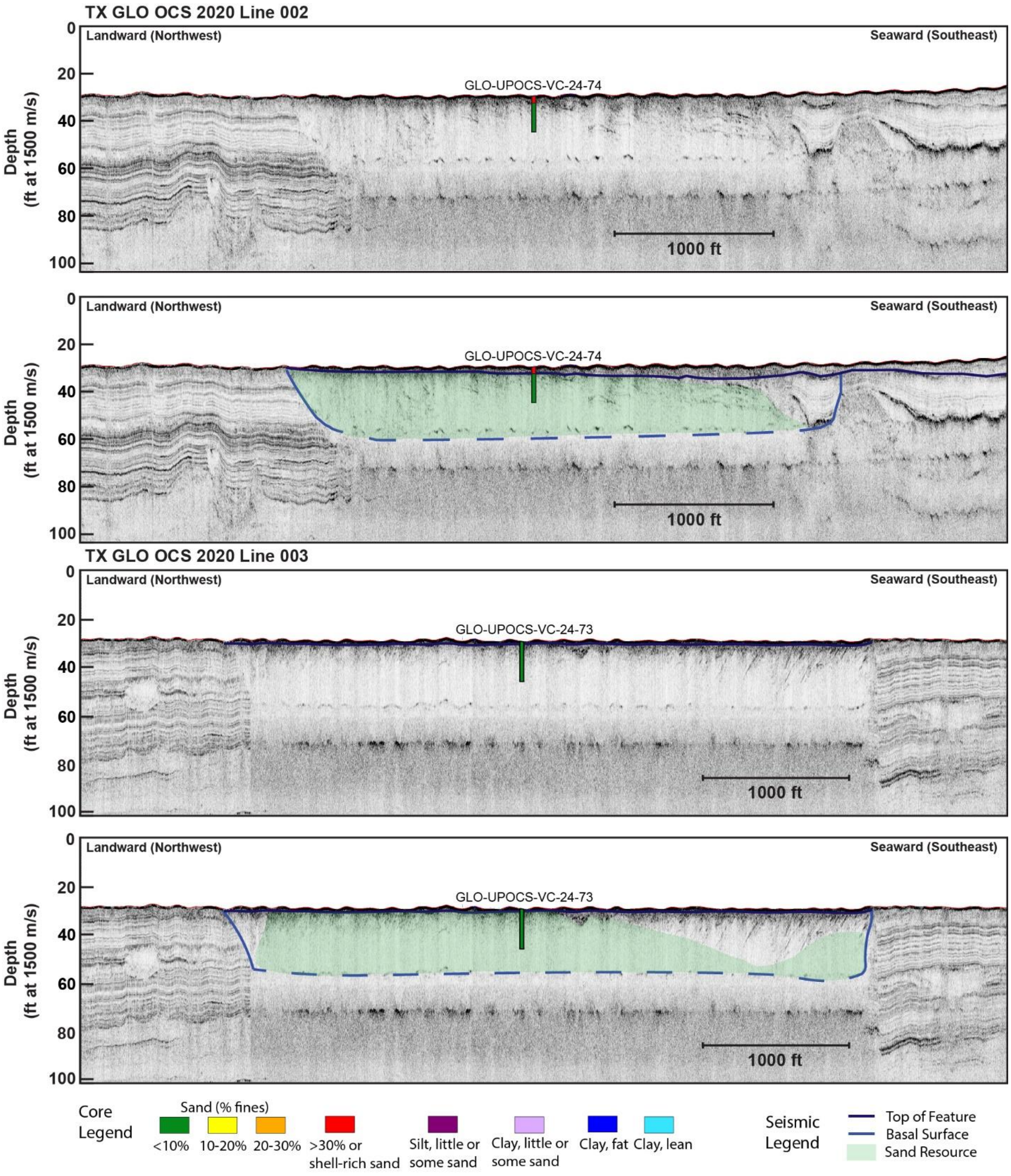
Figure 16. Example sub-bottom data across Pleistocene Channel Belt 1. Channel belt thickness inferred from the channel thalweg. See Figure 15 for location.



5.1.2.2 Pleistocene Channel Belt 2

Pleistocene Channel Belt 2, nearly outcropping at the seafloor, has minimal overburden compared to other identified subsurface features. APTIM and TWI (2022) highlight how the channel belt appears to be truncated at the seafloor and hypothesizes that this reworking of the channel belt deposit could have sourced sand to the nearby Sabine Bank and smaller shoals during their evolution. Two vibracores (GLO-UPOCS-VC-24-73 and 74) sample Pleistocene Channel Belt 2, which consists of laminated, yellowish brown to olive brown sand (3 to 11 percent fines) with trace organics. This sand unit is verified up to 17 feet (5.2 meters) in core and estimated to be roughly 30 feet (9.1 meters) thick if extrapolated beyond the core's footprint in the sub-bottom data (Figure 17). The final vibracore (GLO-UPOCS-VC-24-72) sampling Pleistocene Channel Belt 2 samples 9 feet (2.7 meters) of mixed-sediment (54 to 60 percent fines) containing silty sand to sandy silt and rock fragments. Each interpreted fluvial channel belt sand or mixed-sediment unit is overlain by 0 to 3 feet (0 to 1 meter) of soft, modern marine clay and sand, containing shell hash and whole bivalves. The geotechnical data verifies the original interpretation of Pleistocene Channel Belt 2 being a channel belt of fluvial origin that contains significant sand and mixed-sediment resources with minimal overburden and, in some areas, appears to be actively reworking by oceanographic processes.

Figure 17. Example sub-bottom data across Pleistocene Channel Belt 2. Channel belt thickness estimated from the channel thalweg. See Figure 15 for location.



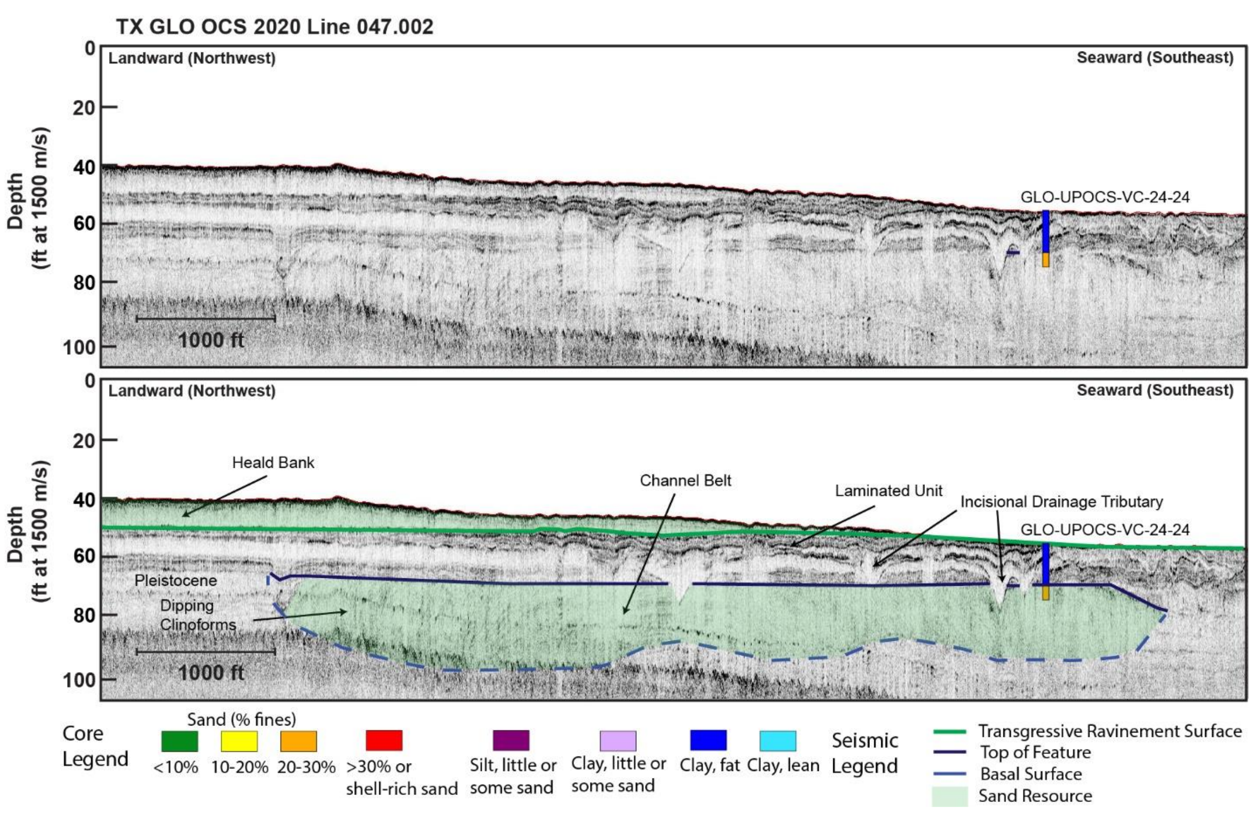
5.1.2.3 Pleistocene Channel Belt 3 and 4

Pleistocene Channel Belts 3, 4, and 5 are located in the central investigation area, seaward of and underlying Heald Bank (Figure 15). The regional channel belts mapped in APTIM and TWI (2022) are only partially preserved due to incision by younger tributary drainages that feed the larger Sabine Incised Valley. All the potential channel belt features are composed of steeply dipping clinoforms or transparent acoustic packages that grade into U-shaped channel forms. Three vibracores targeting Pleistocene Channel Belts 3 and 4 did not verify sand resources. Two vibracores sampled the upper modern marine mud or Pleistocene floodplain deposits and did not sample the target channel belt facies at depth. The last vibracore sampled the upper portion of the target channel belt facies and sampled Pleistocene floodplain and levee sediment. Since the sand content could not be verified, no refined sand resource volume was calculated. Comparing verified seismic facies of similar channel belts, it is likely these features contain mixed-sediment resources due to the overall transparent package with frequent dipping reflectors of variable amplitudes similar to features found and verified in Texas Region 1 (APTIM and TWI Forthcoming).

5.1.2.4 Pleistocene Channel Belt 5

Pleistocene Channel Belt 5 was mapped in APTIM and TWI (2022) and described as exhibiting the most incisional reworking of younger drainage tributaries of the regional channel belts identified. It partially underlies Heald Bank (Figure 15). Channel Belt 5 had one vibracore (GLO-UPOCS-VC-24-24) that contains 5 feet (1.5 meters) of yellowish-brown sand with clay pockets and rock fragments underlying 8 feet (2.4 meters) of modern shelf clay and 6 feet (1.8 meters) of Pleistocene floodplain laminated clay (Figure 18). The sand-rich facies again correlated to a transparent package with loss of acoustic signal below. The extent of sand resources were only interpreted to the limits of available reconnaissance-level sub-bottom and geotechnical coverage and could only be identified in a select portions of Pleistocene Channel Belts 1, 2, and 5.

Figure 18. Example sub-bottom data across Pleistocene Channel Belt 5. See Figure 15 for location.

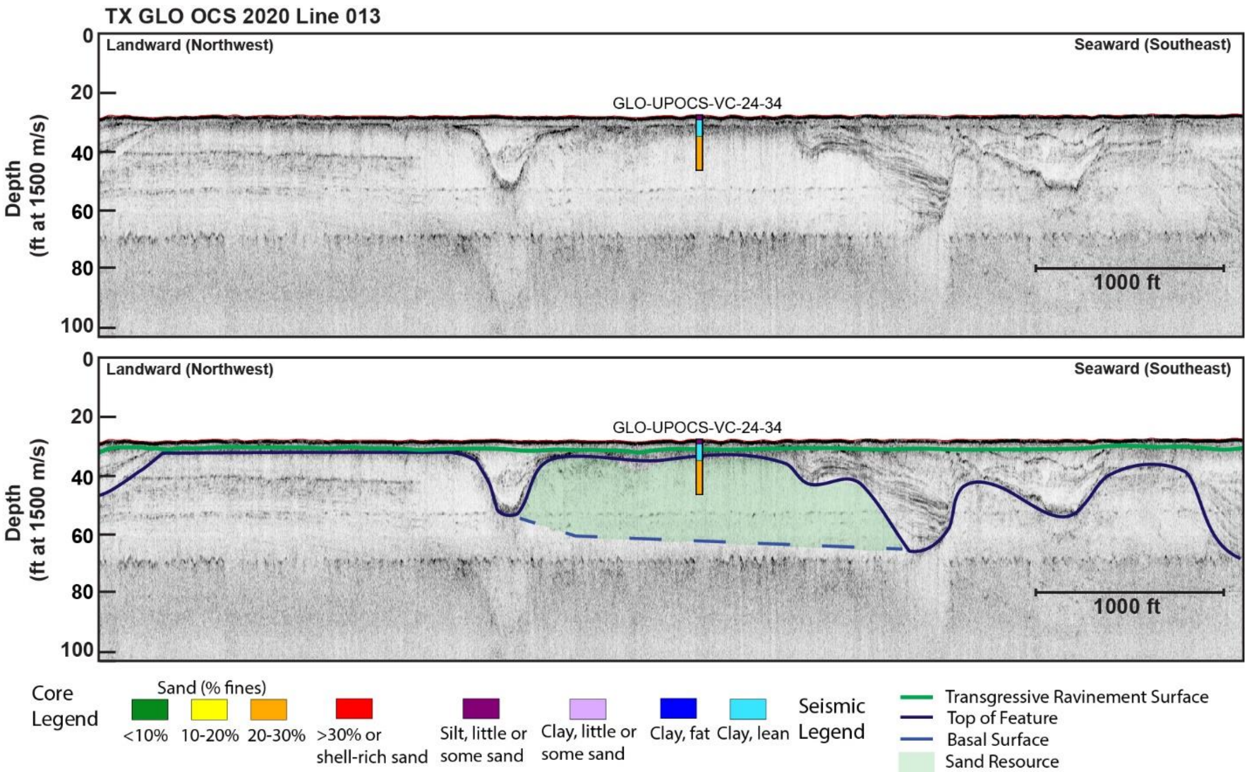


5.1.3 Sabine Incised Valley and Terraces

The majority of the OCS survey area coincides with the generally northeast-southwest trending Sabine Incised Valley. In the northern portion of the survey area, two potential fluvial terraces were mapped by APTIM and TWI (2022), the North and South Sabine Pleistocene Fluvial Terraces. These mapped features correlate to previously identified Pleistocene terraces that are thought to have formed during the most recent falling stage and low stand of the Sabine River system (Thomas and Anderson 1994). The fluvial terraces are adjacent to the Sabine Incised Valley and are positioned stratigraphically higher in the subsurface, making them strategic targets for geotechnical sampling. These features are referred to as terraces and are characterized by transparent to steeply dipping clinoforms grading into a channel fill sequence. The top of the clinoform package has a high-amplitude, strong hazy acoustic return. Although the base of the clinoform package is not observed in sub-bottom, the total thickness is estimated by the channel thalweg, reaching thickness of up to 75 feet (22.9 meters). Compared to the modern and Holocene Sabine River clinoform packages, the Pleistocene terraces observed in the investigation area are substantially larger and were targeted for their significant potential for sediment resources.

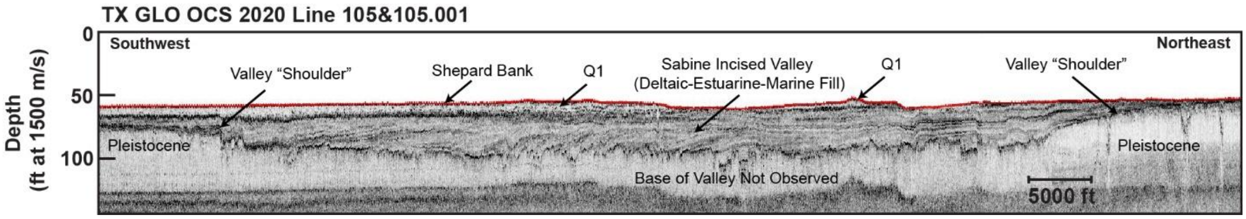
Geotechnical sampling targeting the North and South Sabine Pleistocene Fluvial Terraces encountered relatively thin modern marine shelf fine-grained sediments overlying stiff, oxidized, Pleistocene floodplain or channel fill clay with silt and sand laminations. The vibracores rarely penetrate the stiff fine-grained sediment to the target facies below. One core from each the North (GLO-UPOCS-VC-24-53) and South (GLO-UPOCS-VC-24-34) Fluvial Terraces did verify sand (21 to 28 percent fines) at the base of each vibracore up to 10 feet (3 meters). The yellowish brown to greenish-gray laminated sand with lithified clay fragments appears consistent with other fluvial deposits and correlates to transparent seismic facies with loss of acoustic imaging below and a strong hazy reflector above (Figure 19). Similar transparent facies were verified to contain fine-grained sediment in the upper sections where geotechnical information was available. It appears the verified sand-rich portions of the transparent packages were “brighter” compared to the fine-grained dominant portions of similar facies. These findings are similar to those reported in a sand resource investigation that sampled northern extensions of these fluvial terraces offshore Louisiana (TWI and APTIM Forthcoming). The total sand thickness and composition of the potential sand-rich deposits of the fluvial terraces identified in this investigation will require further refinement through deeper geotechnical sampling.

Figure 19. Example sub-bottom data across the South Fluvial Terrace. See Figure 15 for location.



The Sabine Incised Valley and its smaller drainage tributaries are a major stratigraphic feature throughout the investigation area. The valley fill sequence described in APTIM and TWI (2022) and previous research (Thomas and Anderson 1994; Anderson et al. 2014) follows a typical underfilled valley (Simms et al. 2006) of basal amalgamated fluvial deposits overlain by deltaic and estuarine to marine sediment. In sub-bottom data, the base of the valley is not observed. Instead the deepest strong amplitude return usually correlates to the top of the fluvial sand deposits (Swartz 2019). The laminated to slightly prograding reflector package characterizes the deltaic to estuarine units, on average, between 30 to 40 feet (9 to 12 meters) thick (APTIM and TWI 2022). Geotechnical sampling from 12 vibracores (GLO-UPOCS-VC-24-10, 15, 16, 18, 29, 36-41, and 43) verify the laminated reflector package consists of fine-grained fat gray clays with sand and silt laminations with trace shell hash and whole shells. This is consistent with other estuarine or marine valley fill descriptions in the investigation area (Rodriguez et al. 2004). Several vibracores located between the larger bathymetric expressions of Sabine and Heald Banks (GLO-UPOCS-VC-24-36, 38, 39, 40, and 43) consist entirely of marine-estuarine fine-grained sediment up to 19 feet (5.8 meters) sampled by vibracore. Due to the thick fine-grained deltaic-marine fill sequences the basal fluvial fill sand deposits noted in previous research (Thomas and Anderson 1994; Swartz 2019) were not verified in vibracore (Figure 20).

Figure 20. Example sub-bottom data across Sabine Incised Valley in the Southwestern portion of the investigation area. See Figure 15 for location.



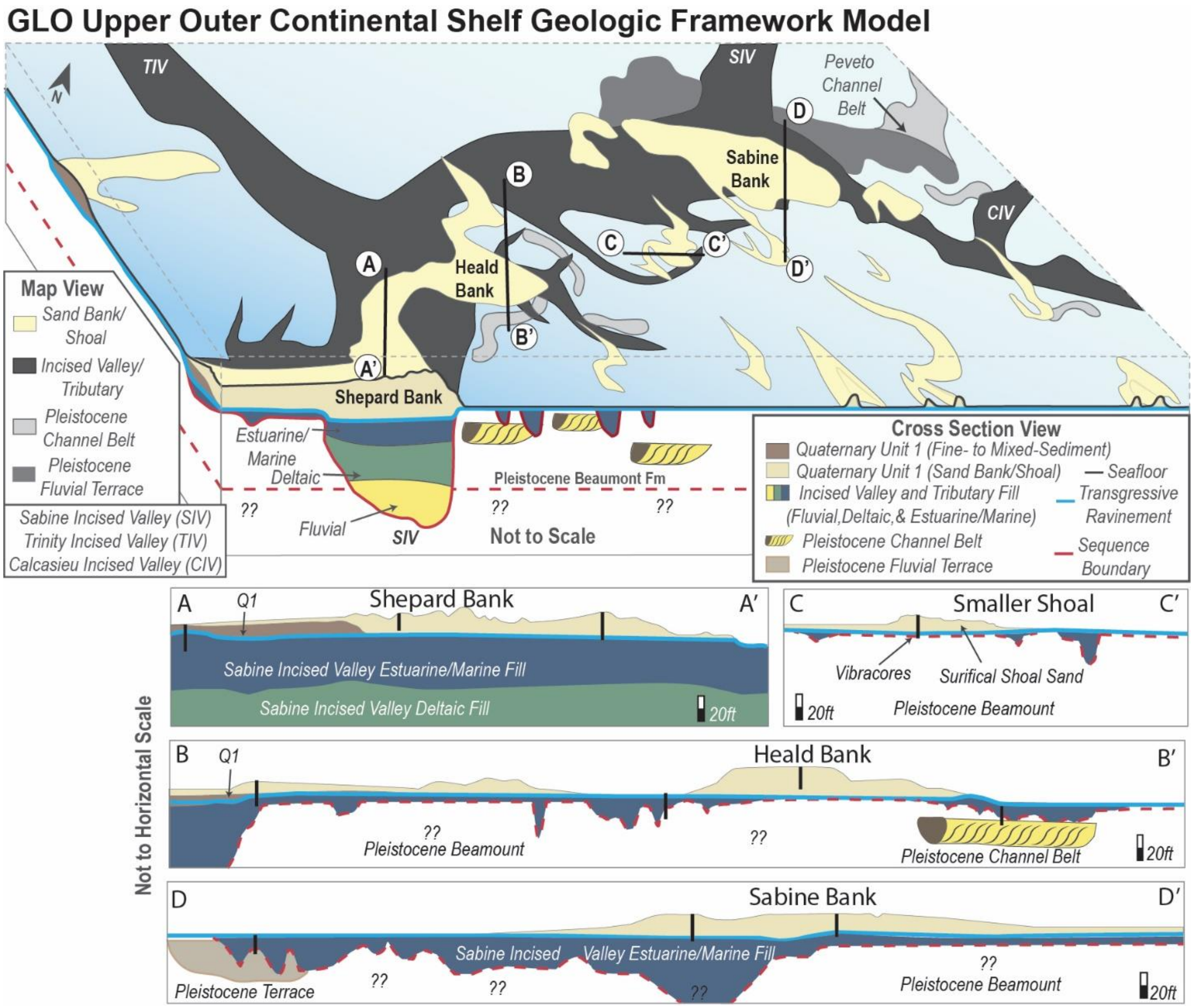
In the southwestern portion of the investigation area, the main Sabine Incised Valley continues south offshore in agreement with previous research (Anderson et al. 2004; Miller, Goff, Gulick, and Lowery 2024; Miller, Goff, Gulick, Wallace, et al. 2024). A thin portion of estuarine or marine sediment overlies shallow Pleistocene deposits underlying the southwestern portion of Heald Bank as sampled by GLO-UPOCS-VC-24-05. This area appears to be infilling a shallow incisional tributary or depression associated with the main Sabine Incised Valley to the east (Figure 14 and Figure 20). Portions of shallow potential Pleistocene fluvial channel belts are in this southwestern portion of the investigation area but could not be correlated across geophysical survey lines at the reconnaissance scale. This area seaward of Heald Bank in the southwestern portion of the study area could contain other sand resources upon further geophysical and geotechnical investigations.

5.2 Updated Geologic History/Framework

The Upper Texas OCS contains numerous potential sand resources contained within regional-scale geologic systems such as the Pleistocene Channel Belt systems, Pleistocene terraces of the Trinity and Sabine Incised Valleys, and the Holocene to modern surficial sand banks and shoals. Other potential sediment resources are found in localized features that are volumetrically significant but, due to survey spacing, are not correlated across more than a single survey line. A conceptual three-dimensional geologic model and generalized cross-sections were developed that highlight the regional geologic features, the relationships of the sand banks and shoals to underlying geology, and the distribution of potential sediment resources (Figure 21). Many of the following observations and geologic or sea level summaries rely on previous research for evolutionary chronologies and are introduced in detail within the Geologic Framework section of the APTIM and TWI (2022) report.

A key observation of this study is the amalgamation of Pleistocene and Holocene stratigraphy in the region, which can lack clearly differentiated sequence boundaries separated by significant deposition as had been proposed in earlier work (Thomas 1991). This has the potential for sedimentary deposits of highly different ages and depositional environments to be located adjacent to each other and at potentially the same depth below the modern seafloor. This is especially apparent when comparing incised valley fill and interfluve Pleistocene Beamount Formation. The Pleistocene subaerial exposure surface, represented by oxidized, stiff sediment, occurs at similar depths below seafloor as previously dated Holocene valley fill sediments within the incised valleys (e.g., Rodriguez et al. 2004). The geologic model (Figure 21) highlights that Holocene and Pleistocene fluvial systems may occur at equivalent depths in the shallow subsurface, rather than be separated by large thicknesses of deltaic or marine deposition. Prior studies have placed these systems into sequence stratigraphic frameworks with emphasis on the occurrence and position of regional sequence boundaries such as those formed during sea level fluctuations. Regional sequence boundaries observed in previous research (Anderson et al. 2016 and references within) typically occur deep in the observed stratigraphy below the primary depth of investigation. The sequence boundaries observed in this investigation constrain the incised valley edges and are amalgamated with the transgressive ravinement surface near the seafloor. This amalgamation and reworking of depositional sequences throughout various stages of fluctuating sea levels leads to the "perching" of Pleistocene stratigraphic elements close to the modern seafloor, making them strategic targets for sand resources. This concept was outlined in Anderson et al. (2016) and Heinrich et al. (2020) for the Texas and Western Louisiana Shelf.

Figure 21. Conceptual geologic model of the Upper OCS of the Texas Shelf.
The model displays the relationship of surficial shoals and Sabine, Heald, and Shepard Banks to the underlying Sabine Incised Valley and subsurface Pleistocene geologic features identified in this investigation. Interpreted cross-sections through various surficial features are also presented to display these relationships at depth.



A generalized geologic history for the region can be summarized as:

1. Middle-Pleistocene falling stage and low-stand advances of deltaic and fluvial systems across the continental shelf, leading to the formation of inter-bedded prodelta and floodplain muds, sandy channel belt and distributary channel elements, and occasional preserved incised valley systems.
2. Middle-Pleistocene transgressions and high-stands leading to valley infilling, fluvial avulsion, and eventual reworking/erosion and the formation of internal sequence boundaries, commonly observed as regional erosional unconformities. Periods 1 and 2 together formed what is locally referred to as the Pleistocene Beaumont and Lissie Formations, which can reach thousands of feet thickness across the inner continental shelf.

3. Late-Pleistocene falling stage and low-stand formation of incised valley systems, fluvial terraces, and associated erosional tributary drainages across the shelf, feeding shelf-edge delta systems. The falling stage to low-stand valleys incise into the existing Pleistocene Beaumont and Lissie Formations.
4. Holocene transgression leading to backstepping of fluvial-deltaic systems within incised valleys, formation of Holocene estuarine and bay environments typically only preserved locally within incised valleys and tributary drainages, and localized avulsions of fluvial systems that "over-fill" valleys based on basin sediment supply.
5. Holocene to modern transgressive submergence and reworking of paleo-barrier island and formation of modern shelf sand bodies. Shelf sand shoals are likely not intact or in place barrier lithosomes but rather an actively evolving and moving shelf sedimentary system that may have initiated as a transgressed paleoshoreline.
6. Modern sea-level high stand (current shoreline position) to develop extant barrier islands and coasts and the relatively mature (if still evolving) straightened shoreline observed today. Marine shoals are continually reworked by oceanographic processes.

While the location, character, and geologic history of the Trinity and Sabine Incised Valley systems has been well described by prior work, this new analysis shows the ubiquity of older fluvial channel belt systems relatively close to the modern seafloor. These older, likely Pleistocene, systems are not deeply buried within the Beaumont Formation sediments, as previously interpreted (Thomas 1991), but often occur at a depth equivalent to or even shallower than the more recent Holocene systems (Figure 21). In several areas, the top of the Pleistocene fluvial stratigraphy is observed to outcrop at the seafloor, in contrast to the basal fluvial stratigraphy of the Sabine Incised Valleys, which are often buried by 30 to 100 feet (9.1 to 30.5 meters) of deltaic and estuarine sediments (Anderson et al. 2014). The overall geologic history of the Upper Texas OCS appears to be comparable to that developed for the adjacent Southwest Louisiana Shelf, where recent reviews found the ubiquity of fluvial stratigraphy and the potential for fluvial sand-bearing deposits to occur at almost every stage of sea level throughout the Pleistocene (Heinrich et al. 2020).

Numerous drainage channels and tributaries of various scales were identified in the investigation area and appear to have incised into the Beaumont Formation during last subaerial exposure during sea level lowstand. These drainages and tributaries are infilled similar to the larger incised valleys with the channel fill composed of deltaic, estuarine, and marine sediments. They differ from the large, incised valleys and the channel belt systems in that the base of the incisional drainages rarely appear to have a significant coarse-grained fluvial component and may not represent high-potential sand resources. Similar to the valleys, the smaller scale channels may provide local areas of accommodation for more recent transgressive sand deposits, increasing their preservation, but the scale of these channel features make correlation difficult at the reconnaissance level.

This study indicates that the previously described Heald and Shepard Banks, along with the numerous unnamed sand shoals, are likely the result of similar geologic origin and active oceanographic processes, rather than reflecting discrete coastal lithosomes or different stages of barrier island evolution as proposed by earlier work (Rodriguez et al. 2004). The bulk of Heald and Shepard Banks exist above the clearly defined transgressive ravinement, indicating either a wholly marine origin for the banks or near complete reworking and mobilization of prior sand deposits leaving the modern banks and sand shoals. Smaller scale bedforms located on the larger Banks demonstrate the active reworking of the larger sand deposits related to oceanographic processes (Ocean Surveys, Inc. 2023).

The distribution of sand shoals and banks within the Upper OCS investigation area and beyond is likely to correlate to a proximal sand deposit in the shallow subsurface or areas of increased local accommodation. If preserved, the shallow subsurface sand deposits genetically linked to the surficial shoals could provide additional sand resources. The larger named banks overlie varying amounts of Sabine Incised Valley Fill with proximal fluvial sand-rich channel belts preserved in the shallow subsurface. Shepard Bank contains sand resources and is situated directly above the main Sabine Incised Valley and a shallow tributary. Underlying the sand bank is estuarine and deltaic valley fill, which previous researchers hypothesized could create increased local accommodation due to consolidation of valley fill sediment for surficial deposition during the transgression of the Texas Shelf (Rodriguez et al. 2004). The thickest portion of Shepard and Sabine Bank overlies the thickest Sabine Incised Valley Fill similar to findings from Miller, Goff, Gulick, & Lowery (2024), Miller, Goff, Gulick, Wallace, et al. (2024), and Ocean Surveys, Inc. (2023). Heald and Sabine Bank overlie variable thicknesses of Sabine Incised Valley Fill. The smaller shoals are generally located on the interfluve areas of the main Sabine Incised Valley, resting above Pleistocene sediment and appear to be loosely correlated to the presence of incisional drainage tributaries. The area seaward of the named banks contains several smaller marine shoals compared to those delineated in the NOAA modeled shoals. The high occurrence of shoals may indicate some underlying sand-rich geology that is genetically linked to the shoals. This type of correlation was suggested further outboard on the shelf and margin (Suter and Berryhill, Jr. 1985). Several additional, previously unexplored, potential surficial and subsurface sand resources likely exist further offshore and east of the current investigation area based on the occurrence of numerous sand shoals, which could significantly increase resource inventories.

5.3 Refined Geological Features

The Upper Texas OCS contains several surficial features that have potential as significant sediment resources. As part of the 2022 investigation, the geophysical data were used to determine potential sand locations as well as assess major regional stratigraphic features located in the investigation area. APTIM conducted a preliminary volume calculation on the potential sediment available within Sabine, Heald, Shepard and adjacent shoals and determined a potential gross volume of ~5.9 BCY (~4.5 BCM). Several Pleistocene fluvial channel belts and terraces were also identified in the subsurface, and from the reconnaissance geophysical data, estimated to potentially contain an additional ~2.1 BCY (1.6 BCM) of sediment resources. The original geometric boundaries and interpretations of depositional environment of these geologic features based on geophysical data have been refined through the integration of 74 vibracores, as well as archival sediment cores and new potential sand resource estimates were presented.

In addition to the large regional units, smaller, isolated features were also identified during data processing. These localized features are observed throughout the study area, and many have a high-potential for sand-bearing deposits but are not observed on adjacent geophysical lines due to the reconnaissance-level line spacing, making characterization and quantification of the isolated potential sand resources difficult at this spatial resolution. These smaller features appear to be related to fluvial channel systems displaying dipping clinoforms, which are indicative of sand-rich sediment in prior investigations. (APTIM and TWI Forthcoming)

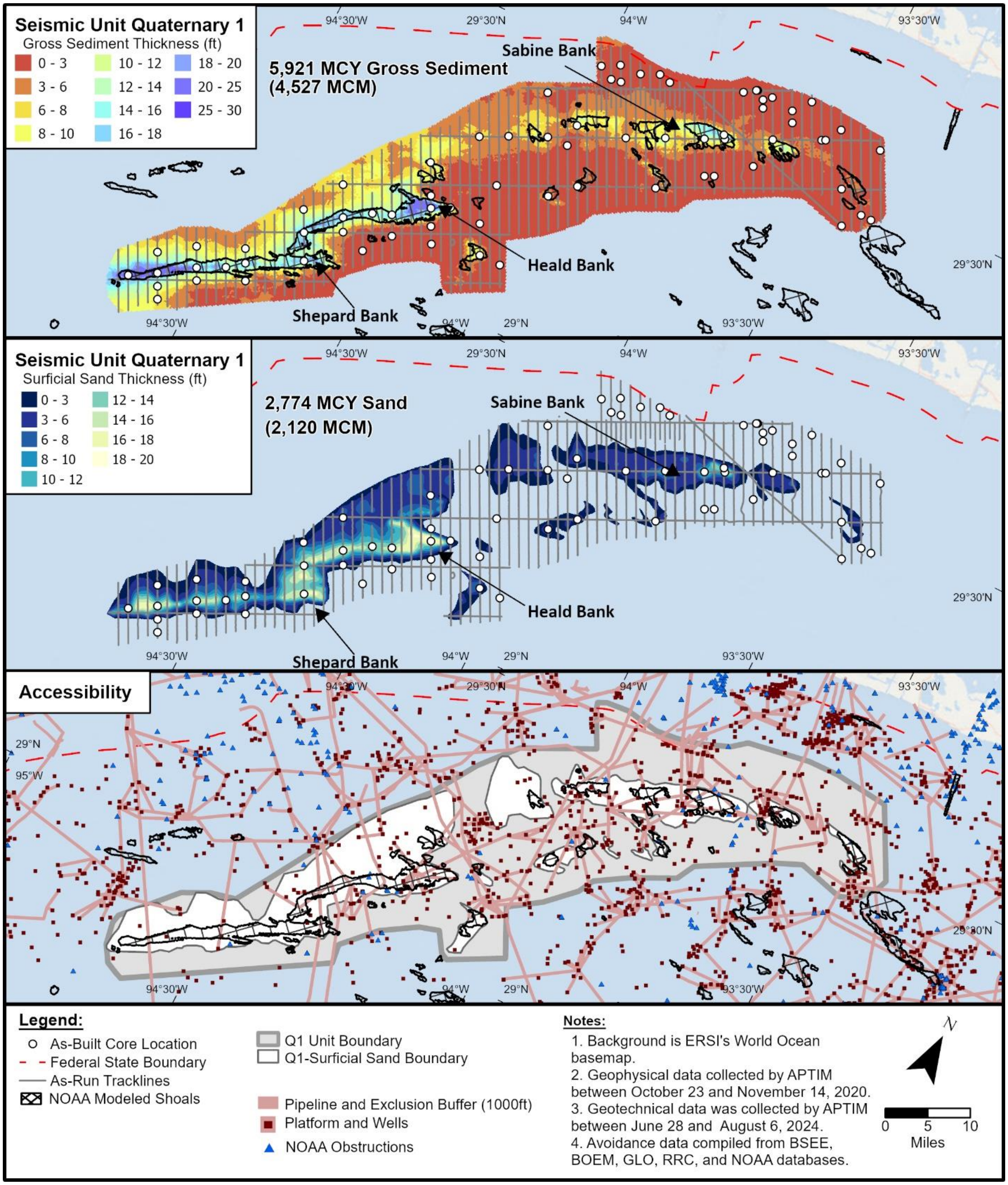
5.3.1 Seismic Unit Q1

The Seismic Unit Quaternary 1 (Q1) identified during the geophysical investigation (APTIM and TWI 2022) is a surficial unit overlying the transgressive ravinement surface that with variable composition. Seismic Unit Q1, as defined in APTIM and TWI (2022), includes the previously described Sabine, Heald, and Shepard Banks identified within Dellapenna et al. (2009) and Rodriguez et al. (2004), as well as smaller surficial shoals and sand sheets.

From the correlation of the geotechnical and geophysical data, APTIM and TWI were able to further characterize the Q1 deposit and generate a secondary isopach for Q1 that isolates the areas with sand content composed of less than 30 percent fines (Figure 22). The two isopachs of potential sediment resources are presented for the surficial Q1 unit, as well as overlays to help determine resource accessibility from various infrastructure and other avoidance areas. The gross sediment volume represents the uppermost unit above the transgressive ravinement surface, while the surficial sand isopach displays the thickness of sands contained within the uppermost Q1 unit. The surficial sand isopach was generated by refining the original geophysical interpretations of the Q1 vertical and spatial boundaries with the current geotechnical sampling. The accessibility panel combines various pipeline, well, and platform locations and their safety buffer (1,000 feet [300 meters]) as well as shipwrecks and other avoidance areas. Gross sediment thickness of the Q1 unit was greatest at Heald and Shepard Bank reaching up to ~30 feet (~9.1 meters). Sand thickness was greatest at Sabine and Heald Banks, up to 20 feet (6.1 meters), as previous investigations have identified. However, the extent of sand contained within Shepard Bank and its flanking adjacent shoal should be highlighted for resource consideration as well. It appears the sand isopach more closely follows the prominent bathymetric expressions of the surficial features but is more expansive than the NOAA modeled shoals. Several of the smaller shoals have sand thicknesses between ~3 to 10 feet (~1 to 3 meters) and extend beyond the current investigation area. The shoals further offshore are shown to have similar thickness from repurposed archival seismic data but lack geotechnical sampling to estimate sand content (Flocks et al. 2023). Identifying resource areas with limited accessibility due to various infrastructure and avoidance areas (Figure 22) can aid in future seafloor multi-use conflict management decisions.

Due to the spacing of the geophysical data and geotechnical sampling over a large reconnaissance investigation area, these isopachs and associated volumes of gross sediment and sand are first order estimates to be refined with more detailed investigations. The original reconnaissance estimates of the Q1 unit within the investigation area was ~5.9 BCY (~4.5 BCM) of gross sediment. Q1 was further characterized and refined through geotechnical sampling and is estimated to contain ~2.8 BCY (~2.1 BCM) of sand with less than 30 percent fines. Sabine Bank has received much of the focus of previous resource investigations (CPE 2002; Ocean Surveys, Inc. 2022; Ocean Surveys, Inc. 2023) however, Heald and Shepard Banks and the smaller shoals contain most of the sand identified in this investigation. These resources have minimal to no overburden and are more extensive than predictions from the NOAA modeled shoals.

Figure 22. Map of potential gross sediment and sand isopachs of Unit Q1 and resource accessibility.
Sand isopachs were generated from reinterpreted seismic data, verified by geotechnical sampling. Resource quantification should be considered first order estimates.



5.3.2 Pleistocene Channel Belts and Fluvial Terraces

The east Texas OCS contains a significant number of potential sand-bearing units located within the study area in the form of subsurface fluvial deposits. As part of this study, five Pleistocene Channel Belt systems were identified, along with two terraces and the Sabine Incised Valley in APTIM and TWI (2022). Through geotechnical sampling and reinterpretation, the original gross sediment volume estimates are refined and new sand resource estimate volumes are presented where possible.

Pleistocene Channel Belts 1 and 2 are located on the northeastern portion of the study area and are characterized by variable amplitude steeply dipping clinoforms and occasional areas of semi-transparent to chaotic acoustic facies. The upper portion of these units either display a transition to a more-layered seismic facies or are truncated by transgressive ravinement. Pleistocene Channel Belts 1 and 2 have a roughly ~40 feet (~12 meters) and 30 feet (9.1 meters) thick sand unit, respectively, with generally less than 5 feet (1.5 meters) of overburden (Figure 23; Figure 24). Geophysical estimates of the larger regional feature produced gross volume estimates of 121 (MCY) (92.5 MCM) and 49 MCY (37.5 MCM) each (APTIM and TWI 2022). Refined estimates for verified sand resources are of 28.4 MCY (21.7 MCM) and 29.1 MCY (22.2 MCM) for Pleistocene Channel Belts 1 and 2, respectively, with minimal overburden. Pleistocene Channel Belt 1 sand resources are free of infrastructure or other avoidance areas impeding the accessibility of the resource after further detailed level investigation. Pleistocene Channel Belt 2 sand resources are much less accessible due to avoidance areas (Figure 23; Figure 24).

Pleistocene Channel Belts 3 through 5 are located on the central portion of the study area, seaward, and under Heald Bank. These channel belt systems show variable geometry and occasional cross-cutting by incisional drainages feeding into Sabine Valley. The channel belts are characterized by steeply dipping clinoforms that grade into U-shaped channel forms at the edge of the belt deposit. The likely sandier portion of the system is roughly 20 to 50 feet (6 to 15.2 meters) thick, with 0 to 20 feet (0 to 6.1 meters) of overburden and a potential gross volume of 78 MCY (59.6 MCM), 67 MCY (51.2 MCM), and 107 MCY (81.8 MCM) for Pleistocene Channel Belts 3, 4, and 5, respectively (APTIM and TWI 2022). The targeted facies of Pleistocene Channel Belt 3 and 4 were not sampled by vibracore and could not be verified. Only Pleistocene Channel 5 was verified, and estimated to contain 10.6 MCY (8.1 MCM) of sand resources. Pleistocene Channel Belt 5 sand resources occur deeper in the subsurface with greater overburden compared to Pleistocene Channel Belts 1 and 2 and has greater accessibility impacts due to infrastructure and other avoidance areas (Figure 25).

The two identified terraces are located to the north and south of the Holocene Sabine Incised Valley and are characterized by a thick unit with steeply dipping clinoforms and between 0 and 15 feet (0 and 4.6 meters) of overburden. The Sabine North Terrace has a gross estimated volume of 472 MCY (360.9 MCM), and the Sabine South Terrace has an estimated gross volume of 1,240 MCY (948.1 MCM) (APTIM and TWI 2022). Geotechnical sampling of the target facies was limited, as most of the vibracores could not penetrate deep enough to verify the Fluvial Terrace's sand content. However, the North Terrace is estimated to contain 34.6 MCY (26.5 MCM) of sand resources (Figure 26), although only 2 feet (0.6 meters) of sand was sampled at the bottom of a vibracore, which did not have any grain size information. The Sabine South Terrace had a few vibracores that identified sand resources up to 7 feet (2.1 meters) thick; however, due to the reconnaissance line spacing, these seismic facies could not be correlated across multiple lines to further constrain the usable sand resource volumes. For this reason, thickness isopachs are presented along tracklines in Figure 27, but a volume was not calculated. Additional data would be required to further constrain the sand resources within the terraces. Both identified sand-rich portions of the fluvial terraces have minimal accessibility issues, but have greater overburden compared to Pleistocene Channel Belts 1 and 2.

The Sabine Incised Valley system is a major stratigraphic unit across the entire study area. The edges of the system are well defined within this investigation; however, the actual base of the valley is not observed due to an amalgamated sand-rich fluvial unit formed during the lowstand and early stage of the transgression that has a very high-amplitude acoustic return and allows for little penetration. Therefore, this investigation was unable to estimate a gross volume of the Incised Valley system, although it is expected to be considerably large and buried under a roughly 30 to 40 feet (9.1 to 12.2 meters) thick estuarine unit, with some smaller areas being slightly less thick.

The major subsurface geologic features observed represent a cumulative gross sediment volume of ~2.1 BCY (~1.6 BCM). These gross sediment volume estimates of major subsurface geologic features were refined to help assess potential sand resources contained within the subsurface features through geotechnical sampling, providing an estimate of 102.7 MCY (78.5 MCM) of sand. The precise composition of these deposits is likely highly variable and requires more detailed geological investigation. The features identified in this investigation are not exhaustive or inclusive of all potential sand-bearing stratigraphy within the region but rather represent systems that are regionally extensive and contiguous to be confidently interpreted across the 1 x 5 mile (1.6 x 8 kilometer) spaced survey grid. Several smaller localized features that could not be correlated across reconnaissance level survey grids and their potential as resources are presented in the following section.

Figure 23. Panel figure of sand sampled in cores, identified sand resources, overburden, and accessibility of Pleistocene Channel Belt 1.

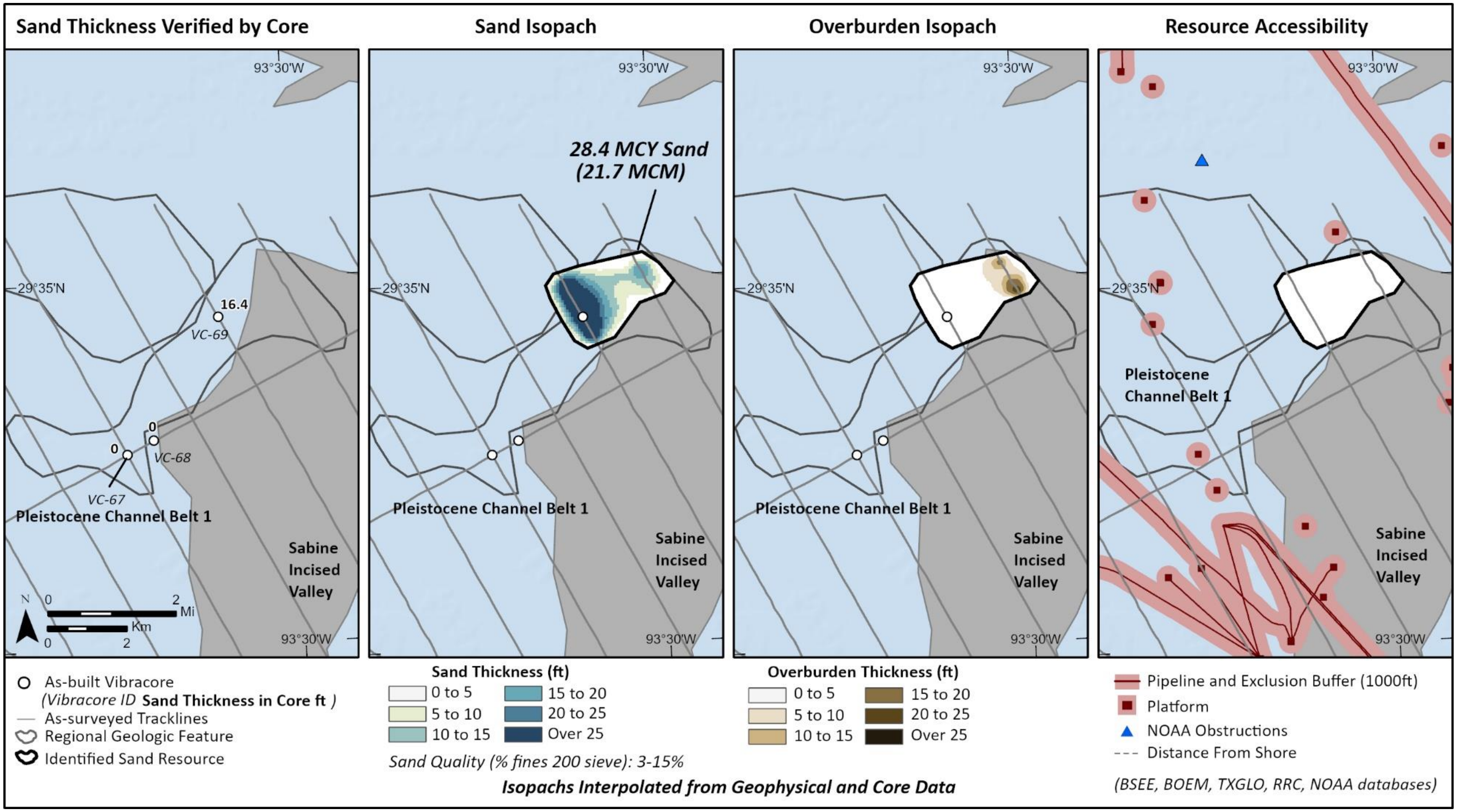


Figure 24. Panel figure of sand sampled in cores, identified sand resources, overburden, and accessibility of Pleistocene Channel Belt 2.

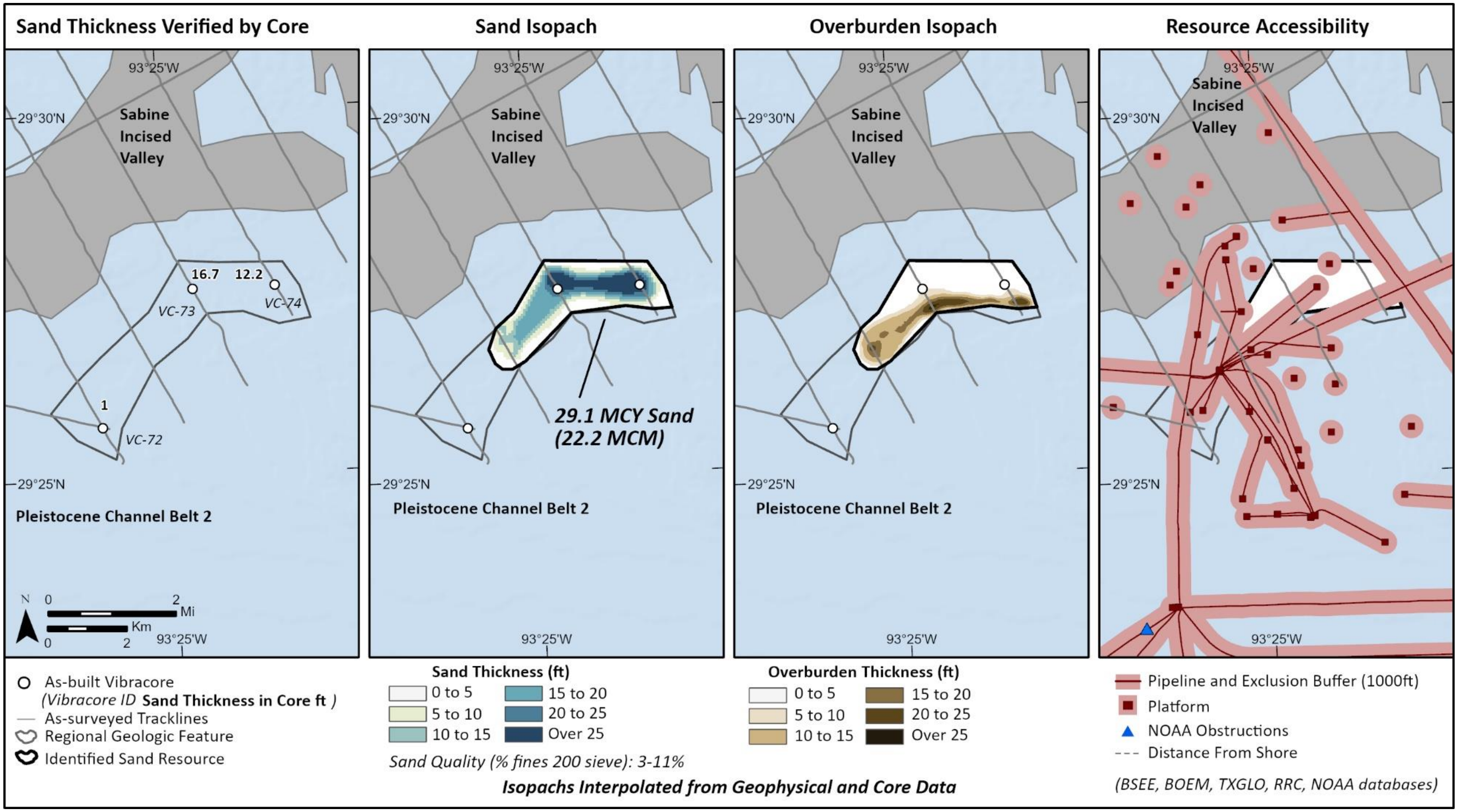


Figure 25. Panel figure of sand sampled in cores, identified sand resources, overburden, and accessibility of Pleistocene Channel Belt 5.

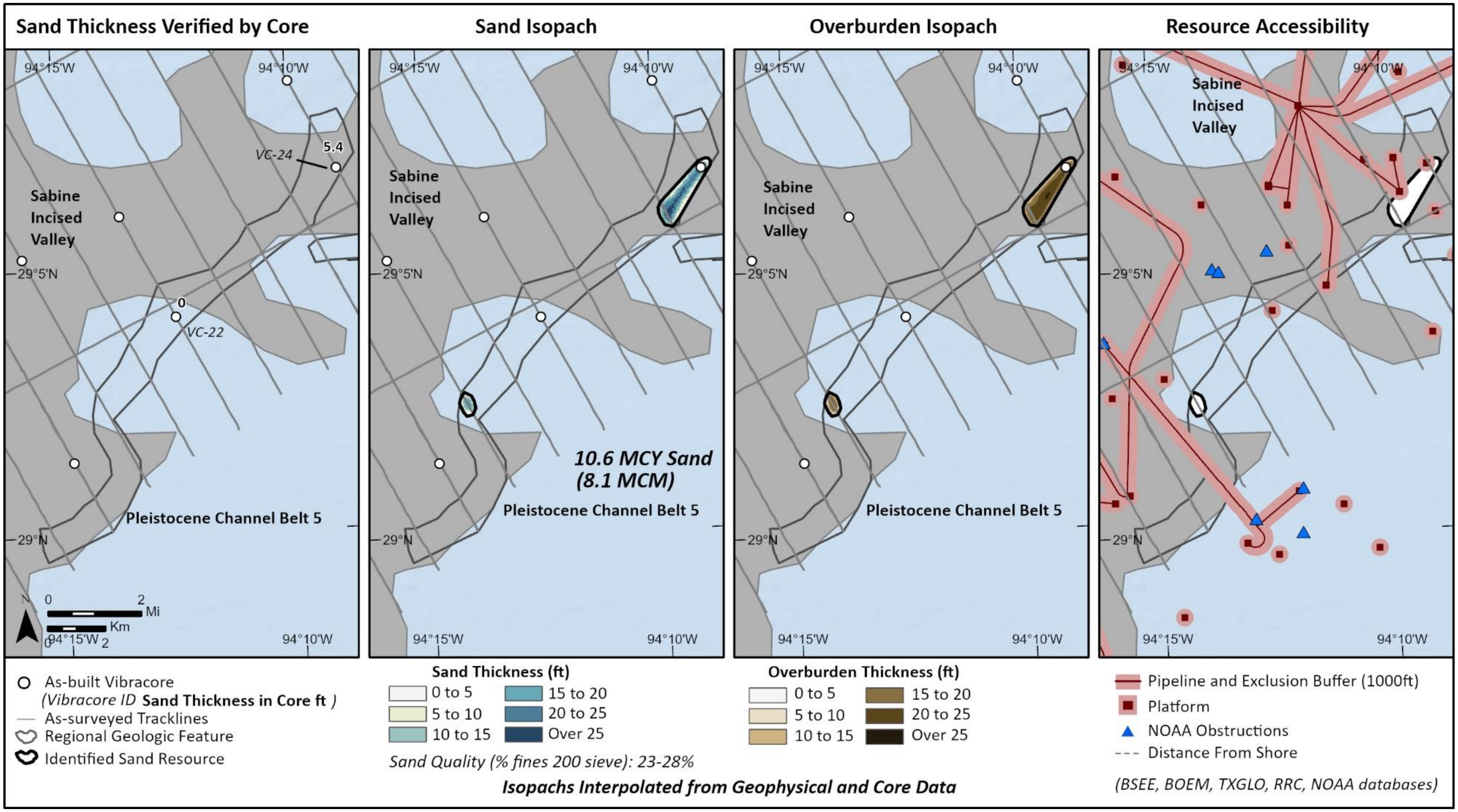


Figure 26. Panel figure of sand sampled in cores, identified sand resources, overburden, and accessibility of Pleistocene Fluvial North Terrace.

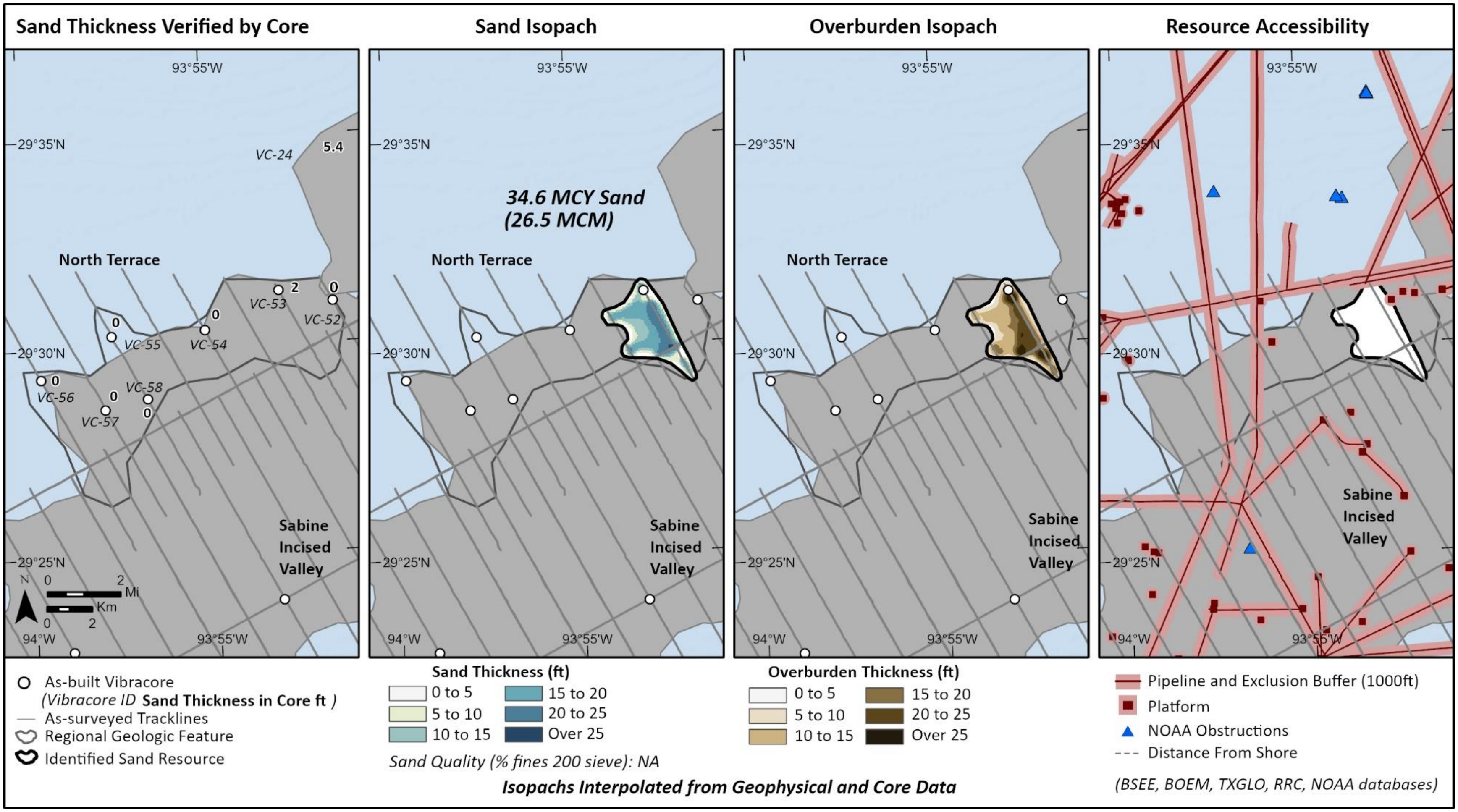


Figure 27. Panel figure of sand sampled in cores, identified sand resources, overburden, and accessibility of Pleistocene Fluvial South Terrace.

Note, sand-rich facies could not be correlated between tracklines so no volume was calculated, but sand and overburden thicknesses are presented along tracklines.

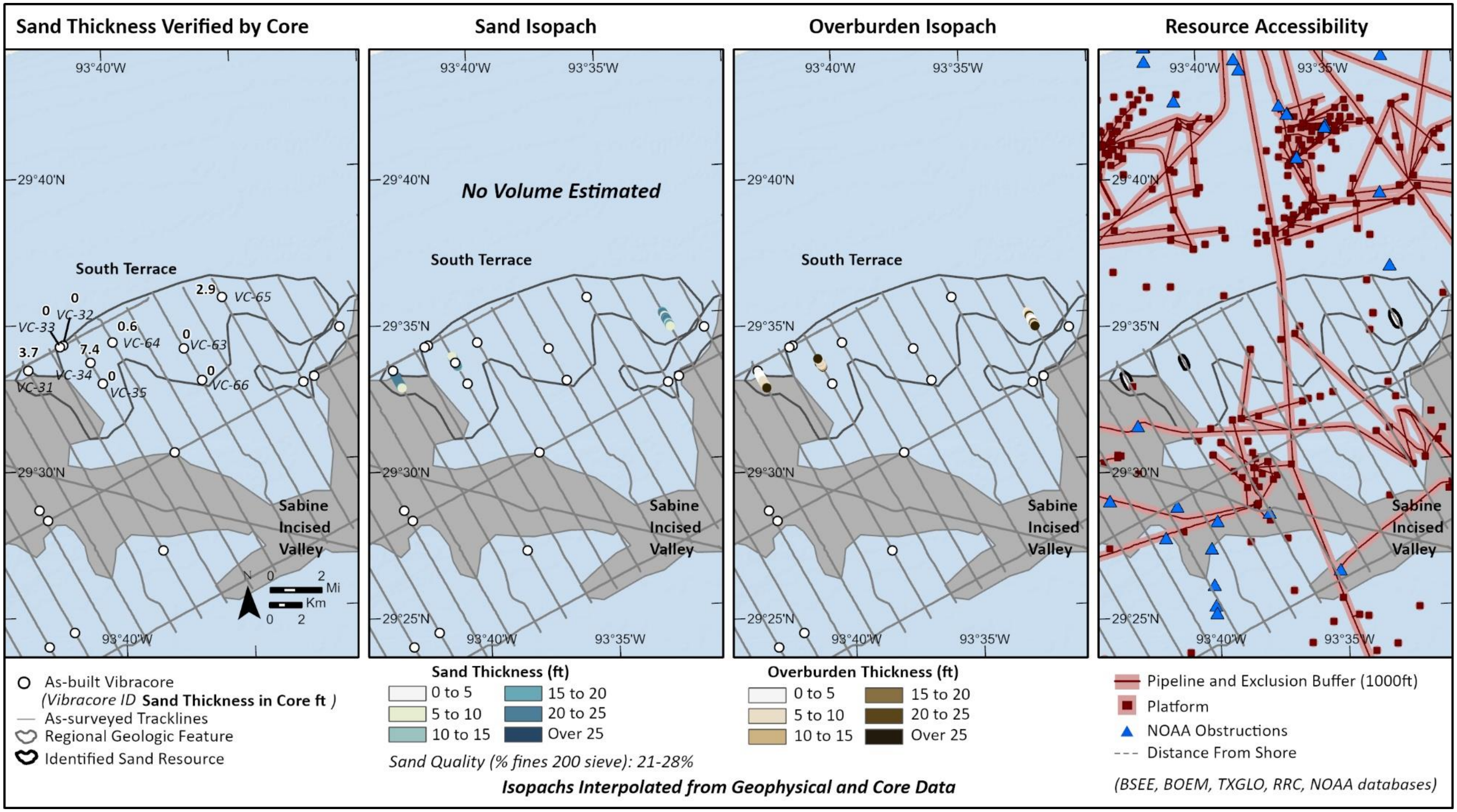


Table 6. Potential sand volume identified within study area.

Feature	Sampled (was a core taken)	VC name(s) (GLO-UPOCS-VC-#)	Sand at Surface (ft)	Sand at Depth (overburden/thickness, ft)	Sand Volume (MCY)
Seismic Quaternary Unit 1 (Surficial Sands)	Y	1,2,3,7,8,9,11,12,13,14 15,16,17,18,20,21,25,27 29, 36,37,40, 41,44, 46, 50, 59, 60,61,62	Up to 18	0	2,774
Pleistocene Channel Belt 1	Y	67, 68, 69	16.4	0	28.4
Pleistocene Channel Belt 2	Y	72, 73, 74	16.7	0	29.1
Pleistocene Channel Belt 3	Y	26, 28	0	0	0
Pleistocene Channel Belt 4	Y	23	0	0	0
Pleistocene Channel Belt 5	Y	22, 24	0	14.2/5.4	10.6
Sabine North Terrace	Y	31, 32, 33, 34, 35, 63, 64, 65, 66	0	16.9/2	34.6
Sabine North Terrace	Y	52, 53, 54, 55, 56, 57	0	7.3/7.4	NA
Total	NA	NA	NA	NA	2876.7

NA – not applicable; MCY – million cubic yards

5.3.3 Localized Features

Of the 174 localized features identified during the geophysical survey, 14 were targeted by vibracores (Figure 28 and Table 7). Five vibracores were originally taken with the intent of identifying and qualifying the geotechnical properties of Q1; however due to the length of the vibracore, these five vibracores were also used to sample a localized feature that was present below the transgressive ravinement surface (Q1). Of the 14 vibracores taken that targeted localized features, only GLO-UPOCS-VC-24-48 and GLO-UPOCS-VC-24-49 indicated that the localized feature could be a potential sand resource. The remaining vibracores sampling localized deposits were comprised of lean and/or fat clay. GLO-UPOCS-VC24-48 (Figure 29) targeted localized feature 46 (L46) and showed that the channel infill is likely sand with percent fines ranging from less than 10 to 20 percent. GLO-UPOCS-VC-24-49 targeted L36 and sampled the deposit as having an 8-foot (2.4-meter) thick sand layer (Figure 30), with percent fines ranging between 9 to 23 percent. However, the identified sand unit of L36 has an overburden of 7 feet (2.1 meters) of fat clay, which could impede its accessibility.

Figure 28. Localized features targeted by vibracores.

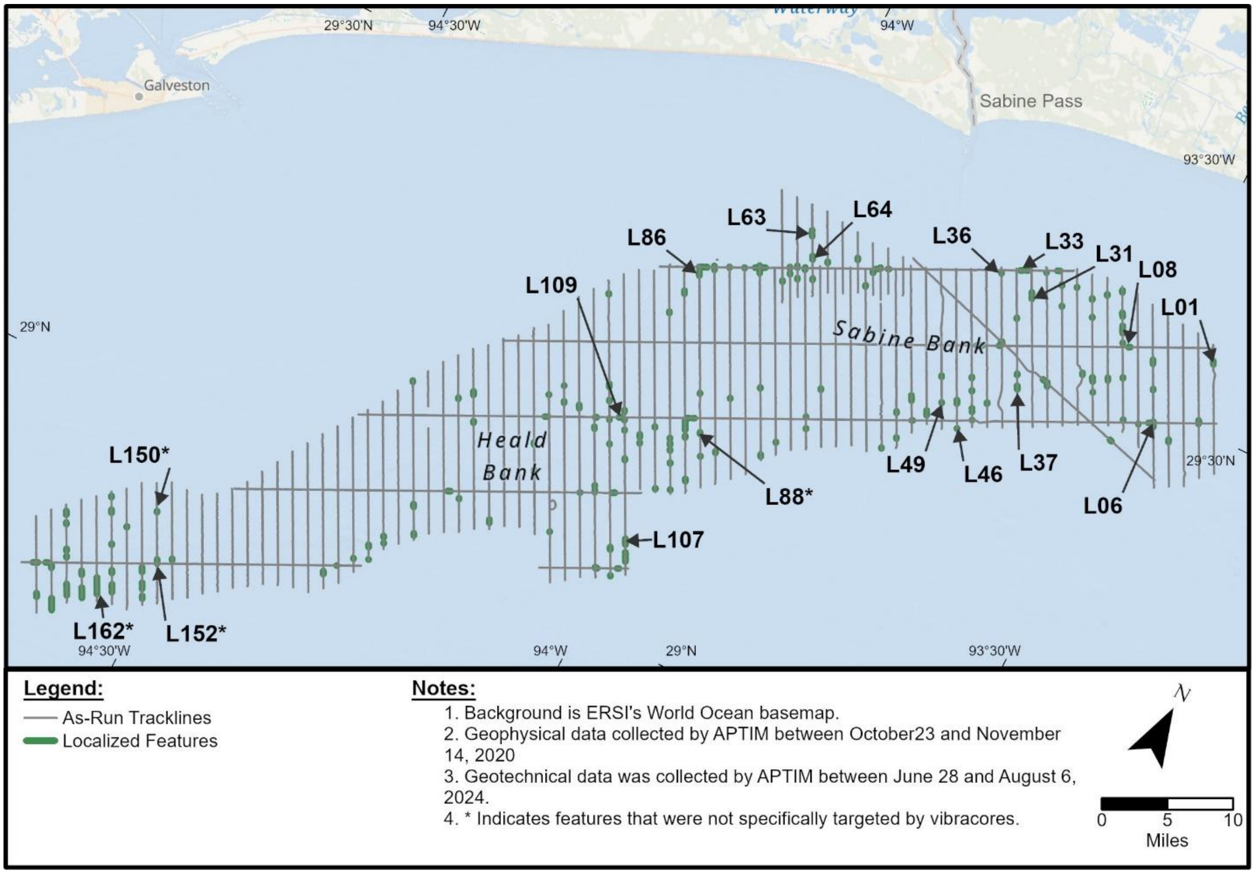


Table 7. Localized features and their potential for sand deposits.

Localized feature	Target	Vibracore ID	Sand at Surface (how thick)	Sand at Depth (overburden/thickness)
L01	Localized Feature	GLO-UPOCS-VC-70	0	0
L06	Localized Feature	GLO-UPOCS-VC-71	0	0
L08	Localized Feature	GLO-UPOCS-VC-68	0	0
L31	Localized Feature	GLO-UPOCS-VC-35	0	0
L33	Localized Feature	GLO-UPOCS-VC-33	0	0
L36	Localized Feature	GLO-UPOCS-VC-49	0	7.3 ft under clay/8.2 ft of sand (10-20% fines)
L37	Localized Feature	GLO-UPOCS-VC-31	0	0
L46	Localized Feature	GLO-UPOCS-VC-48	15.4 ft (5.4 20% fines/10 <10% fines)	0
L49	Localized Feature	GLO-UPOCS-VC-47	0	0
L63	Localized Feature	GLO-UPOCS-VC-55	0	0
L64	Localized Feature	GLO-UPOCS-VC-58	0	0
L86	Localized Feature	GLO-UPOCS-VC-51	0	0

Localized feature	Target	Vibracore ID	Sand at Surface (how thick)	Sand at Depth (overburden/thickness)
L88*	Seismic Unit Q1	GLO-UPOCS-VC-44	1.9 ft shelly sand/ 5.6 ft <10% fines (tot: 7.5 ft)	0
L107	Localized Feature	GLO-UPOCS-VC-30	0	0
L109	Localized Feature	GLO-UPOCS-VC-42	0	0
L150*	Seismic Unit Q1	GLO-UPOCS-VC-08	6.3 ft >30% fines	0
L152*	Seismic Unit Q1	GLO-UPOCS-VC-06	0	0
L162*	Seismic Unit Q1	GLO-UPOCS-VC-05	0	0

Note: * indicates that core was not initially targeting a localized feature (explained below).
< - less than; > - greater than; % - percent; ft – feet/foot

Figure 29. Vibracore GLO-UPOCS-VC-24-48 taken on localized feature L46 on seismic line 018.

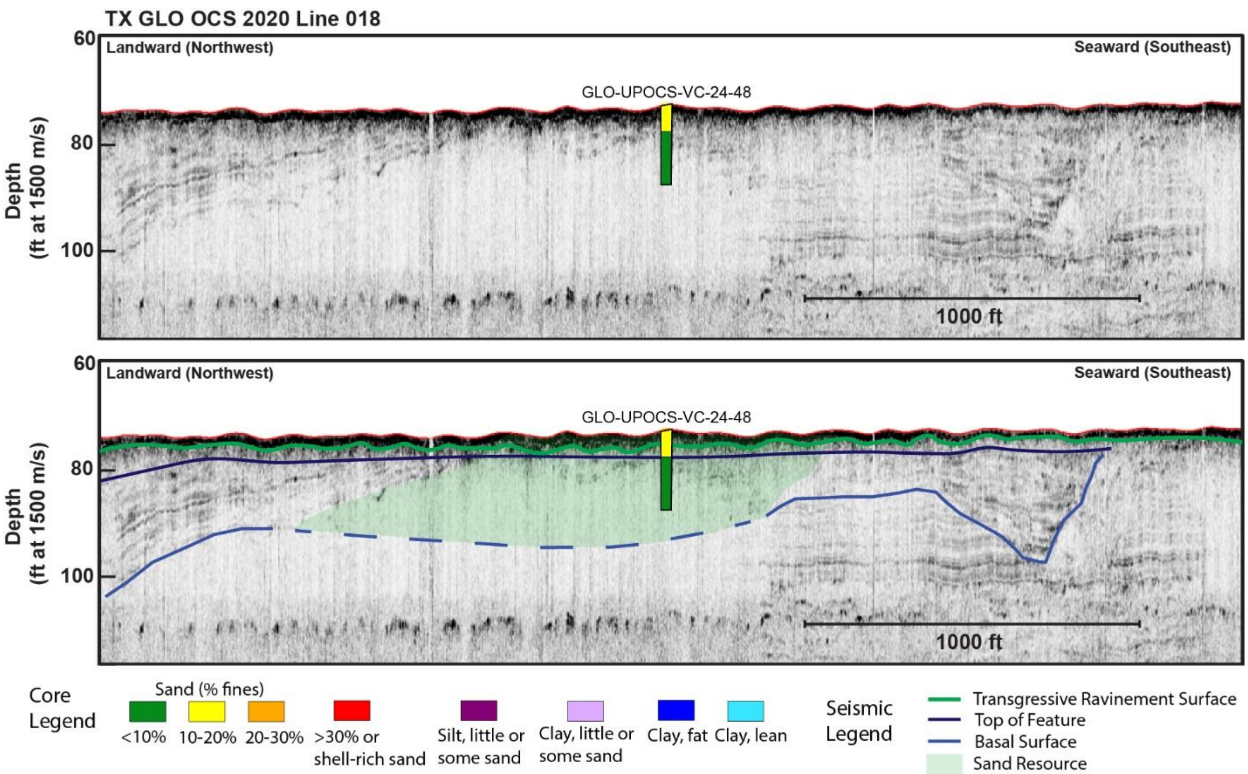
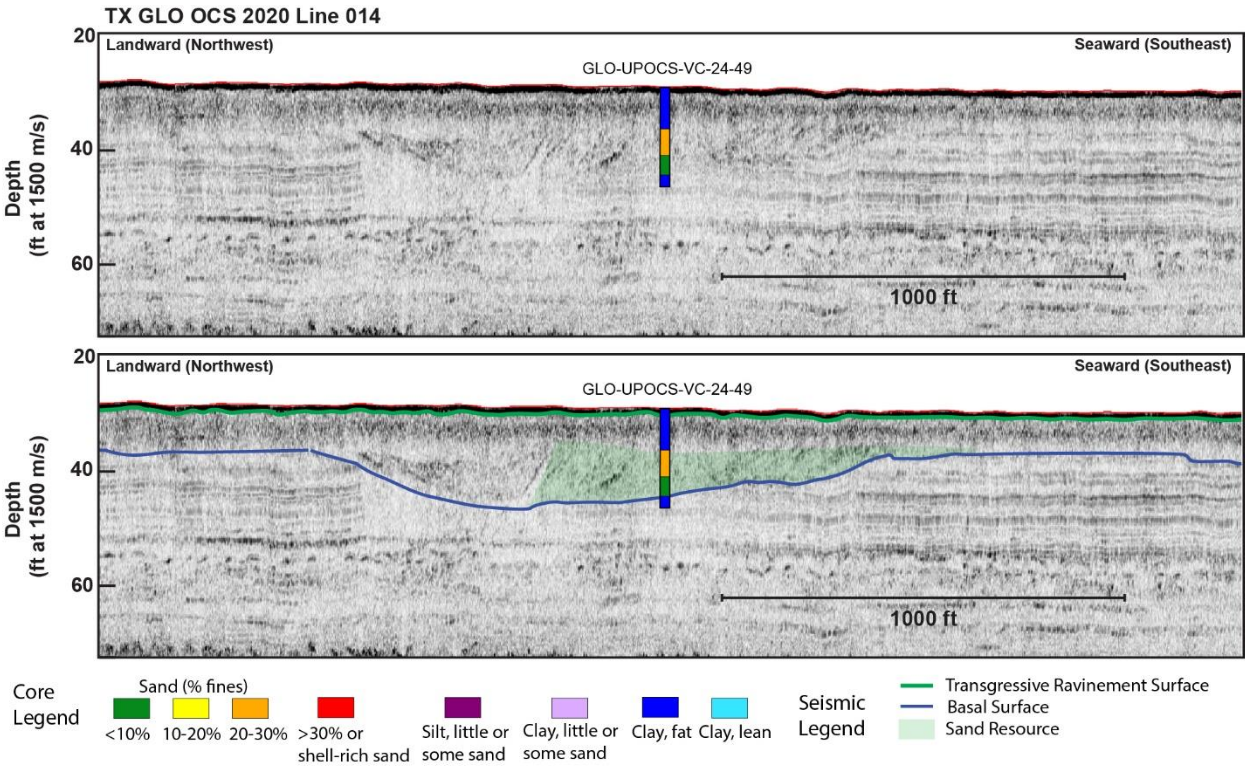


Figure 30. Vibracore GLO-UPOCS-VC-24-49 taken on localized feature L36 on seismic line 014.



Some of the sampled localized features, the targeted deposit, and likely the sandier portion of the resource, were not reached due to the nature of the overburden. The targeted potential sand resources that were not sampled by the vibracore exhibit a seismic acoustic signal indicative of dipping clinoforms. Dipping clinoforms were sampled in the adjacent Region 1 (APTIM and TWI Forthcoming) study and were found to be sand-rich. Therefore, it is likely that with additional data, some of the localized features showing similar seismic facies as the sandier portions channel belt systems could be identified as additional resources. GLO-UPOCS-VC-24-30 recovered 11.7 feet (3.6 meters); however, it did not reach the intended acoustically transparent layer that was labeled as a localized feature in the previous GLO Upper OCS Geophysical report (Figure 31 and Figure 32) (APTIM and TWI 2022). Similarly, GLO-UPOCS-VC-24-55 only recovered 9.8 feet (2.9 meters) and did not fully penetrate the targeted acoustically transparent layer. With additional data collection efforts, these resources could be further mapped and identified as potential resources.

Figure 31. Vibracore taken on localized feature L107 on seismic line 040.

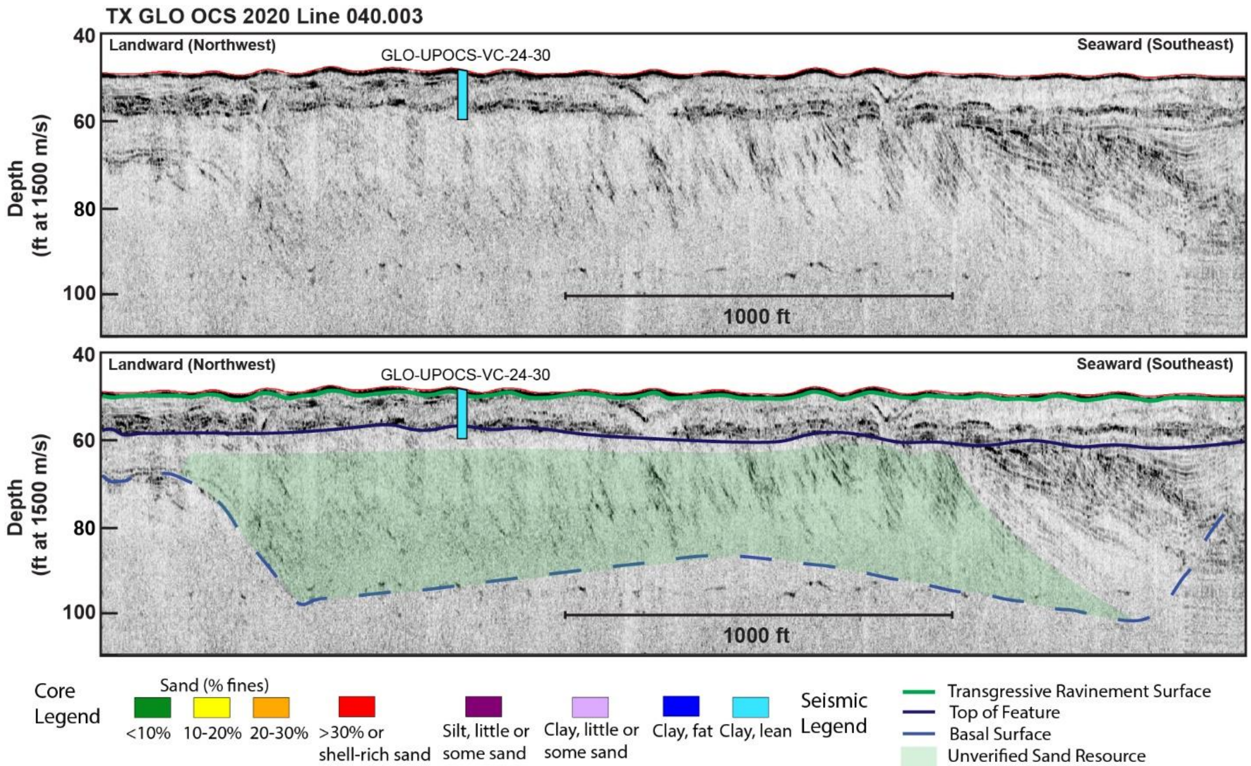
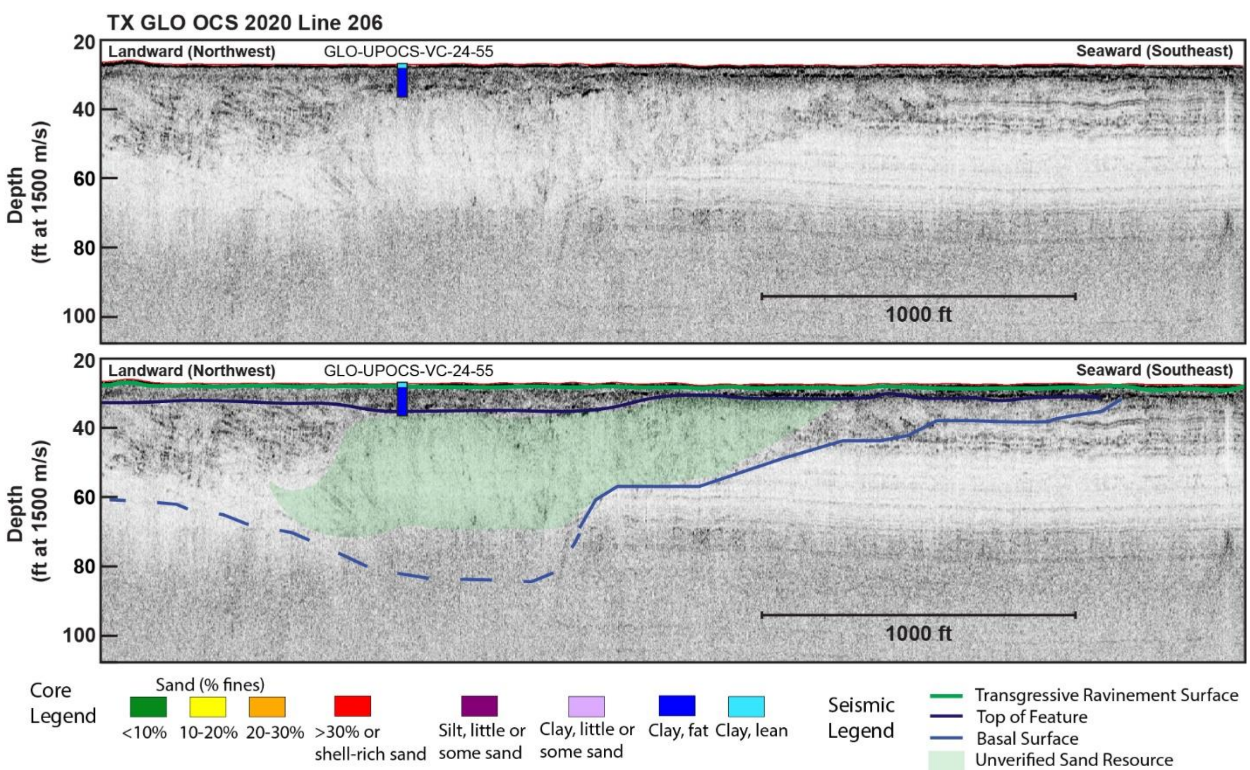


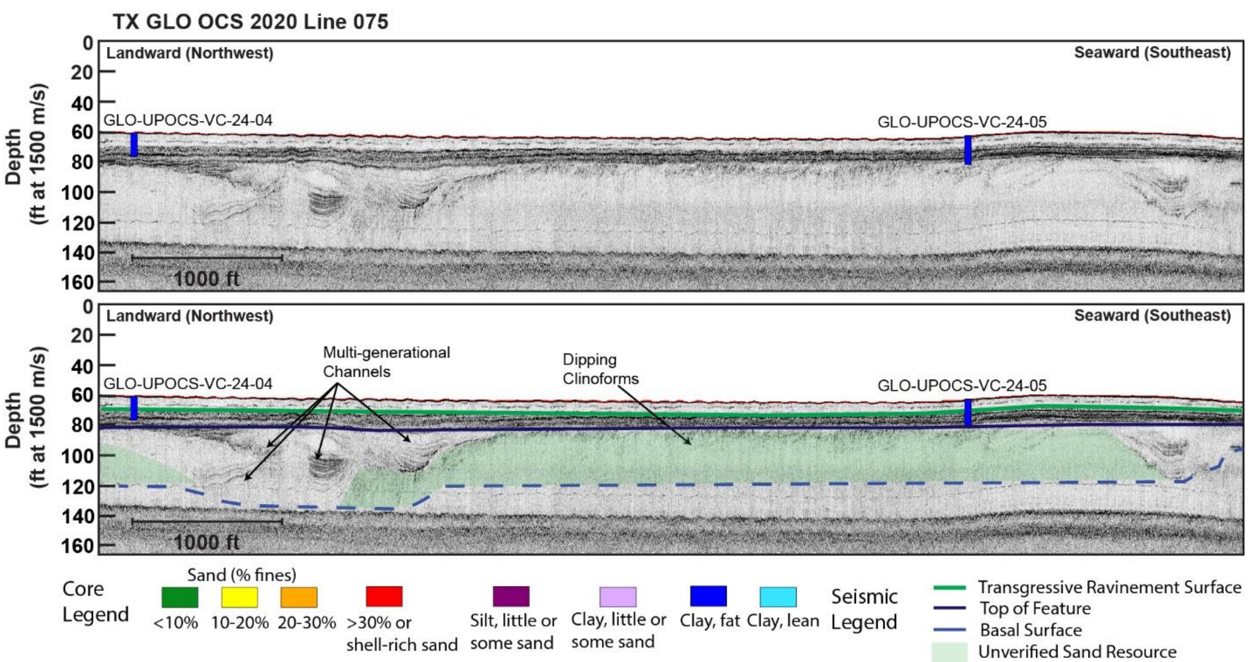
Figure 32. Vibracore GLO-UPOCS-VC-24-55 taken on localized feature L63 on seismic line 206.



To identify the geotechnical properties of Q1, APTIM initially obtained five vibracores; however, two of the five vibracores were able to sample the underlying localized features, which were found to contain sandy deposits (GLO-UPOCS-VC-24-08 and GLO-UPOCS-VC-24-44). The remaining three vibracores indicated a deposit that consisted of lean and/or fat clay. GLO-UPOCS-VC-24-08 was collected in L150 and sampled a 6.3 feet (1.9 meters) layer of sand and silty sand with percent fines that were greater than 29 percent in the localized feature. GLO-UPOCS-VC-24-44 (L88) indicated a channel infill of 5.6 feet (1.71 meters) of sand with less than 10 percent fines with a 2-foot (0.61-meter) overburden layer of sandy shell hash.

Localized features in the southern portion of the investigation area identified from geophysical data were interpreted as potentially sandy deposits. They are characterized by dipping clinoform packages grading into stacked multi-generational incisional channels (Figure 33). Due to the nature and amount of overburden the two vibracores originally taken to identify geotechnical properties of Q1 did not sample the potentially sandy localized feature at depth.

Figure 33. Example sub-bottom data across stacked multi-generational Pleistocene channel belts in southern portion of OCS investigation area.
Vibracore GLO-UPOCS-VC-24-04 and 05 taken on localized feature L152 on seismic line 75. Inset figure from Figure 13.



Given the localized nature of these deposits and the reconnaissance line spacing, APTIM and TWI were unable to calculate potential resource volumes. Additional geophysical and geotechnical data targeting these resources are needed to further constrain the boundaries of the feature and estimate the feature's available resource volumes.

6 Conclusion

The Texas GLO and BOEM contracted APTIM with its team member TWI to conduct geotechnical sampling along Sabine, Heald, and Shepard Bank, as well as adjacent deposits to further assist the GLO and BOEM with identifying and delineating sediment resources along the Texas Outer Continental Shelf. The goal of the project is to build on the investigation efforts initially conducted by APTIM and TWI in

2022, which consisted of the collection of 1,133 nm (2,098.3 km) of full-suite geophysical data (seismic sub-bottom, sidescan sonar, and magnetometer) and hydrographic data (single beam bathymetry), followed by data interpretation, and identification of major regional stratigraphic features that could be a potential sand resource. From the conclusions of the study conducted in 2022, APTIM and TWI were further tasked with collecting 74 vibracores in the previously investigated area to assist with further delineating, constraining, and characterizing the previously identified resources and assessing their potential usability as sand resources for future coastal restoration needs.

Between June 28, 2024, and August 6, 2024, APTIM collected 74 vibracores that were then analyzed and integrated with geophysical data to refine major stratigraphic feature interpretations and resource potential, as well as update the previously developed regional geologic framework model. It is important to note that previous gross sediment volumes presented in APTIM and TWI (2022) are still considered potential resources and are presented in this report. Since the geotechnical data collected as part of this study did not sample the entirety of the resource, APTIM and TWI were unable to confirm the presence or quality of the resources where they were not sampled and are retaining their “potential” designation based on the earlier geophysical data interpretation. Additional data collection that samples the entirety of the resource would be needed to fully confirm the deposit. Where possible, estimated volumes were calculated with the additional geotechnical data to further assist in constraining the sandier portions of the resource.

The surficial Seismic Unit Q1 representing the uppermost unit above the transgressive ravinement surface, was delineated in the geophysical portion of the investigation and estimated to contain ~5.9 BCY (~4.5 BCM) of sediment. With the geotechnical investigation, that volume was further constrained to the specific sampled regions and the sand portion of this uppermost unit could contain ~2.8 BCY (~2.1 BCM) of surficial sand resources. The sand quality varies from less than 5 percent fines to 30 percent fines. In addition to the major banks in the region (Heald, Sabine, and Shepard), APTIM and TWI also identified smaller shoals within Q1 that were also sampled to have significant sediment resources. The identified sand portions of the small shoals and sand bank facies varied from feature to feature; however, the more prevalent facies consisted of an upper unit with internal architecture overlying a transparent unit bounded by the transgressive ravinement surface. Similar internal transparent seismic facies on the sand banks or smaller shoals show drastic variability in sediment composition, highlighting the importance of geotechnical ground-truthing. Areas of “hazy” seafloor reflectors at the seaward base of the shoals were correlated to areas of thick shell hash.

Of the named Sabine, Heald, and Shepard Banks, Heald and Shepard Banks contain equally as thick sands as Sabine Bank and appear to have a larger spatial footprint. However, Heald Bank’s potential sand resources are the most impacted by multiple use and hazards due to oil and gas infrastructure and other obstacles. The thickest portions of sands are along the shoal or bank crest and generally follow the seafloor expression as identified in bathymetry. There is an exception to this in the southwest portion of the investigation area on the flank of Shepard Bank, where an over 10-foot (3-meter) thick sand unit was sampled with little bathymetric expression. Generally, fine-grained Holocene or Pleistocene sediment outcrop seaward of the shoal or bank crest, whereas a thinning sand sheet is found landward of the shoal crest. Several smaller shoals that are not named are verified to contain ~3 to 10 feet (~1 to 3 meters) of sand and extend beyond the current investigation area offshore Texas and Louisiana and appear more extensive than the areas highlighted by the NOAA-modeled shoals. This investigation identifies several significant surficial sand resources contained within the broader Q1 deposit, some previously unverified. The smaller unnamed shoal system could present a host of new resource targets if expanded beyond the current investigation area boundaries.

The previously identified subsurface fluvial Pleistocene Channel Belts and terraces are estimated to contain 102.7 MCY (78.5 MCM) of sand resources. Pleistocene Channel Belts 1, 2, and 5 are verified with geotechnical data to contain sand, while Pleistocene Channel Belts 1 and 2 provide the most promising, homogenous sand resources with little to no overburden. The verified sand-rich seismic facies within the larger channel belt feature are characterized by transparent to faintly dipping reflectors with a loss of acoustic imaging below. Pleistocene Channel Belt 1 is less impacted by existing infrastructure and other avoidance areas that limit the accessibility of the sand resources. The Pleistocene Fluvial Terraces remain largely unverified by geotechnical sampling, as most cores could not penetrate deep enough to sample the target facies. “U” shaped channel forms with draping or laminated reflectors are confirmed to contain fine-grained interbedded clays, silts, and sands. Hazy upper portions of the terrace feature are verified as stiff, oxidized Pleistocene fine-grained floodplain sediment. Limited core samplings do show the presence of sand, up to 7 feet (2 meters); however, the 75-foot (23-meter) thick target facies of steeply dipping and bright transparent packages seen at depth within the terraces warrants further exploration using deeper geotechnical sampling methods to determine its potential as a sand resource.

In addition to the large regional units, smaller, localized features were also identified during geophysical data processing. These smaller features are normally isolated channels or sediment pockets, which are indicative of sand or mixed sediments of the identified features, and 14 of them were sampled with vibracores. Of the sampled localized features, four were identified as being potential sandy resources with varying geotechnical properties and overburden. With additional geophysical and geotechnical data, these highlighted localized features could prove to be a potential sand resource. Due to the reconnaissance line spacing and variable nature of the geology of the area, quantification of the potential volume of sand within these localized features at this stage is impossible; however, preliminary findings indicate that these deposits could be used as future sand resources.

The features identified in this investigation are not exhaustive or inclusive of all potential sand-bearing stratigraphy within the region, but rather represent systems that are regionally extensive and contiguous to be confidently interpreted across the 1 x 5 mile (1.6 x 8 kilometer) spaced survey grid. Through this reconnaissance geophysical and geotechnical investigation, ~5.9 BCY (~4.5 BCM) of combined potential gross sediments, of which, ~2.8 BCY (~2.1 BCM) of surficial sand resources were identified in the Upper Texas OCS. Several smaller unnamed shoal systems and underlying Pleistocene fluvial deposits were previously unidentified and present high quality resource targets for further investigations.

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Appendix A: Archaeological Clearance Memo

Appendix B: Maps

Appendix C: Vibracore Logs, Photographs, Granularmetric Reports and Curves (digital)

Appendix D: Digital Deliverables (digital only)