Texas General Land Office
Central Coast Outer Continental Shelf Offshore Sand Source Survey

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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, Michael Lowiec, and APTIM's Geophysical and Hydrographic Survey teams with geophysical data collection, analysis, and interpretation. Beth Forrest (APTIM) provided support throughout the study and contributed to written sections of the report. APTIM's field crew included Chris Dvorscak, Duke Thornburgh, John Patrick Burden, Michael Lazo, Sarah Finkle, Colton Watkins, Jeff Bueche, Austin Pierce, Ryan Stiglbauer. Partnering field crew included Maricel Beltran Burgos (The Water Institute, TWI), Rob Hollis (TWI), Diana DiLeonardo (TWI) and Shannon Chiarel (RECON). John Swartz, Rob Hollis, and Mike Miner from TWI contributed to survey planning, synthesis of existing geologic and geophysical data and literature, data interpretation and development of conceptual geologic models, and report preparation.

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Beau Suthard (APTIM) worked under the guidance of Texas General Land Office Coastal Erosion Planning and Response Act (CEPRA) Project Manager Kelly Brooks. Partners included TWI (Mike Miner, Ph.D., Rob Hollis, and John Swartz, Ph.D.). Funding for this project was provided through BOEM Award Number M21AC00020 managed by the Texas General Land Office CEPRA program.

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Acronyms and Abbreviations

%	percent
~	approximately
AD	Alluvial-Deltaic Feature
ACZ	Acoustic Celar Zone
AGC	Automatic Gain Control
APTIM	Aptim Environmental & Infrastructure, LLC
APTIM-CPE	APTIM (formerly known as Coastal Planning & Engineering, Inc.)
ArcGIS	Arc Geographic Information System
BCM	billion cubic meters
BCY	billion cubic yards
BOEM	Bureau of Ocean Energy Management
CB	Channel Belt
CEPRA	Coastal Erosion Planning and Response Act
CORS	National Geodetic Survey Continually Operating Reference Stations
DGPS	Differential Global Positioning System
EA	Final Environmental Assessment on Sand Survey Activities
EBS	East Breaks Side
EGN	Empirical Gain Normalization
FRBH	Freeport Rocks Bathymetric High
ft	feet (foot)
GLO	General Land Office
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HRG	High-Resolution Geophysical
HRG	High-Resolution Geophysical
Hz	hertz
In	inches
kHz	kilohertz
km	kilometer(s)
m	meter(s)
m/ms	meter(s) per millisecond
MCM	million cubic meters
MCY	million cubic yards
MFS	maximum flooding surface
mi	mile(s)
MIS	Marine Isotope Stage
Mm	millimeters
mm/yr	millimeter(s) per year
MMP	Marine Minerals Program
MRU	Motion Reference Unit
NAD	North American Datum
NAVD	North American Vertical Datum
NAVSTAR	Navigation Satellite Timing and Ranging
nm	nautical mile(s)
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
nT	nanotesla

OCS	Outer Continental Shelf
PAM	Passive Acoustic Monitoring
PPK	Post-Processing Kinematic
PSO	Protected Species Observer
SEPM	Society for Sedimentary Geology
SU	subunit(s)
SVP	Sound Velocity Profiler
TBC	Trimble Business Center
TIF	tagged image file
TMB	Texas Mud Blanket
TVG	Time-Varying Gain
TWI	The Water Institute
UGC	User-Defined Gain Control
USCG	U. S. Coast Guard
USMB	Upper Slope Mini Basin
UTIG	University of Texas Institute for Geophysics
yrs	years

Executive Summary

Through a grant from the Bureau of Ocean Energy Management (BOEM), the Texas General Land Office (GLO) contracted Aptim Environmental & Infrastructure, LLC (APTIM), with team member The Water Institute (TWI) to conduct geophysical surveys to assist the GLO and BOEM with identifying and delineating sediment resources along the Texas Central Coast Outer Continental Shelf (OCS). The APTIM team conducted an extensive review of existing geophysical and geotechnical data to ensure no duplication of data occurred. Marine hazard and resource data were also acquired and compiled, reviewed, and incorporated to further develop the geophysical survey plan. APTIM reviewed the existing data to assess seafloor depth, seafloor hazards, base of overburden, top of sand, base of sand, channels/paleochannels, and ravinement surfaces. Based on this evaluation, the APTIM team developed a survey plan that made the most efficient use of existing data while avoiding collecting duplicate data.

An initial survey plan was developed consisting of 1,212 nautical miles (nm [2,245 kilometers[km]]) of full suite geophysical and single beam bathymetry data consisting of 1 nm (1.9 km) spaced shore perpendicular lines and 5 nm (9.3 km) spaced shore parallel lines in the northern area, and 5 nm (9.3 km) shore perpendicular lines with five (5) tie lines. Between September 22 and October 13, 2022, the APTIM crew conducted 24-hour survey efforts and collected 1,218 nm (2,256 km) of full suite geophysical (sub-bottom, sidescan sonar, magnetometer, and single beam bathymetry) data along the Texas Central OCS offshore the GLO Regions 1, 2, and 3 (Protraction Number TX2, TX3, TX4, TX5, TX6) within the investigation area in support of the GLO Sediment Management Plan Surveys of the Federal OCS. At the time of this report, no new geological data were collected.

Interpretation of the reconnaissance geophysical survey data collected along the Texas Central OCS identified major regional stratigraphic features located across the study area and developed a regional geologic framework of major depositional systems that have the potential to contain accessible sand resources. Note that these interpretations are based primarily on geophysical data and no new geological data to ground truth and inform sediment resource quality and textural properties had been collected at the time of this report. The Texas Central Coast OCS contains a significant number of potential sand-bearing units located within the study area in the form of fluvial deposits and sand bank features, and surficial units. Nineteen large-scale features were identified and loosely organized by regions as follows: 1) OCS Galveston and Brazos protraction areas (TX5, TX6) and 2) OCS Matagorda, Mustang, and North Padre Island protraction areas (TX2, TX3, TX4).

Within the Galveston and Brazos protraction areas of the Central Coast OCS, there are six regionally mappable, likely sand-bearing sediment units interpreted from geophysical data with less than 20 feet (ft [6.1 meters [m]]) of overburden. As part of this investigation, one surficial shoal, three channel belts, one alluvial-deltaic feature with potentially sandy subunits, and one undifferentiated sandy feature were identified and estimated to contain roughly 1.54 billion cubic yards (1.2 billion cubic meters) of potentially restoration-compatible resources. The largest potential sediment resource target is found within the Colorado Incised Valley and is interpreted to be amalgamated fluvial channel belt deposits. This feature continues from GLO Region 2 state waters (APTIM and TWI 2024) into the current Central Coast OCS investigation area and potentially further offshore. Twelve other regionally mappable geologic units were identified within the Central Coast OCS Region yet were limited due to the amount of overburden. The overburden is related to the Texas Mud Blanket, a Holocene muddy deposit that thickens seaward, up to 100 ft (30.5 m) in the investigation area.

The features identified in this investigation are not exhaustive or inclusive of all potential sand-bearing stratigraphy within the region but represent systems that are sufficiently regionally extensive and contiguous to be confidently interpreted across the 1 nm x 5 nm (1.8 km x 9.2 km) spaced survey grid. The major geologic systems observed represent a cumulative gross volume of ~1.54 billion cubic yards (1.2 billion cubic meters) of potentially restoration compatible resources, which excludes overburden. The

precise composition of these deposits is likely highly variable and requires more detailed geological investigation, as detailed in the vibracore collection plan. As seen in previous investigations offshore Texas, the variability of sediment can be quite high, indicating that the actual volume of usable, shore-compatible, fine-grained sands may be 10 percent or less of the gross volume. The majority of these large, depositional systems have never been previously observed in this detail and help to constrain areas of fluvial-deltaic activity of the Texas coastal rivers throughout the Pleistocene and Holocene.

1 Introduction

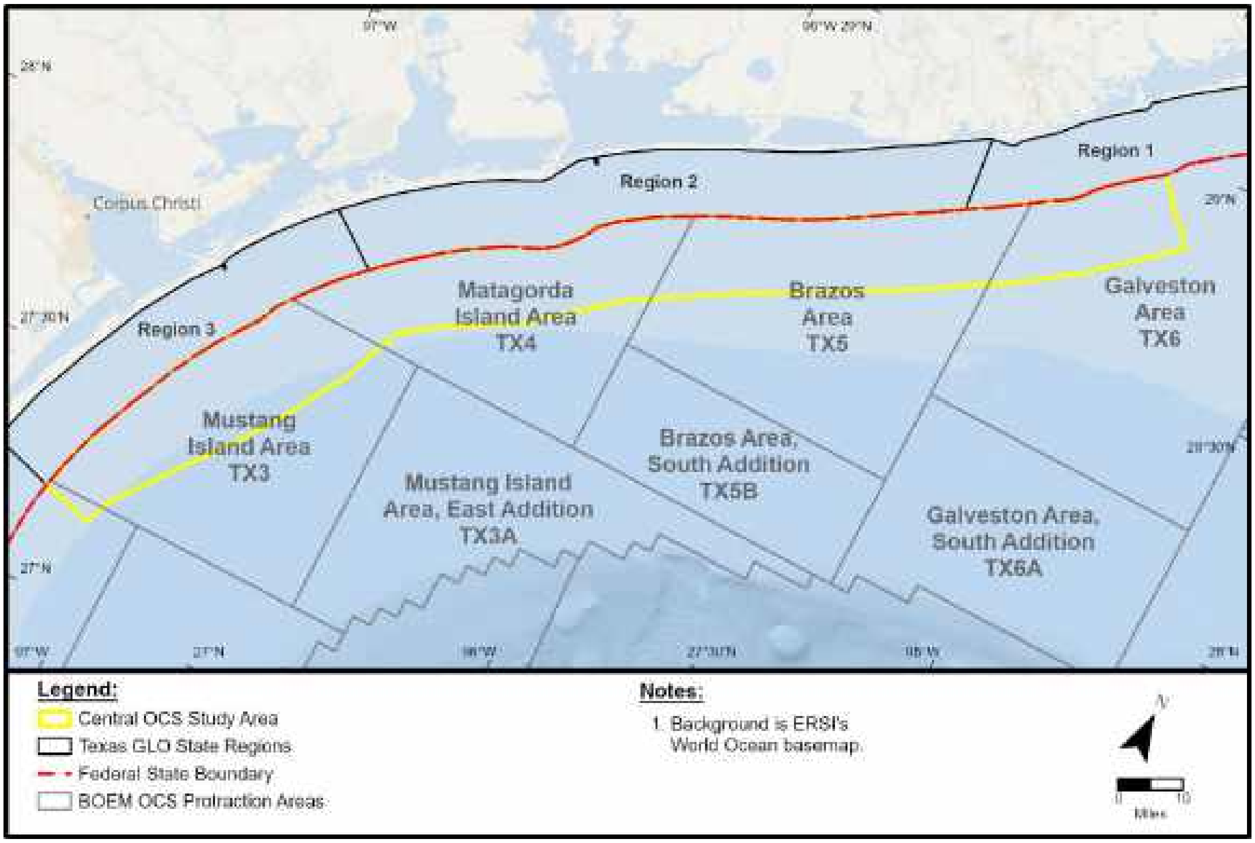
The Texas General Land Office (GLO) awarded Aptim Environmental & Infrastructure, LLC (APTIM), along with The Water Institute (TWI), a contract to conduct geophysical surveys along the offshore portion of the central Texas Outer Continental Shelf (OCS) using funding from the Bureau of Ocean Energy Management (BOEM), (Figure 1). The goal of the project was to primarily assist in a multi-agency response to categorize sediment resources offshore for development of policies and inventories for coastal restoration, with the purpose of better maintaining ports and navigation channels (dredging), determining appropriate sediment disposal sites, and determining the location of sediment deposits for their restoration efforts intended to mitigate beach erosion caused by storms and currents. A secondary goal of the project was to provide the GLO with a dataset that correlated recent state-side geophysical data (collected July 25 through September 19, 2022 [location of surveys collected in GLO Region 2 and 3 shown in Figure 1]) with OCS data for a more comprehensive understanding and mapping of geologic features in the area.

To efficiently coordinate this investigation, the GLO, BOEM, APTIM, and TWI developed a two-phase project approach. The first phase consisted of the desktop study, previously submitted, followed by the second phase reconnaissance-level geophysical data collection (chirp sub-bottom, sidescan sonar, magnetometer, and single beam fathometer) and data processing and interpretation in order to delineate potential sand deposits along the Central OCS region.

The Task 1 desktop study consisted of historical data compilation followed by a review of the data to provide a comprehensive understanding of existing data coverage and geological framework. APTIM compiled bathymetric and sub-bottom data, as well as geotechnical information (vibracores and grab samples when available) and scientific reports, to assist in the identification of potential sand resources which resulted in the development of a survey plan. Information on the compiled data, resources used, and data types from Task 1 that supported the survey plan are described in Section 3 below. After the desktop study was completed, APTIM transitioned into the Task 2 geophysical survey data collection and processing portion of the project. APTIM proposed to collect up to 1,212 nautical miles (nm [2,245 kilometers [km]]) of geophysical data.

Between September 22 and October 11, 2022, APTIM collected a total of 1,218 nm (2,256 km) of geophysical data in federal waters along protraction areas (TX2, TX3, TX4, TX5, and TX6) offshore Brazoria, Matagorda, Jackson, Calhoun, Aransas, San Patricio, Nueces, and Kleberg counties defined by the GLO as Region 1, 2 and 3 (Figure 1). Upon completion of the geophysical data collection, APTIM began processing and interpreting the data. Sidescan sonar and magnetometer data were reviewed for any potential hazards and areas to avoid and to delineate any characterizations of the seafloor. The seismic sub-bottom data were used to delineate any shoals and channel deposits within the study area and estimate a potential gross volume of sediments that could be available for coastal restoration efforts. Moreover, the seismic data were reviewed for any features/structures that could provide additional information on the overall geologic framework of the area and be compared to the information gathered during the desktop study and potentially assist with revising some of the previous conclusions about the framework of the area.

Figure 1. Overview of Study Area



2 Task 1 Historic Data Review/Survey Plan Development

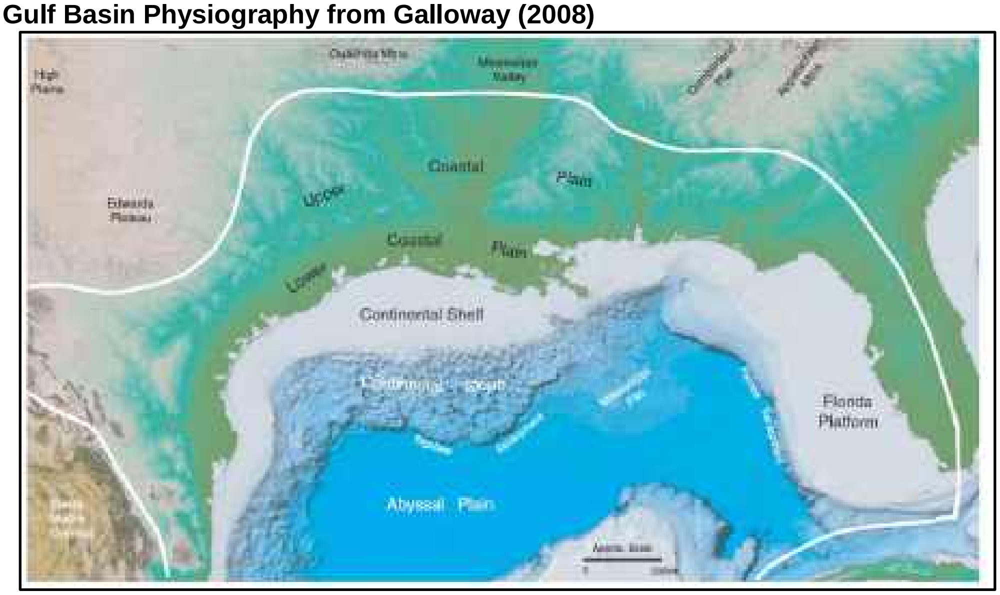
2.1 Geologic History

Below is a description of the formation of the Gulf of Mexico Basin as well as the coastal plain of central and eastern Texas with applicability to sediment resource occurrence and preservation.

2.1.1 Gulf Basin Evolution Early Gulf of Mexico Formation

The Gulf of Mexico Basin is the product of crustal extension, rifting, and seafloor spreading during the breakup of the supercontinent Pangea as the North American Plate separated from the South American and African Plates (Salvador 1991; Buffler et al. 1994; Galloway 2008). The basin is filled with up to 9.5-mile (mi) -thick (15.3 km) sedimentary deposits that range from Jurassic to recent ages with some older Triassic sedimentary rocks preserved locally in graben structures associated with Triassic rifting (Salvador 1991). Extension continued through early Jurassic when flooding of the basin from the Pacific Ocean and subsequent evaporation of sea water resulted in deposition of thick evaporite deposits, primarily the Jurassic Louaan Salt (Burke 1975; Galloway 2008). Widespread salt deposition in this period has greatly influenced subsequent surface morphology, brittle deformation, development of shelf stratigraphic sequences, and hydrocarbon production (Galloway 2008). After salt deposition, a later phase of seafloor spreading continued opening the basin to develop basaltic oceanic crust that underlies much of the deepwater Gulf of Mexico (Nguyen and Mann 2016). Early Cretaceous carbonate reefs and platforms rimmed the basin and defined its modern extent; however, by the late Cretaceous the area of the North American continent draining into the Gulf increased as did associated terrigenous deposition, inhibiting further carbonate development. This continental scale drainage reorganization led to burial of carbonates by thick clastic (sandstones and mudstones) deposits that persisted from late Cretaceous through Quaternary time producing the broad continental shelf and slope of the northern Gulf (Figure 2; Galloway 2008).

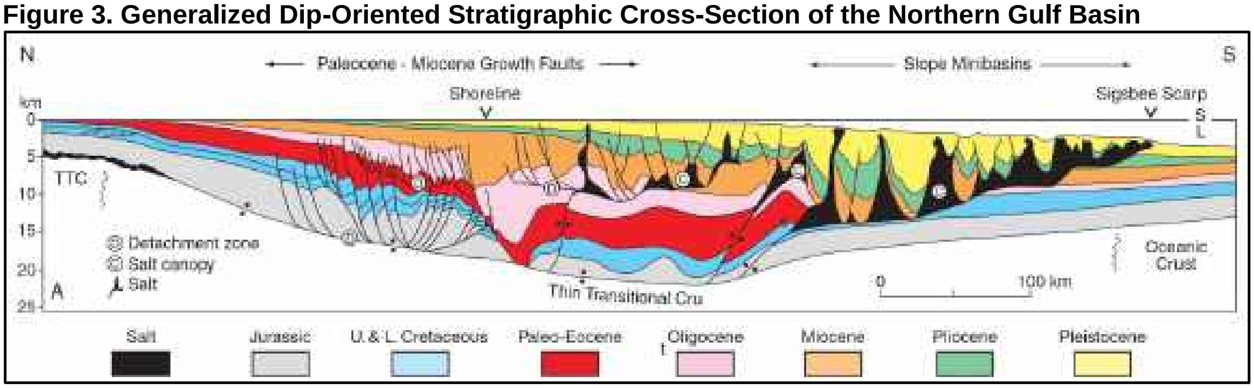
Figure 2. Gulf Basin Physiography from Galloway (2008)



Note the broad continental shelf and Sigsbee Escarpment along the base of the continental slope that is the result of basinward salt extrusion.

Loading of the Louann salt resulted in extrusion of salt vertically upward through overlying Jurassic through Cenozoic sections in the form of salt diapirs and tongues, as well as laterally basinward to form sheets that extrude to the surface as observed along the Sigsbee Escarpment (Figure 3 and Figure 4; Diegel et al. 1995). This deforming basal deposit greatly influenced Cenozoic structural evolution of the Gulf as younger, prograding deposits forced salt motion and attendant brittle deformation of the overlying strata (halotectonics) that is characterized by development of uplift in areas where salts are migrating vertically or laterally and subsidence over areas of salt withdrawal (Diegel et al. 1995). This process of creating accommodation for sediment deposition over evacuating salts facilitates a feedback response where increased sediment loading forces extrusion and continued subsidence drives further loading and extrusion. The influence of salt on the modern landscape is readily apparent, particularly in east Texas and the easternmost portion of the study area. High Island (Figure 4) and multiple offshore diapirs have influenced recent geomorphology and seafloor sedimentary character locally (Figure 5 Meckel and Mulcahy 2016).

Figure 3. Generalized Dip-Oriented Stratigraphic Cross-Section of the Northern Gulf Basin

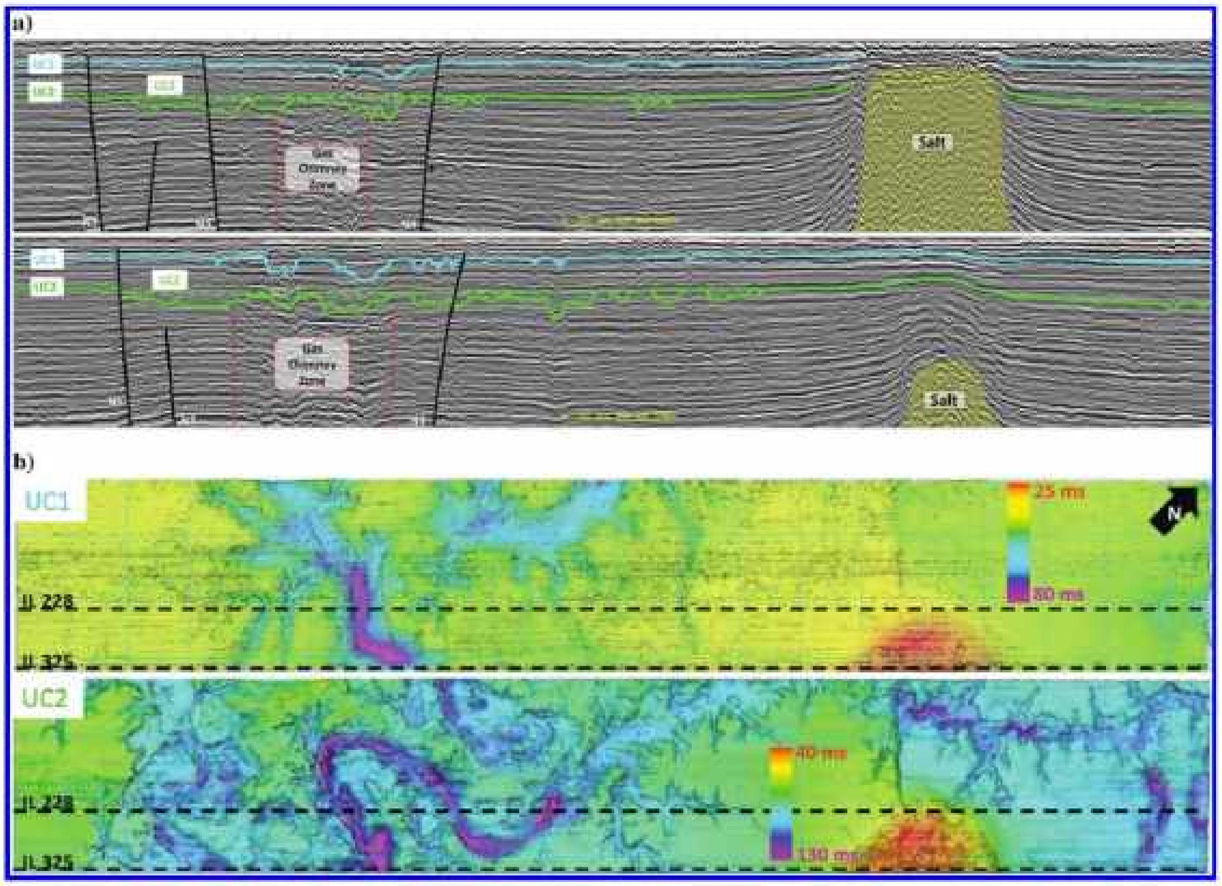


Note the basinward dipping Jurassic to Pleistocene deposits and influence of salt diapirism. From Galloway (2008).

Figure 4. Satellite Imagery of Texas Coast with Location of High Island Salt Dome Outlined (left, NASA Earth Observatory)

Aerial image of High Island Salt Dome during floodwaters of Hurricane Ike (right, Houston Chronicle).

Figure 5. 3D Seismic Sections Across Salt Dome in Central Texas Outer Continental Shelf of Inline 325 and 228, Respectively



Amplitude extracts (panel B) of horizon UC1 and UC2 show steering of Pleistocene fluvial valleys by nearby salt dome. From Meckel and Mulcahy, 2016.

2.1.2 Quaternary Geology

The Quaternary coastal plain of east Texas and offshore inner continental shelf consists of fluvial deposits and coastal deposits associated with sea level fluctuations and basin subsidence. Stratigraphically, this has resulted in a series of unconformity-bounded, seaward dipping clastic wedges that are Pliocene to Late-Pleistocene age producing coast-parallel terraces due to variations in erosional resistance (Fisher et al. 1972; 1973; Young et al. 2012; Heinrich et al. 2020). Each of these wedge units are characterized by terrestrial deposits that grade basinward into coastal and shallow marine deposits (Figure 6). Of interest to this discussion is the most recent Pleistocene unit, the Beaumont Formation that comprises a complex of Pleistocene depositional units (Figure 7). The surface of the Beaumont Formation is often characterized by oxidized sands and stiff clays (paleo-soil horizons) due to subaerial exposure during the most recent sea level lowstand. In most areas of the lower coastal plain, the Beaumont Formation forms the land surface where Holocene coastal and alluvial deposits are absent. Detailed discussion of the Quaternary geology of the upper Texas coastal plain can be found in Young et al. (2012) and the Environmental Geologic Atlas of the Texas Coastal Zone series produced by the Texas Bureau of Economic Geology (McGowen et al. 1976; Fisher et al. 1972; 1973). See Figure 8 for study area location and Quaternary geologic features of interest.

Figure 6. Idealized Dip Cross-Section for the Upper Central Texas Coastal Plain from Young et al. (2012)

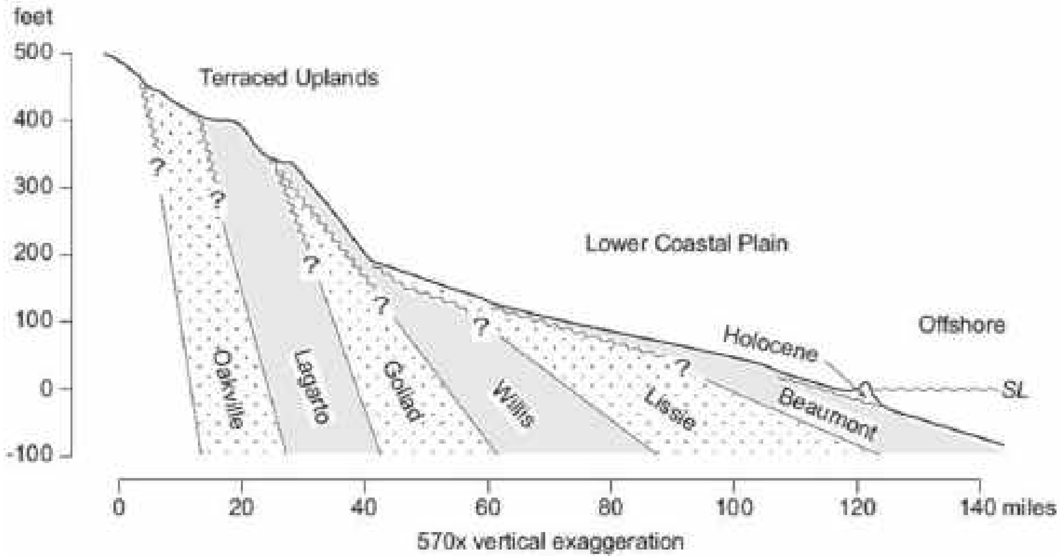


Figure 7. Generalized Dip Cross-Section for the Eastern Texas-West Louisiana Coastal Plain Quaternary Deposits from Heinrich et al. (2020)

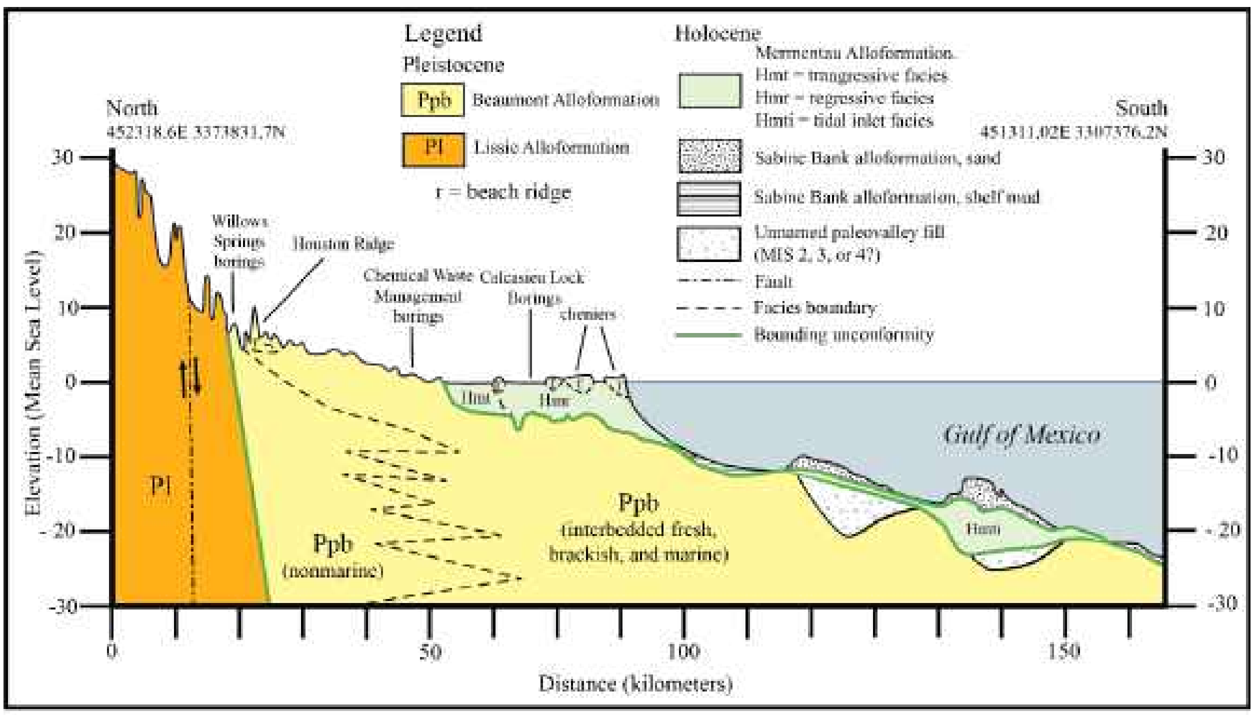
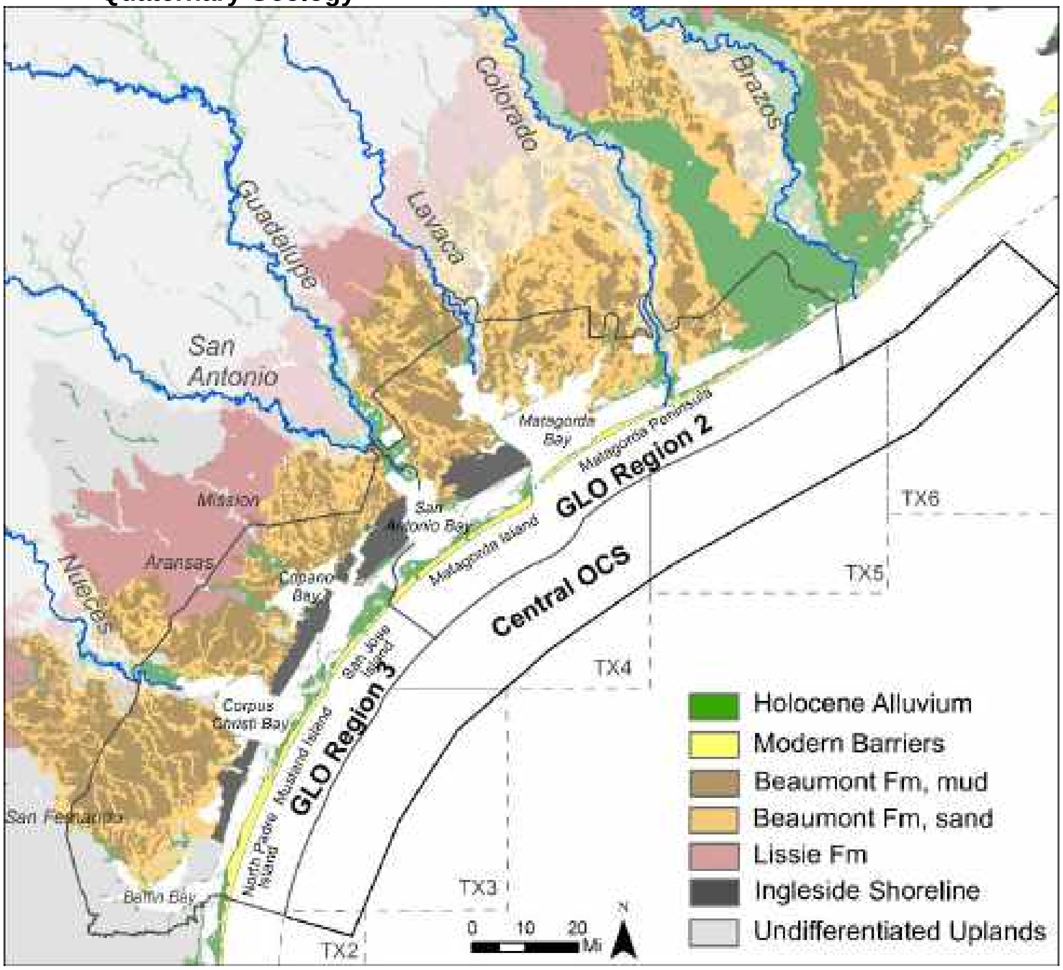


Figure 8. Central OCS Study Area as well as GLO Region 2 and 3 Areas and Surrounding Quaternary Geology

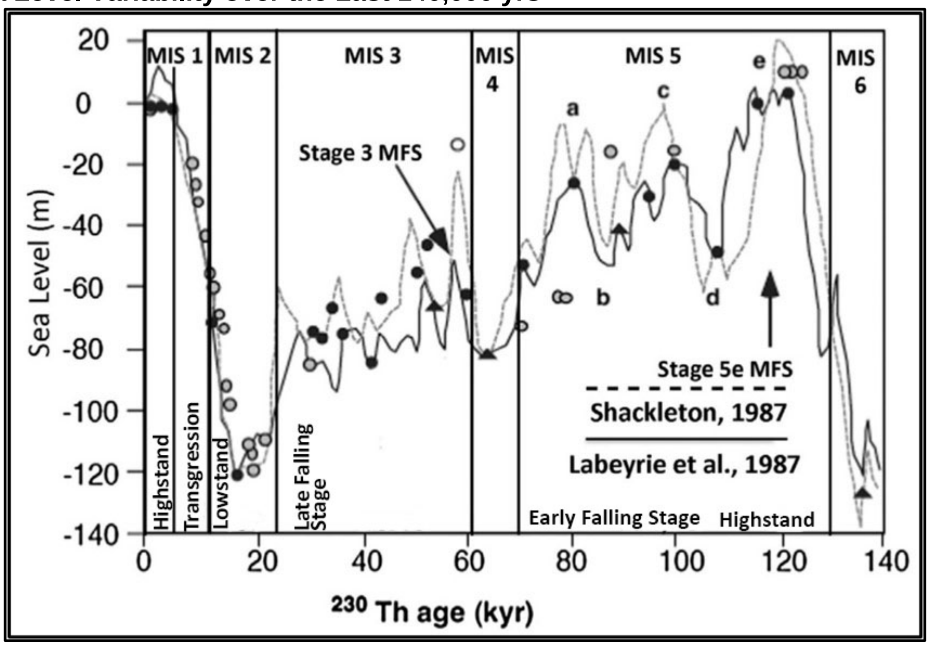


Note: Major Rivers denoted in blue and their respective drainage basins in white. The Beaumont Formation has been subdivided into its mud- and sand-dominated members (Modified from McGowen et al. 1976). Protraction areas represented in dashed lines.

2.1.3 Late Quaternary Sea Level Changes (120,000 years ago to present)

Coastal and fluvial response to sea level changes in the study area has dominated the geomorphic evolution (deposition and erosion of sediments) of the study area since the mid-Pleistocene (~900,000 years [yrs] ago). These changes in sea level are the results of periodic growth of continental ice sheets that reduce the volume of seawater and lower sea levels on the order of hundreds of feet and result in Gulf shorelines migrating basinward to coincide with the shelf edge during maximum lowstands of sea levels. Conversely, melting glacial ice results in sea level rise, a term referred to as *transgression*. For the purpose of this discussion relative to sediment resources within the study area, an understanding of the most recent glacio-eustatic cycle (beginning ~120,000 yrs ago) is important (Figure 9). During this time sea level was approximately 30 feet (ft) (9.1 meters [m]) above present levels (Simms et al. 2013) and the shoreline correlated with the preserved Ingleside Shoreline that extends from eastern Louisiana to Corpus Christi, Texas. The Ingleside Shoreline represents the highstand(s) barrier island shoreline dating to approximately 120,000 yrs (Price 1933; Otvos and Howat 1996, Simms et al. 2013). Subsequent to this highstand, sea level began to fall until about 70,000 yrs ago when it was approximately 250 ft (76.2 m) below present levels. This was followed by a warming period where sea level rose to approximately 50 ft (15.2 m) below present and then fell to about 400 ft (122 m) below present by 22,000 yrs ago with the shoreline located at the shelf edge (Anderson et al. 2004; 2016). This most recent lowstand of sea level persisted from approximately 22,000 to 17,000 yrs ago (Anderson et al. 2004). Between 17,000 and 4,000 yrs ago sea level rose ~400 ft (122 m), to close to its present position along the modern coastline (Anderson et al. 2016).

Figure 9. Sea Level Variability over the Last 140,000 yrs



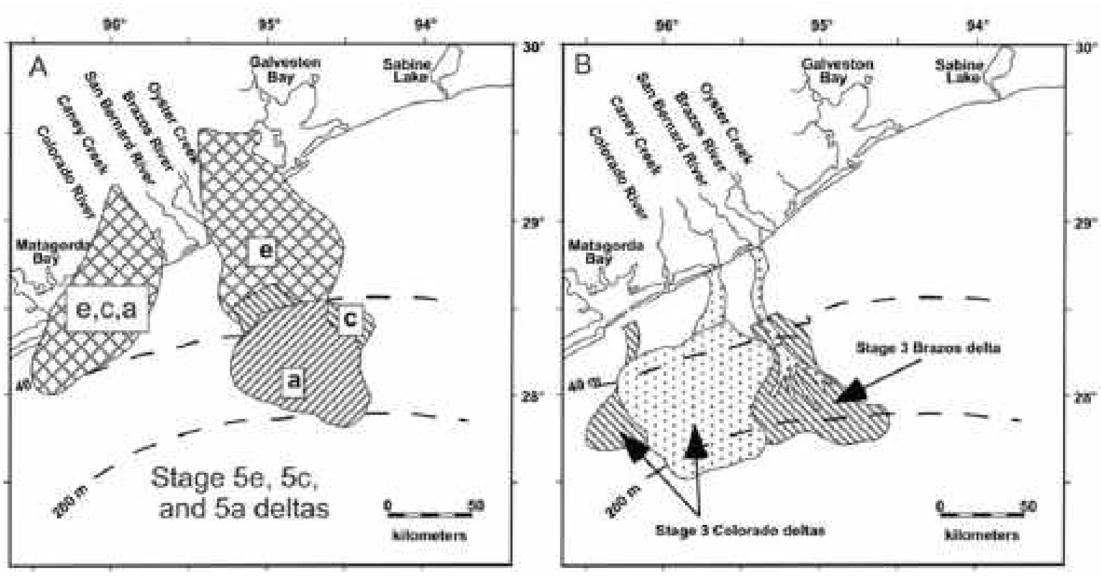
Note the present and 120,000 yr highstands, falling stage between 120,000 and 22,000 yrs ago, the lowstand from 22,000 to 17,000, and transgression from 17,000 to 4,000 yrs ago. Marine Isotope Stage (MIS). Maximum flooding surface (MFS). Modified from Anderson et al. (2016).

The following sections discuss depositional and erosional response within the study area to changes in sea level and the development of shelf sand deposits. The discussion is divided into FS and lowstand, transgression (sea level rise), and highstand deposits.

2.1.3.1 Highstand, FS and Lowstand (~120,000-17,000 yrs ago)

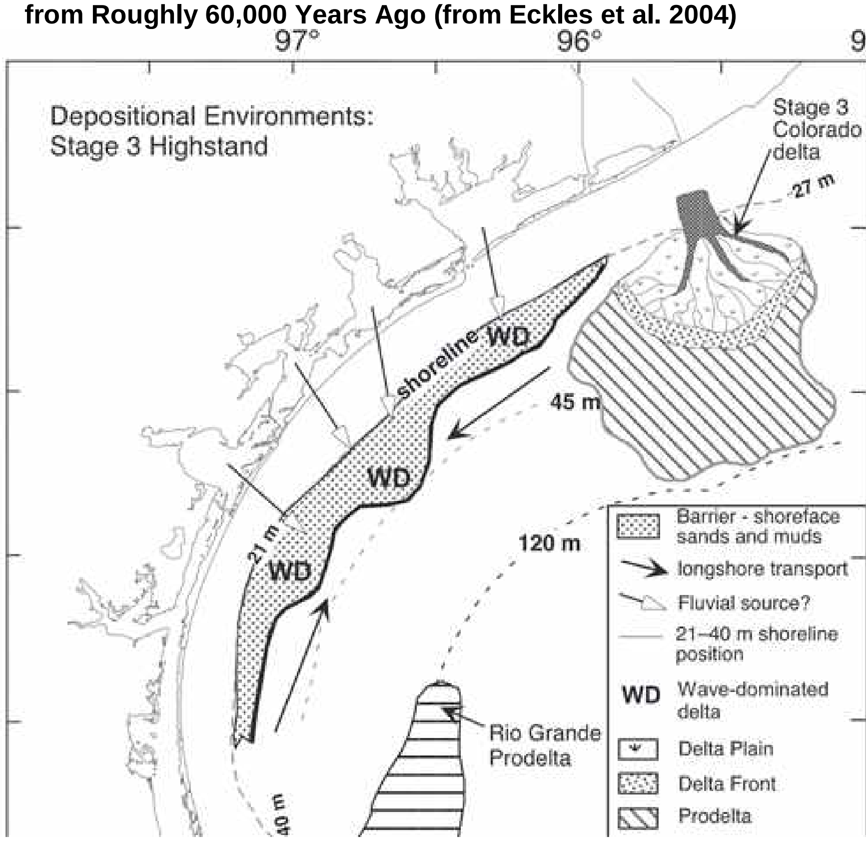
During the falling stage of sea level ~120,000 – 22,000 yrs ago, river channels began vertically incising down into pre-existing shelf deposits (e.g. Beaumont Formation and older); however, development of deep incised valleys did not dominate until late FS and into the lowstand (Anderson et al. 2016). Highstand and FS deltas of the Colorado and Brazos systems formed and migrated basinward producing a series of large deltaic deposits that are elongate in a dip direction (in contrast to the more lobate transgressive deltas discussed below Figure 10 (Abdulah et al. 2004, Anderson et al. 2016). A series of strandplain deposits, sourced from reworked deltaic sediment from the north and south, prograded basinward fronting the smaller systems of the Central Texas Coast (Eckles et al. 2004). Rather than building large fluvially dominated deltas, Eckles et al. (2004) suggests the low sediment delivery from the Lavaca, Guadalupe, Mission and Nueces Rivers built shore parallel, lobate wave dominated deltas (Figure 11). Limited accommodation for sediment deposition on the shelf coupled with extended subaerial exposure in the weathering environment during lowstand and subsequent wave ravinement (erosion) during transgression led to the delta tops and sandy mouth bars being eroded (Morton and Suter 1996; Anderson et al. 2016).

Figure 10. Highstand (A) and falling stage (B) Fluvial-Deltaic Deposits on the Middle to Upper Texas Shelf



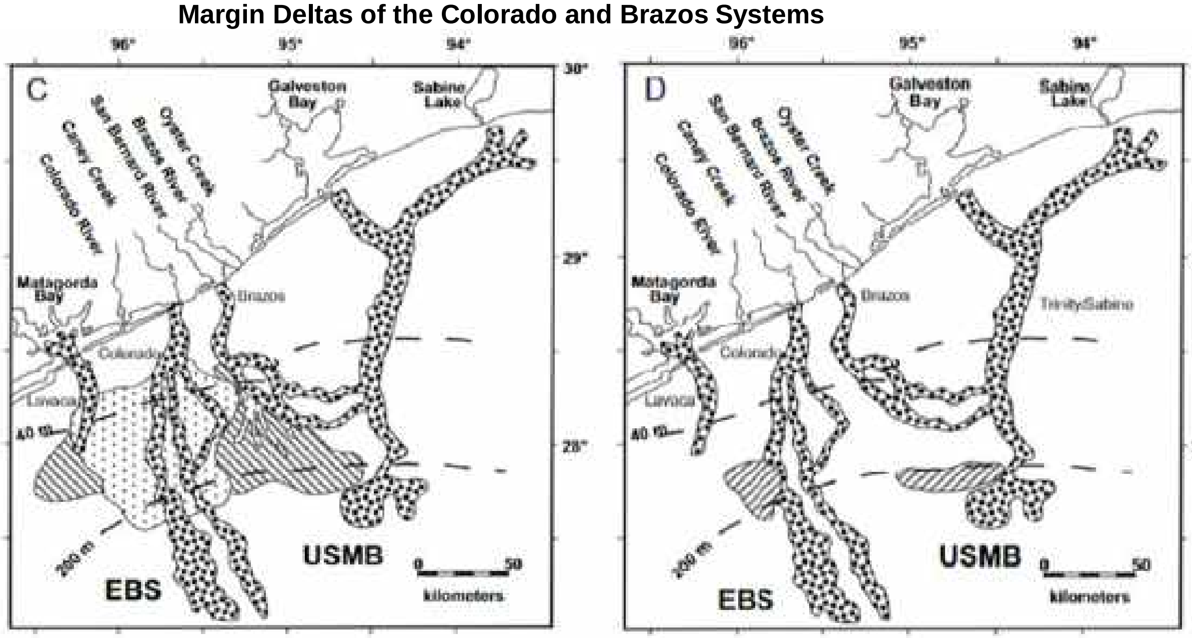
Note that these deposits are not fully preserved due to subsequent erosion during transgression. From Abdulah et al. (2004).

Figure 11. Late falling stage Wave Dominated Delta of Central Texas and its Sediment Sources from Roughly 60,000 Years Ago (from Eckles et al. 2004)



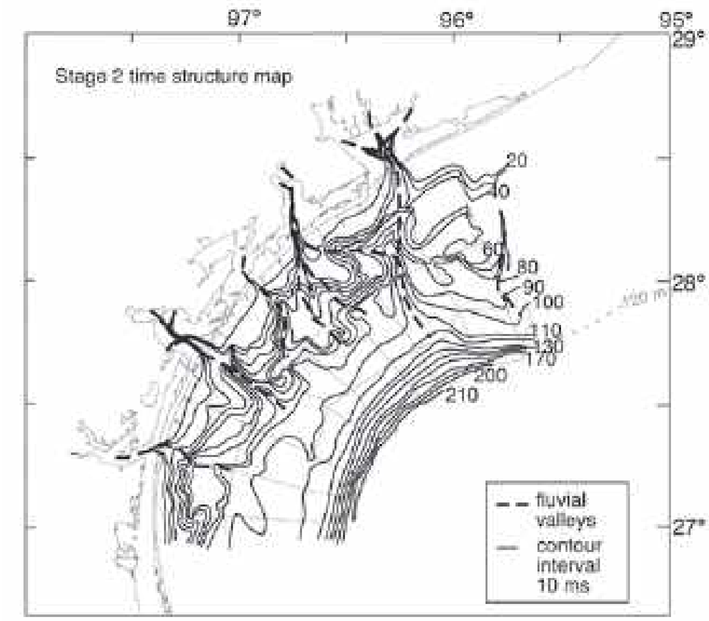
During sea level lowstands, large rivers incise valleys deep into the exposed continental shelf in order to reach a lowered Gulf level. These lowstand shelf valleys result in sediment bypassing of the adjacent, topographically high interfluves, and develop shelf edge deltas (Anderson et al. 2016). The Colorado and Brazos incised valleys are the prominent lowstand features in the study area both contributing to large shelf margin deltas. The Brazos abandoned its highstand channel and merged with the Trinity-Sabine valley system on the inner shelf, while the Colorado Valley incised through its highstand deltas, reoccupying its previous channel location (Abdulah et al. 2004; Figure 12). The central Texas systems of the Lavaca (Matagorda Bay), Guadalupe/San Antonio (San Antonio Bay), Mission/Aransas (Copano Bay), Nueces (Corpus Christi Bay) and San Fernando (Baffin Bay) (Figure 13) cut straight and deep channels due to the relatively steep shelf gradient, incising up to 35 m (115 ft) along the modern shoreline. However, there are no lowstand deltas or fans preserved from these systems. Either they were never deposited, or they were removed during transgression (Abdulah et al. 2004; Figure 13). During this time of maximum sea level lowstand (22,000 – 17,000 yrs ago), exposure of the entire continental shelf resulted in a regionally correlative erosional surface referred to as the Late Wisconsinan Unconformity (Anderson et al. 2016; Heinrich et al. 2020). Incised valley depths relative to the adjacent interfluve surface ranged from 100-130 ft (30.5- 39.6 m) deep; however, due to infilling during sea level rise the valley is completely full and there is no bathymetric expression on the modern seafloor (Thomas and Anderson 1994; Swartz 2019).

Figure 12. Late falling stage and Lowstand Valleys and Shelf Fan Deposits (C) and Lowstand Shelf Margin Deltas of the Colorado and Brazos Systems



Note: EBS is the East Breaks Slide and USMB is the Upper-Slope Mini Basin (from Abdulah et al. 2004).

Figure 13. Lowstand Valleys of the Central Texas Systems



Note the lack of lowstand deltaic deposits (from Eckles et al. 2004).

2.1.3.2 Transgression (~17,000 – 4,000 yrs ago)

During the period from ~17,000 – 10,000 yrs ago rapid sea level rise (~4.2 millimeters [mm] [0.16 inches [in]])/yr; Figure 14) did not facilitate extensive transgressive deposition on the shelf besides backstepping deltas associated with the Colorado and Brazos rivers (Anderson et al. 2016). The two youngest Colorado transgressive deltas are interpreted to have transitioned from a fluvially dominated to a wave dominated delta around 12,000 to 9,500 yrs ago (Snow 1998, Abdulah et al. 2004), and present potentially viable sand resources on the inner shelf (Figure 15). After that time, sea level rise slowed resulting in development and preservation of deposits—relevant to this sand resources discussion—comprising incised valley fills and fine-grained overburden of the Texas Mud Blanket (Anderson et al. 2022).

Figure 14. Holocene (past ~10,000 yrs) Sea Level Curve from Anderson et al. (2016)

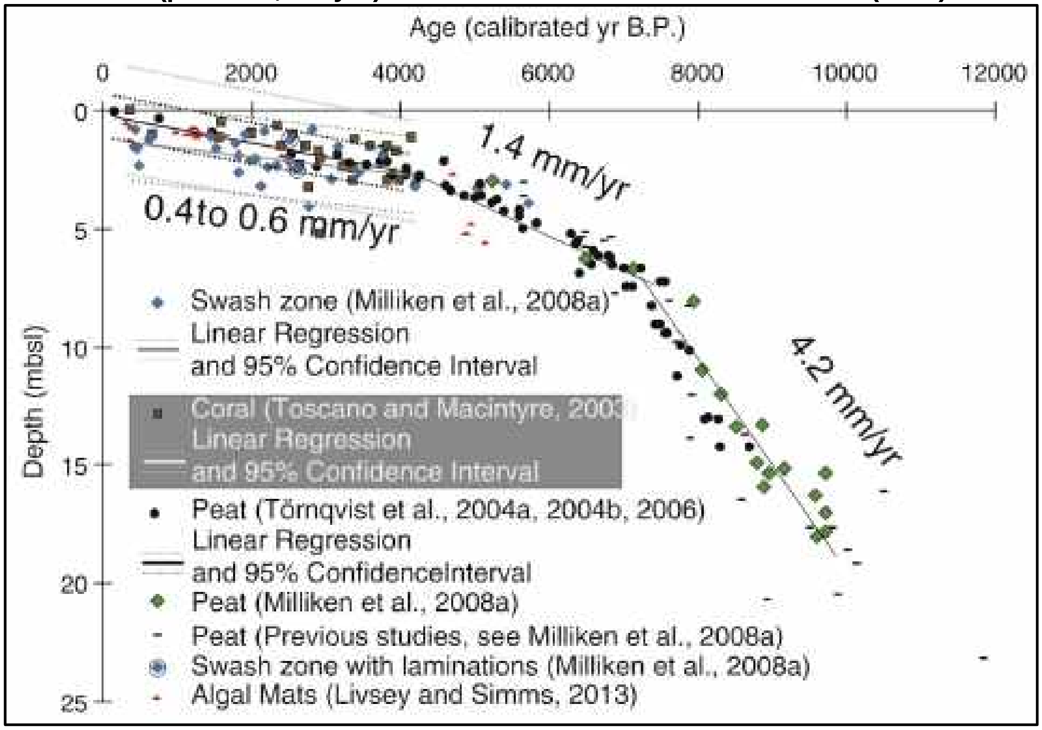
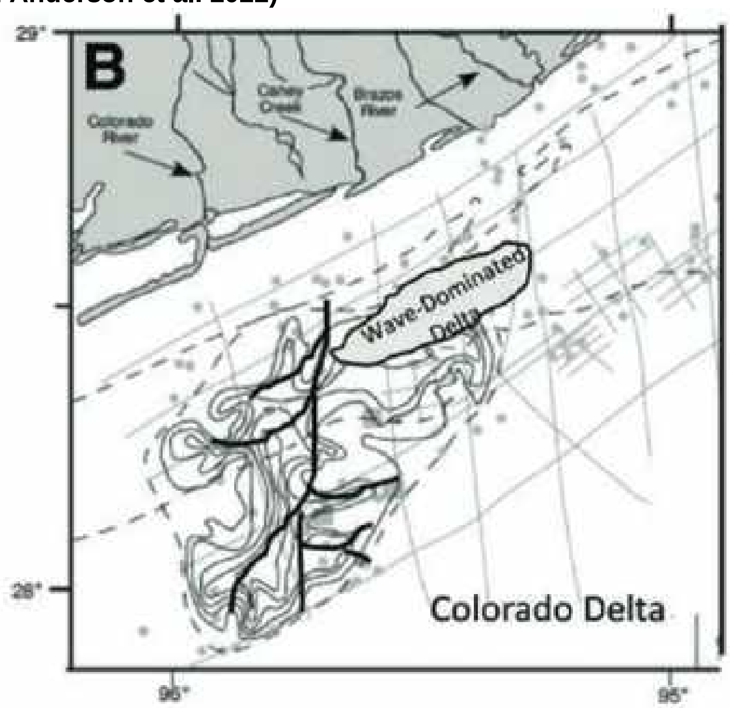


Figure 15. Transgressive Colorado Delta's, Overall Geometry Transitions from Elongate to Shore Parallel Indicating Increased Wave Reworking with Less Fluvial Sediment Input (from Anderson et al. 2022)



The grey box surrounding corals is from initial source material and has no specific significance to this review.

2.1.3.3 Incised Valley Fills

Within the study area, the Lavaca, Guadalupe, Mission, Nueces, and Colorado/Brazos systems had contrasting fluvial infilling that has been termed underfilled and overfilled, respectively (Simms et al. 2006). The Colorado/Brazos (which flanks the eastern boundary of the study area) completely infilled with fluvial deposits, consisting of mostly muddy floodplain deposits with isolated channel sands (Abdulah 1995; Abdulah et al. 2004; Taha and Anderson 2008; Figure 16). Both systems appear to have avulsion frequencies of about once per 2,500 yrs, with the most recent avulsion of the Colorado occurring 1,000 yrs ago when it moved about 25 mi (40.2 km) west of its prior location at Caney Creek forming constructional alluvial ridges (Anderson et al. 2022, Swartz et al. 2022; Figure 17). Previously unidentified Holocene Alluvial Plain deposits (adjacent to this study area) with minimum overburden were found just offshore of the modern Brazos alluvial system with a dense grid of high-resolution geophysical data (APTIM and TWI 2021; Figure 18). These potential channel belt sands correlate to updip lowstand and transgressive Brazos channel sand equivalents identified by Taha & Anderson (2008; Figure 16).

Figure 16. Isolated Channel Belts of the Brazos and Colorado Systems Mapped from Borings Representing Many Stages of Channel Switching (from Taha and Anderson 2008; Anderson et al. 2016)

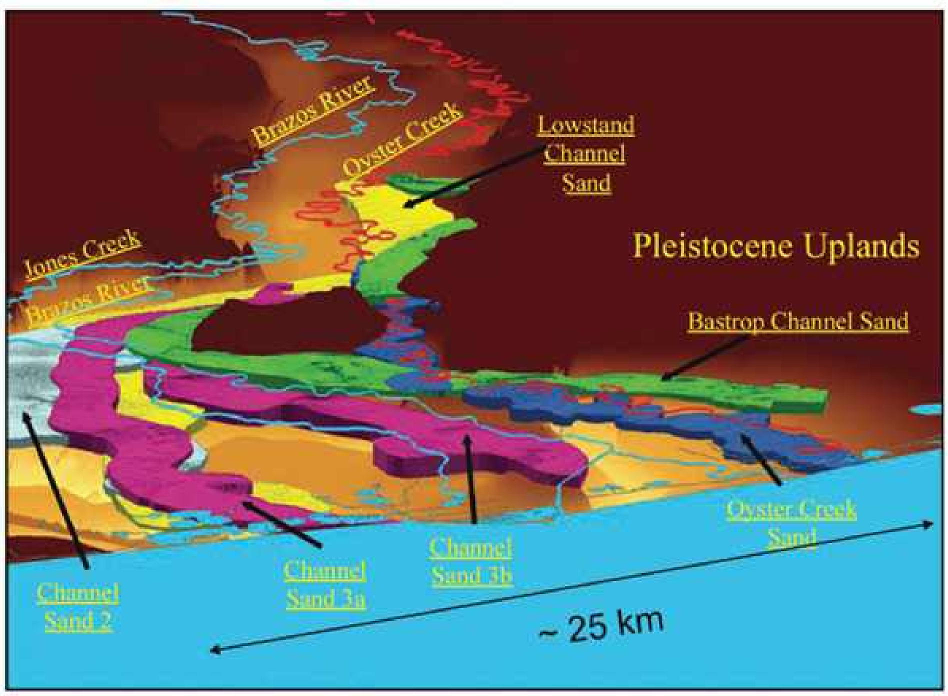


Figure 17. Lidar Showing the Overfilled Valley Mapped from Borings, Note the Aggradational Alluvial Ridges (from Anderson et al. 2022)

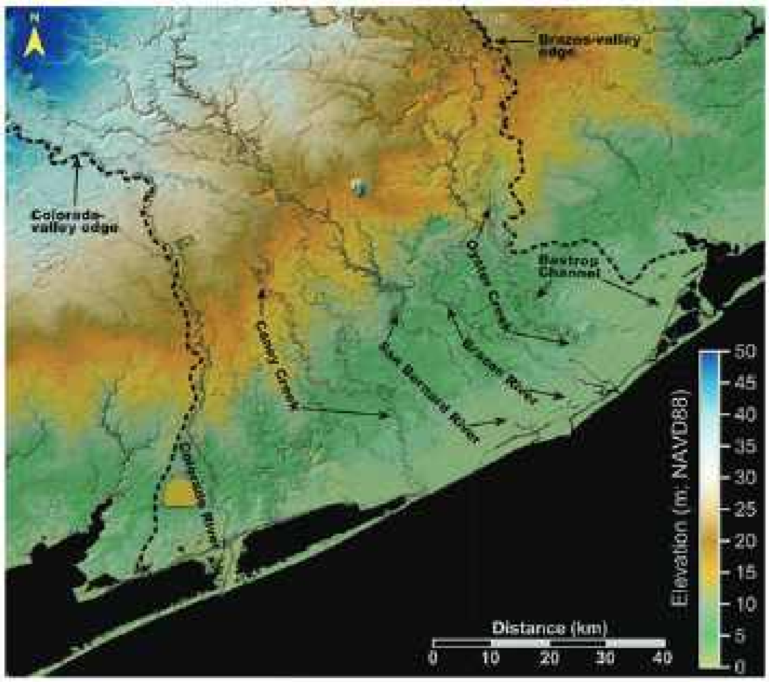
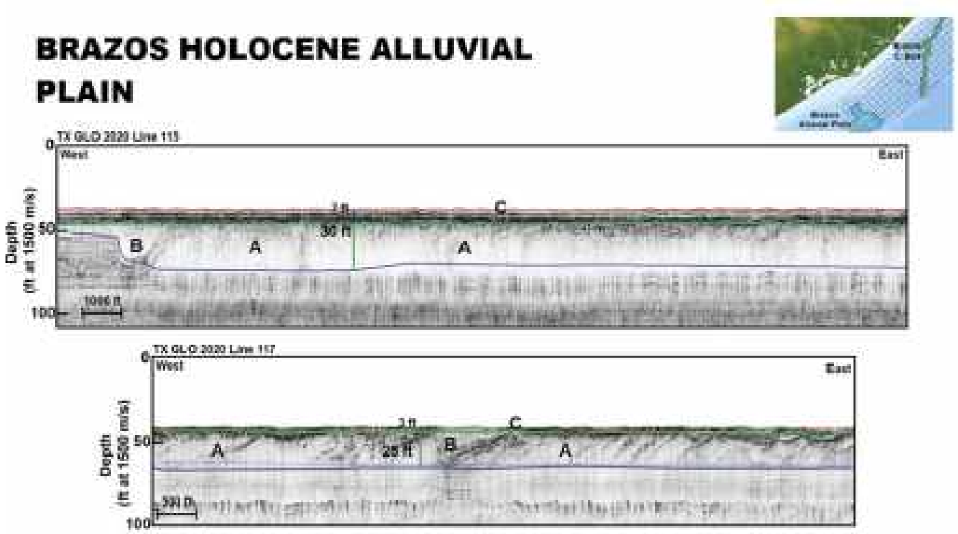


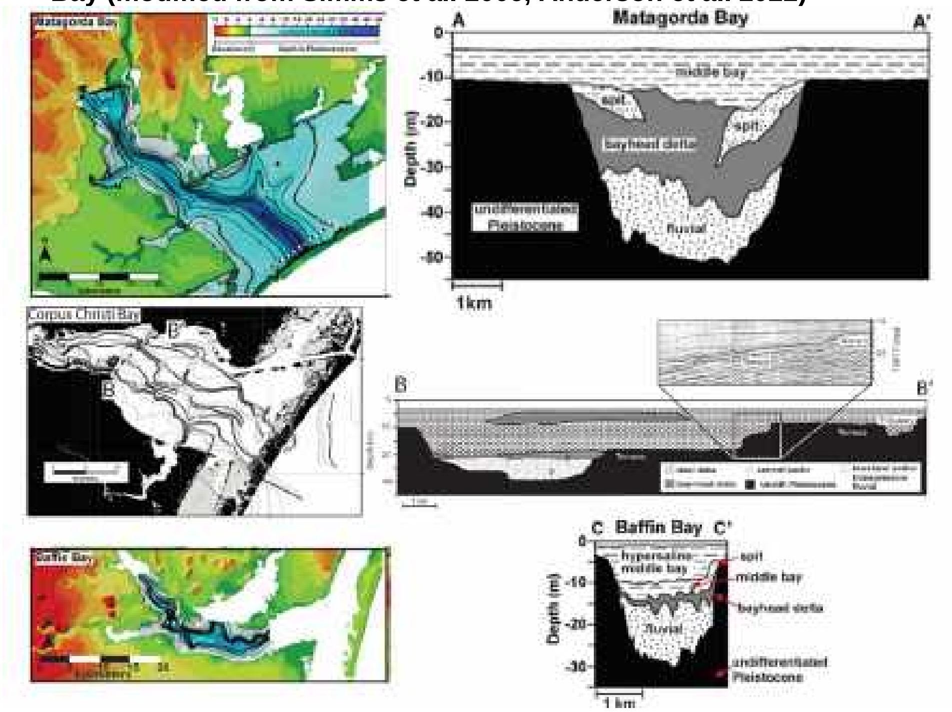
Figure 18. Potential Sandy Holocene Alluvial Plain Deposit Identified Adjacent to this Study Area



Note: The blue horizon marks the basal unconformity of the underlying layered Beaumont stratigraphy from the above dipping clinoforms and variable transparent/chaotic seismic reflectors. The green horizon is the top of the dipping reflector package (from APTIM and TWI, 2021)

The underfilled central Texas valley systems did not completely fill with fluvial deposits during transgression, and instead the valleys became estuarine depositional sinks (Morton and Price 1987; Thomas and Anderson 1994; Anderson et al. 2016; Swartz 2019).The central Texas incised valley's fill are characterized with vertical sequences that fine upward from basal channel sands and amalgamated point bar deposits (in contrast to the discrete channel sands observed in the Colorado/Brazos incised valleys) into bayhead deltas, estuarine, and tidal-associated deposits that backstep landward tracking with the transgressive shoreline position (Figure 19, Anderson et al. 2022). The lower fluvial section of the Lavaca, Guadalupe, Mission, Nueces, and San Fernando valley fill had previously been determined to contain significant volumes of beach quality sand within these systems; however, the thick, muddy overburden and depth to this sandy unit have impeded development as a viable sand resource. The Nueces Valley displays a narrow, steep, geometry with broad terraces on either side (Simms et al. 2008) providing higher preservation potential of coastal lithosomes or in some cases relict fluvial channel deposits. It is possible these valleys acted as nearshore sinks during transgressive reworking of FS Pleistocene strandplain deposits, but better constraint is needed regarding their fill architecture and geometry on the inner shelf.

Figure 19. Valley Geometry and Fill Architecture of Matagorda Bay, Corpus Christi Bay, and Baffin Bay (modified from Simms et al. 2006, Anderson et al. 2022)



2.1.3.4 Paleochannel Fills

In contrast to incised valley fills that contain multiple channel belts, discrete near-surface channel fills have been observed throughout the study area representing stream systems that incised into interfluves during lowstand or were preserved basal channel fills from previous highstand or falling stage streams. Compared to the Upper Coast of Texas detailed investigations of potential paleochannel systems in Central Texas OCS are minimal, while some of those that do exist point to similar form as those observed elsewhere in the Gulf of Mexico (Meckel and Mulcahey 2016). Here we describe a series of highly detailed investigations of channel forms located in the Upper Coast OCS that are likely to be representative of those encountered in the Central Coast OCS due to similarities in geologic setting, and in some cases, likely formative river systems (Young et al. 2012). In an analysis that mosaiced of over 300 shallow hazards surveys conducted for oil and gas development offshore western Louisiana and east Texas, Heinrich et al. (2020), demonstrated the ubiquity of these features in the study area (Figure 20). Dellapenna et al. (2009) collected sediment cores in some of these features that had been identified from geophysical data and sand content was minimal or below the depth of core penetration. However, as demonstrated by Coastal Planning & Engineering, Inc. (APTIM-CPE) (2001) in support of Holly Beach, Louisiana Restoration, high-density geophysical and geological data can identify the elusive channel sands that occur within sinuous ribbons of muddy sediment within the fluvial channel belt (Figure 20, Figure 21 and Figure 22 Heinrich et al. 2020). Adjacent to the study area, a previously unidentified laterally migrating channel belt, likely related to a Pleistocene Brazos system, was located with a high-density grid of geophysical data offshore of Follet's Island (APTIM and TWI 2021; Figure 23). The trend of this system aligns with updip sandy fluvial deposits of the Pleistocene-aged Beaumont Formation. These isolated systems provide a reference strategy for other potential sand resources with updip Pleistocene equivalents within the study area.

Figure 20. Paleochannel and Paleovalley Deposits as Interpreted on Over 300 Individual Oil and Gas Hazards Survey Reports Conducted on Federal Offshore Lease Blocks (Defined by Irregular Purple Grid) Offshore Sabine and Calcasieu Passes. The Interpretations were Mosaiced to Develop this Map. From Heinrich et al. (2020)

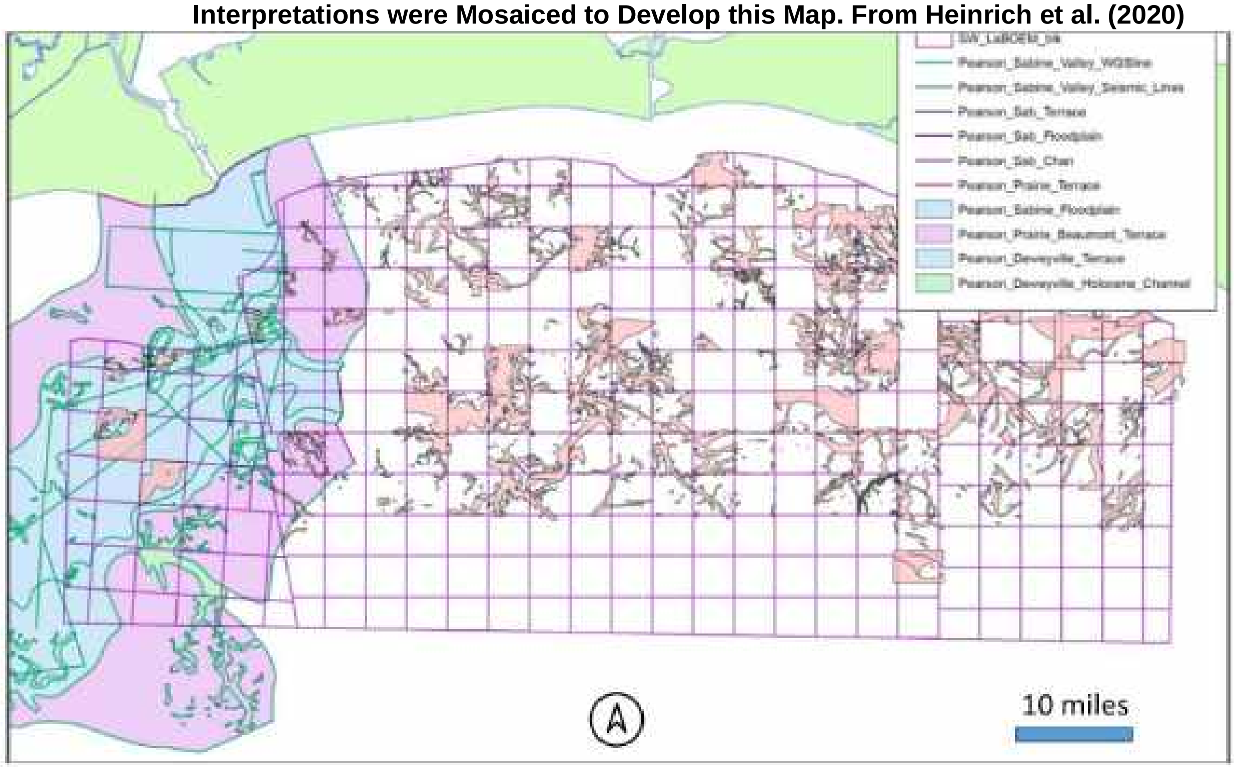
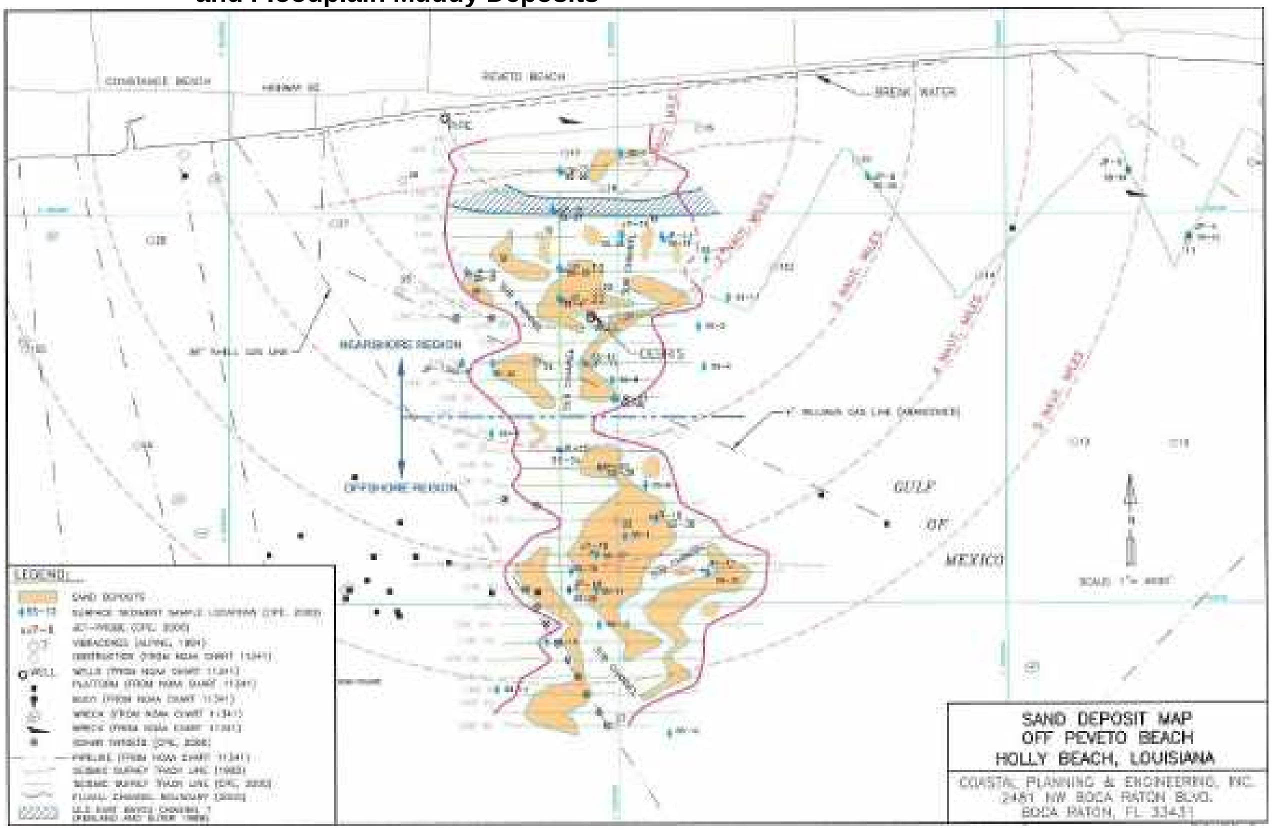


Figure 21. Sand Deposit Map of the Peveto Paleochannel Offshore Holly Beach, Louisiana Demonstrating the Complexity of Location Channel Sands Within the Channel Fill and Floodplain Muddy Deposits



Note: The southernmost deposits on this map were ultimately extracted to construct the Holly Beach Restoration Project. See Figure 21 for a conceptual model of paleochannel fills. From Heinrich et al. (2020), modified from Coastal Planning & Engineering, Inc. (APTIM-CPE, 2001).

Figure 22. Conceptual Hierarchy of Fluvial Deposits from Heinrich et al. (2020) Modified from SEPM Web

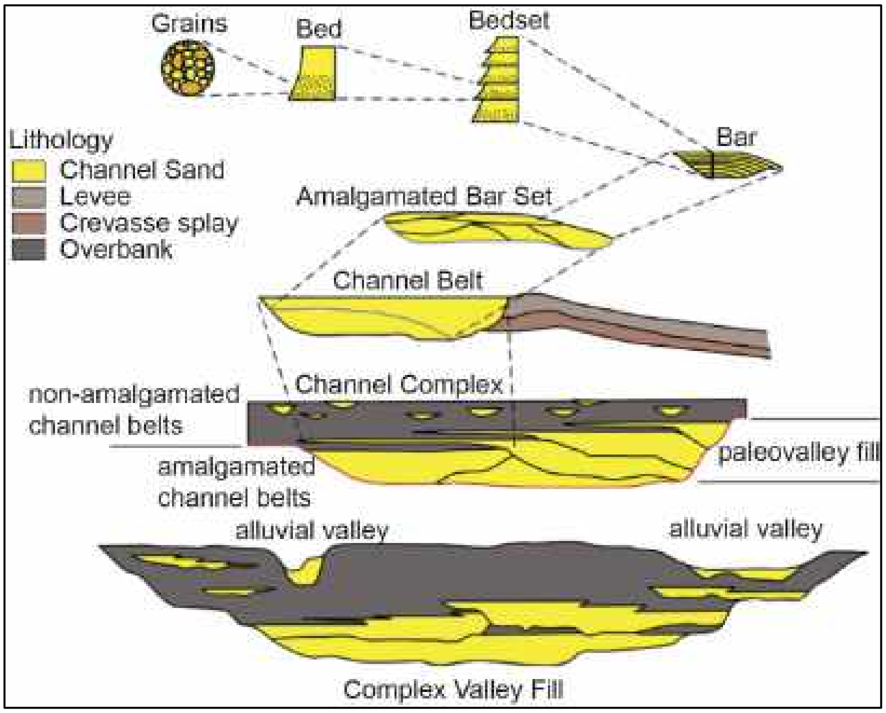
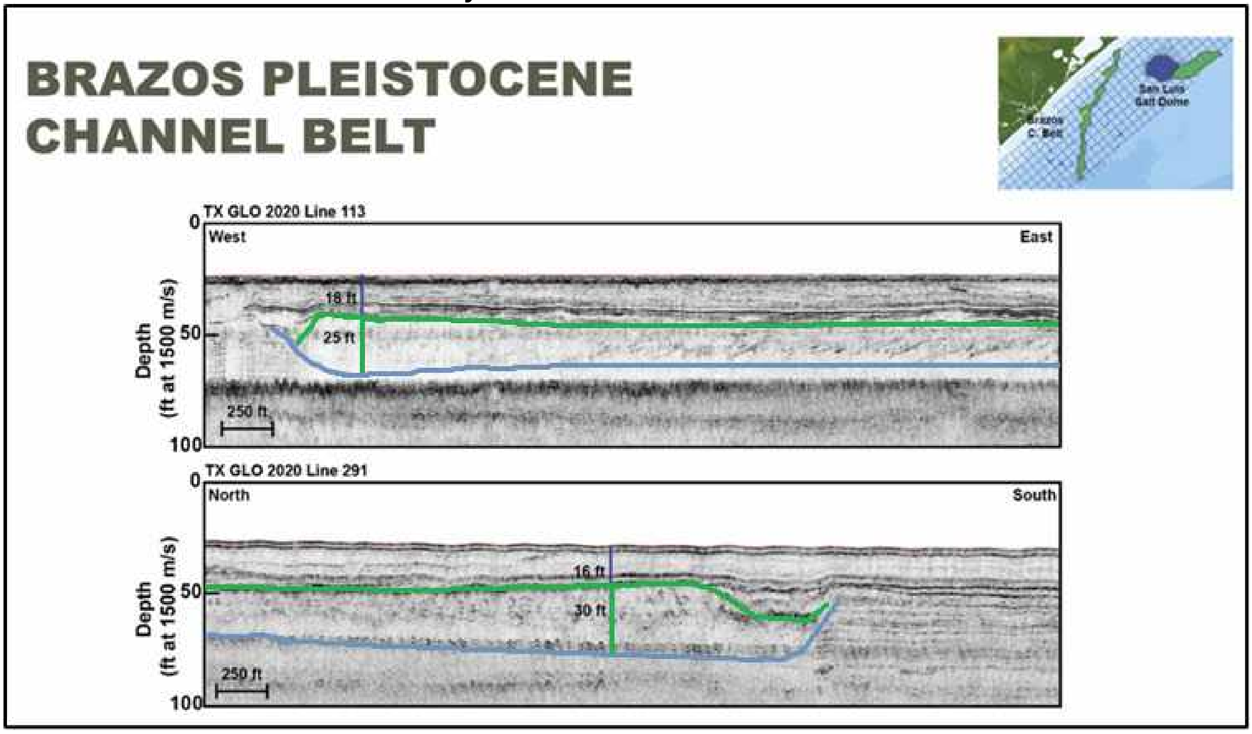


Figure 23. Example of Preserved Channel Belt Adjacent to This Study Area, Likely Related to a Pleistocene Brazos System



Note: The blue horizon marks the basal unconformity of the underlying layered Beaumont stratigraphy from the above dipping clinoforms and variable transparent/chaotic seismic reflectors. The green horizon is the top of the dipping reflector package. Note the transition from dipping clinoforms to channel form at the edge of the feature. (From APTIM and TWI 2021)

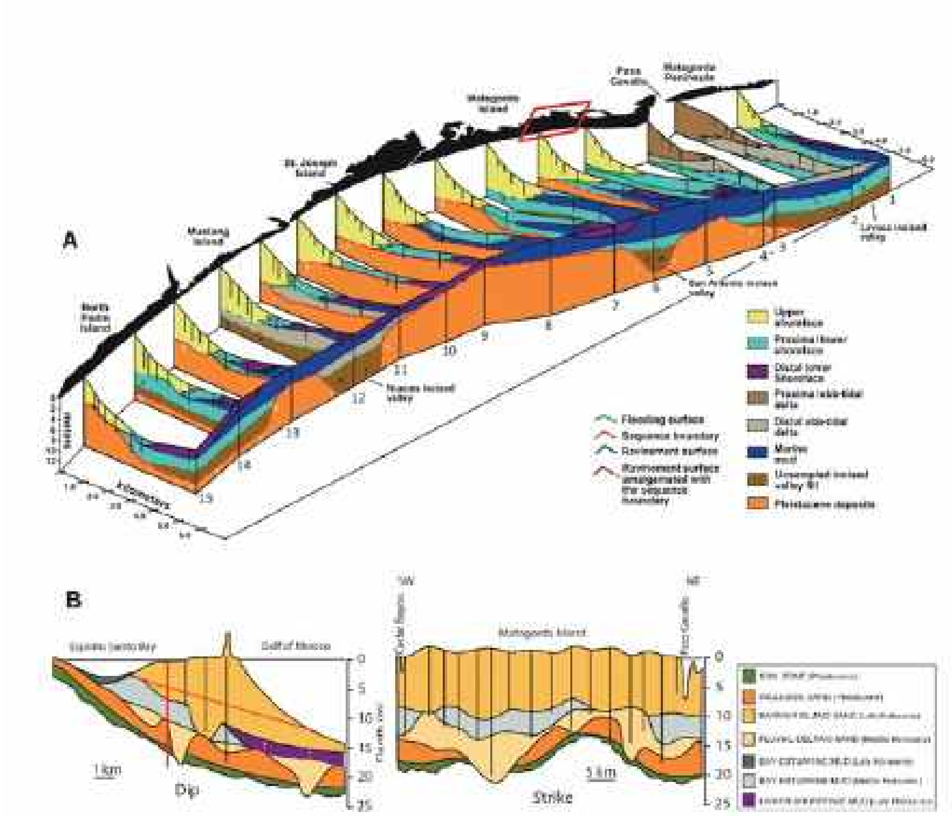
2.1.4 Transgressive Ravinement

While the depositional response to sea level rise is manifested as incised valley fills and shelf sand bodies, response to wave and tidal current erosion (ravinement) dominated the study area and has resulted in removal of much of the upper sections of fluvial and coastal deposits associated with falling sea level (FS deltas and channel systems), lowstand (landforms that developed on interfluves), and early transgression (upper sections of incised valley fills and barrier shoreline deposits). Preservation of coastal deposits is extremely rare on the Texas shelf with the potential exception of Sabine and Heald sand banks (Rodriguez et al. 2004; Anderson et al. 2016). Smaller stream channels that did not incise valleys or that were perched on interfluves are also rarely preserved (Anderson et al. 2016). The effective depth of transgressive ravinement in the study area was approximately 25-35 ft (7.6-10.6 m) and still is today along the modern shoreface (Wallace et al. 2010); therefore, the upper 25-35 ft (7.6-10.6 m) of all antecedent deposits were removed as the coastline migrated landward during the transgression (Wilkinson 1975; Siringan and Anderson 1994; Rodriguez et al. 2001).

2.1.5 Highstand (~4,000 yrs ago to present)

Approximately 4,000 yrs ago the rate of sea level rise drastically slowed to an almost stable ~0.5 mm/yr (0.02 in/yr) allowing for the modern coastal system to mature as barrier islands prograded seaward and significant lateral spit accretion from headlands developed peninsulas such as Matagorda (Wilkinson 1975; Anderson et al. 2022). Much of the sand that exists in the modern coastal system was provided during transgressive ravinement of antecedent deposits on the shelf (e.g., FS deltas, transgressive barrier islands, shallow stream channels; Weight et al. 2011; Anderson et al. 2016; Hollis et al. 2019). This concept of the modern coastal system being genetically related to preserved fluvial deposits on the shelf is an important consideration for assessing sand source suitability for beach nourishment. Sand supply to the coast from the central Texas systems was non-existent by this time because the valleys had filled with estuarine deposits with their modern depocenters comprising bayhead deltas. The Colorado/Brazos River continued to supply sand to the coast during highstand, but only intermittently during major flood events (Rodriguez et al. 2000; Anderson et al. 2022). The central Texas coast barrier system is believed to contain 75 percent (%) of the sand within the modern Texas coastline due to their older age and converging longshore currents (Anderson et al. 2016 and references within) although barrier island thickness varies due to antecedent topography (Rodriguez et al. 2001; Anderson et al. 2022; Figure 24 panel A). Interfluve areas between lowstand incised valleys are likely comprised of Beaumont muds and sands where Ingleside Shoreline sands are absent in the nearshore as shown on Figure 24 panel B.

Figure 24. Facies Underlying Central Texas Barriers and in the Nearshore (A and B Modified from Rodriguez et al. 2001; Anderson et al. 2022)

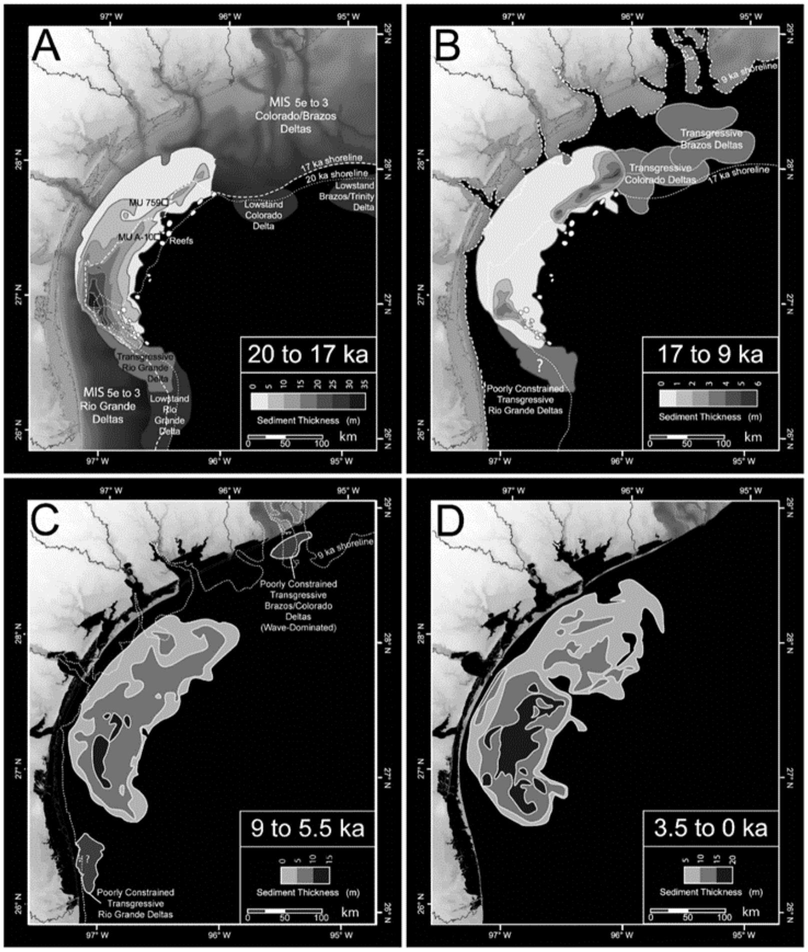


Note the antecedent topography of the Pleistocene surface created by lowstand incised valleys and the correlation of barrier thickness and depth to Pleistocene. Shore perpendicular and parallel cross sections of Matagorda Island (B) show modern coastal lithosomes overlying fluvial-deltaic and Ingleside sands (modified from Wilkinson 1975).

2.1.6 Texas Mud Blanket

The accommodation of the central Texas shelf embayment created by subsidence and lack of large FS to lowstand shelf deltas was infilled with transgressive muds of the Texas Mud Blanket ([TMB] Weight et al. 2011). Deposition took place since the beginning of the transgression with most sedimentation occurring after 3,500 years ago (Figure 25). Major sediment inputs were fine-grained plume sediments sourced from the Mississippi, Brazos, and Colorado Rivers, as well as local ravinement of the Colorado/Brazos and Rio Grande shelf deltas to the north and south (Eckels et al. 2004; Weight, et al. 2011). This creates a seaward thickening wedge of overburden overlying the FS strandplain deposits and paleo-delta systems associated with the Rio Grande and Colorado rivers. The expansion of the Texas Mud Blanket in the middle to late Holocene led to a shutting down of sand sources from the shelf to the modern coastline, leading to rapid landward retreat of the shoreline in the late Holocene (Odezulu et al. 2020).

Figure 25. Evolution and Thickness of the Fine-Grained Texas Mud Blanket Since the Lowstand (from Weight et al. 2011)



3 Task 2 Reconnaissance-Level Geophysical Survey

3.1 Geophysical Investigation

On September 22, 2022, the APTIM crew prepared the offshore vessel, M/V *Terry Bordelon*, for geophysical survey operations. From September 23 to October 11, 2022, APTIM conducted a comprehensive geophysical (chirp sub-bottom, sidescan sonar, and magnetometer) and hydrographic (single beam fathometer) survey offshore central Texas (Table 1; Figure 26). Using the M/V *Terry Bordelon*, APTIM conducted 24-hours per day operations during favorable weather conditions. Over the course of 18 operational days, APTIM collected a total of 1,218 nm (2,256 km) of geophysical data around the clock in 12-hour shifts, averaging a total of 67.6 nm (125.2 km) per day.

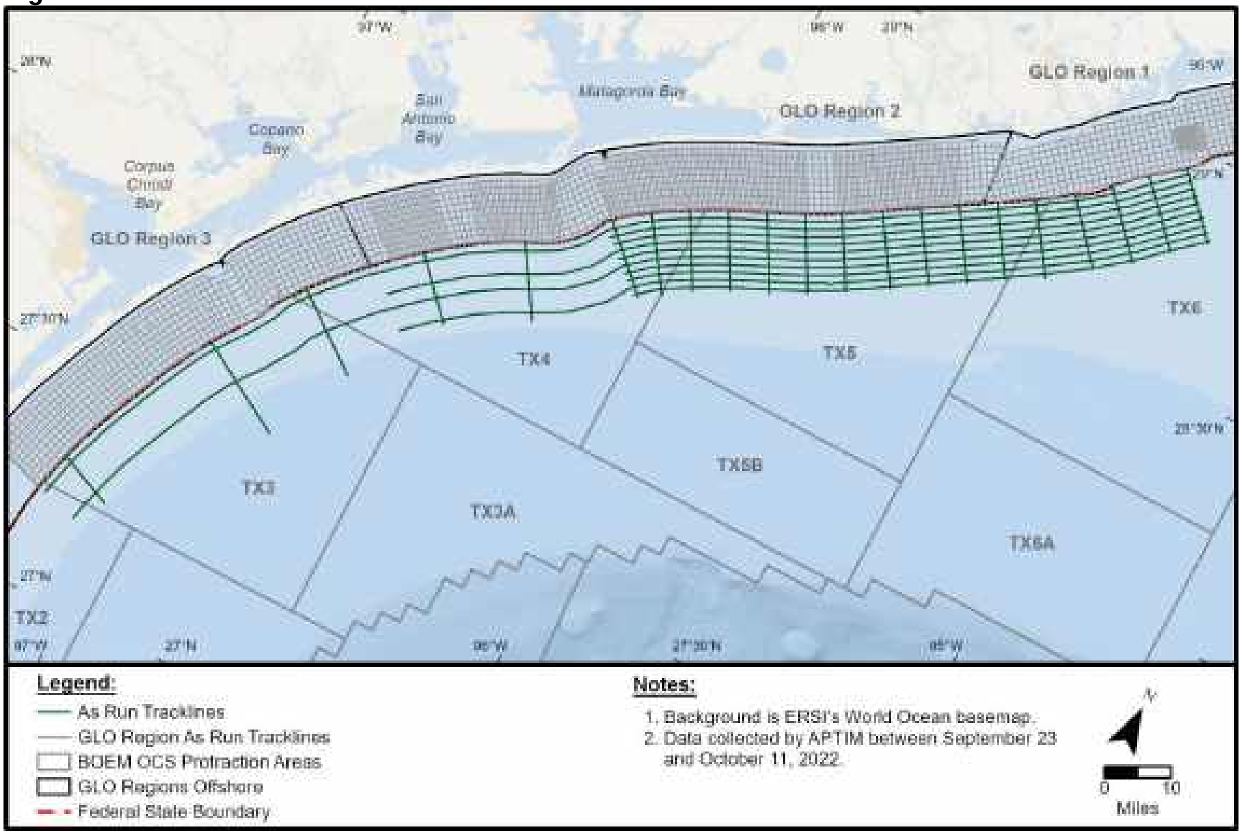
On September 22, 2022, the APTIM crew arrived at Freeport Launch Services in Freeport, Texas and boarded the M/V *Terry Bordelon* and proceeded with setting up the thermal camera system necessary for Protected Species Observer (PSO) operations. Once complete, the crew began transiting to the survey site in the afternoon of September 23, 2022. The crew arrived on site in the Central Coast OCS study area in the late afternoon of September 23, 2022 and began data collection. The survey continued until September 27, 2022, when the vessel was forced to pull gear and retreat to Freeport due to inclement weather resulting from Hurricane Ian. The vessel arrived at dock in Freeport in the late afternoon on September 27, 2022 and remained on weather standby until pushing off on the morning of September 30, 2022. Operations continued until the early morning of October 6, 2022 when the M/V *Terry Bordelon* docked at Freeport Launch Services in Freeport, Texas for a scheduled crew change. On the late afternoon of October 6, 2022 the vessel transited back to the survey site and resumed survey operations. Survey continued regular operations until late in the evening of October 11, 2022 when it was completed. On October 12, 2022 the vessel returned to Freeport to drop off some of the survey crew before beginning the transit to Houma, Louisiana for demobilization. On the afternoon of October 13, 2022, the M/V *Terry Bordelon* arrived in Houma and began demobilization.

Throughout the duration of the survey, there were no PSO sightings that required a shut-down of the geophysical systems, however on September 23, 2022, ramp up procedures were interrupted due to dolphins entering the exclusion zone.

Table 1. Proposed and Collected Nautical Miles (nm) of Survey Data

Location	Dates	Proposed (nm/km)	Collected (nm/km)
Central Coast OCS Geophysical data collection (bathymetric, magnetometer, seismic, sidescan sonar)	September 23, 2022 to October 11, 2022	1,212/2,245	1,218/2,256

Figure 26. As Run Tracklines



3.2 Equipment and Survey Methods

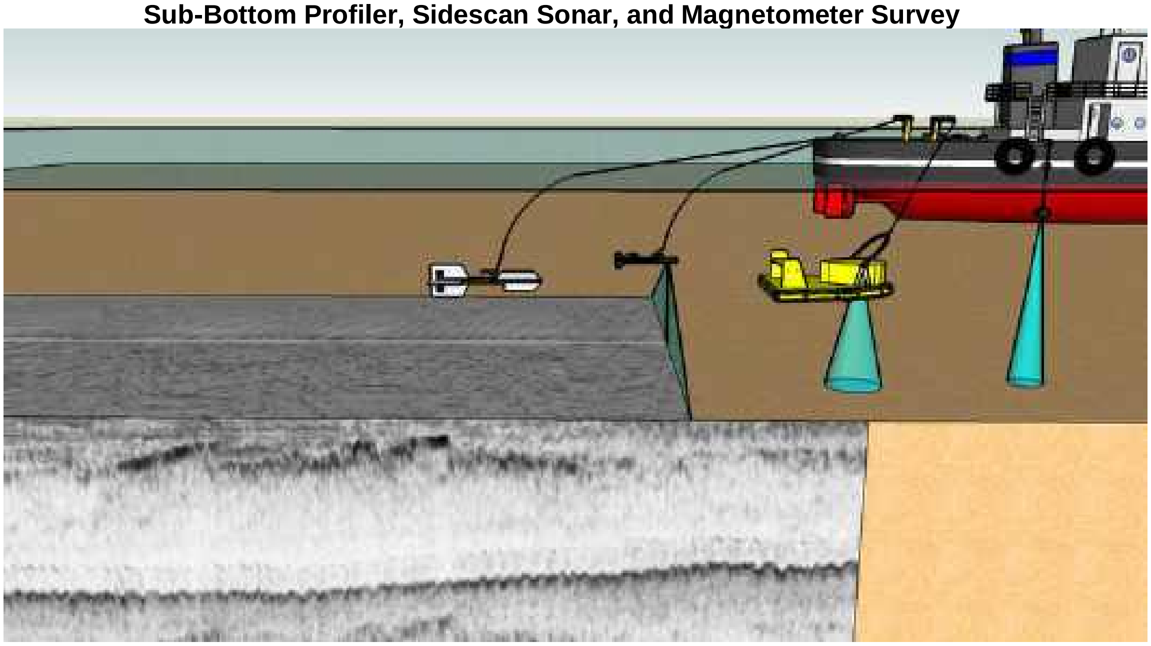
The Task 2 geophysical investigation included single beam bathymetric, sidescan sonar, seismic reflection profiling, and magnetometer surveys. The survey systems are listed and discussed in detail below and presented in Table 2. The single beam bathymetric, sidescan sonar, seismic reflection profiling, and magnetometer surveys were conducted concurrently using the setup illustrated on Figure 27. Geophysical data were collected under the responsible charge of Beau Suthard, a licensed Professional Geoscientist (Geology) registered in the State of Texas (License #12902).

Table 2. Equipment Used During the Geophysical Investigation

Equipment Type	Description	Acquisition Parameters
Navigation	Trimble Post-Processing Kinematic, Differential Global Positioning System (Trimble SPS 461) interfaced with HYPACK 2020®, TSS DMS-05	N/A
Single beam Hydrographic Echosounder	Odom Hydrographic Systems, Inc. "Teledyne E20"	200 kHz, 4-degree transducer
Sound Velocity Profiler	Valeport's SWiFT SVP	N/A
Sub-Bottom Profiler (Seismic Reflection)	EdgeTech 3200 with SB-512i Sub-bottom Profiler	Pulse. 0.7-12 kHz, Power. 40% Ping Rate. 7.0 hz Acquisition Depth: 40m
Sidescan Sonar	EdgeTech 4200 sidescan sonar system	300 kHz, 230 m Range Scale; 600 kHz, 120m Range Scale
Magnetometer	Geometrics G-882 Digital Cesium Marine Magnetometer	0.02 nT P-P 0.1 second sample rate
Processing Software	HYPACK 2022®, Single Beam Max, ESRI ArcGIS 10.8.1, Chesapeake Technology Inc.'s SonarWiz 7 and Golden Software's Surfer 12	N/A

Notes: hz – hertz, kHz – kilohertz, m – meter, N/A – not applicable, SVP – Sound Velocity Profiler, nT P-P – nanotesla peak to peak

Figure 27. Schematic Diagram Showing the Typical Deployment of Sensors. Joint Bathymetric, Sub-Bottom Profiler, Sidescan Sonar, and Magnetometer Survey



3.2.1 Navigation

The positioning system deployed for the survey was a Trimble SPS-461 Differential Global Positioning System (DGPS). The receiver automatically acquired and simultaneously tracked the NAVSTAR 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 determined the time, latitude, longitude, height, and velocity once per second. Global Position System (GPS) accuracy with differential correction provided for a position accuracy of 1 to 4 ft (30 to 122 centimeters). A Trimble Global Navigation Satellite System (GNSS) receiver was used onboard the survey vessel to log GNSS positions for post-processing GNSS data. GNSS data were logged at 5 hertz (Hz) during survey operations for accurate real-time positions, and to aide in post-processing.

A Trimble GNSS receiver was also used onboard the survey vessel to log GNSS positions for post-processing. Post processed kinematic (PPK) allows for higher quality position and elevation solutions when processed with nearby National Geodetic Survey Continually Operating Reference Stations (CORS). GNSS data were logged at 5 Hz during survey operations.

All coordinates presented in this report are in U.S. Survey Feet, relative to the North American Datum 1983 (NAD83), Texas State Plane Coordinate System, South Central. Elevations are presented in U.S. Survey Feet, relative to the North American Vertical Datum 1988 (NAVD88) relative to Geoid 18.

3.2.2 HYPACK Inc.'s HYPACK 2020® Data Collection and Processing Program

APTIM's navigation, magnetometer, and depth sounder systems were interfaced with an onboard computer and the data were integrated in real-time using HYPACK Inc.'s HYPACK 2020® software. HYPACK is a state-of-the-art navigation and hydrographic surveying system. The location of the towfish tow point were measured in relation to the center of mass of the vessel. Positioning for each geophysical system was provided by utilizing the towfish layback driver in HYPACK. This tool allows the user to set up towpoint offsets for each towfish and, during data acquisition, adjust cable out lengths, which will correct the final system position in real-time by taking into account the towpoint offsets as well as the individual catenary factor established for each system. The catenary factor was calculated based on the weight of the system and its towing configuration. The final towfish position is then shared with each of the systems and raw geophysical data is collected with layback corrections. The length of cable deployed between the tow point and each towfish were also measured and entered into HYPACK to monitor the position of each system in real-time. Online screen graphic displays included the pre-plotted survey lines, the updated boat track across the survey area, adjustable left/right indicator, as well as other positioning information such as boat speed, quality of fix measured by Position Dilution of Precision, and line bearing. 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. Offsets for the DGPS, transducer and motion reference unit were calculated by measuring the distance of each system from the center of mass and utilizing the system offset set up within the HYPACK Hardware interface.

3.2.3 Bathymetric Survey

The Odom Hydrographic Systems, Inc.'s ECHOTRAC E20, a single frequency portable hydrographic echo sounder, was used to perform the bathymetric survey. The ECHOTRAC E20 operates at frequencies between 10 and 250 kilohertz (kHz) and is a digital, survey-grade sounder. A 200 kHz, four (4) degree transducer was used for the bathymetric survey. Soundings were collected at maximum ping rates to provide an accurate depiction of the seafloor. Sounder calibration was performed periodically throughout the survey (typically at the beginning and end of each survey day). The echo sounder was calibrated via bar checks and a sound velocity probe. Valeport's SWiFT Sound Velocity Profiler (SVP) measures 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 15 to 30 ft (4.6 to 9.1 m) in 5 ft (1.5 m) increments to verify the transducer draft and speed of sound. Echogram data showing the results of the bar check calibration were displayed on the sounder electronic charts during descent of the bar.

Real-time navigation software (HYPACK) was used to provide navigation to the helm to minimize deviation from the line azimuth. This software provided horizontal position to the sounding data, allowing real-time review of the data in plan view or cross-section format. A TSS DMS-05 Motion Compensator was used onboard the survey vessel to provide instantaneous heave, pitch, and roll corrections. Tie lines were collected to verify survey accuracies.

3.2.4 Magnetometer Survey

A Geometrics G-882 digital cesium marine magnetometer (Figure 28) was used to detect magnetic anomalies within the survey area. The magnetometer runs on 110 volts alternating current and is capable of detecting and aiding the identification of any ferrous, ferric, or other objects that may have a distinct magnetic signature. Factory set scale and sensitivity settings were used for data collection (0.004 nanotesla [nT]/ πHz rms; typically, 0.02 nT peak-to-peak at a 0.1 second sample rate or 0.002 nT at 1 second sample rate). The magnetometer was towed to maintain an altitude of no greater than 19.7 ft (6 m) above the seafloor and far enough away from the vessel to minimize boat interference. Navigation and horizontal positioning for the magnetometer were provided by the Trimble DGPS system via HYPACK 2020® and using a towfish layback correction. Magnetometer data were recorded in the native raw HYPACK file format using HYPACK 2020® survey software. The purpose of the magnetometer survey was to detect the presence of potential underwater wrecks, submerged hazards, or other features that would affect borrow area delineation and dredging activities.

Figure 28. Geometrics G-882 Digital Cesium Marine Magnetometer

Note: Magnetometer is used to investigate magnetic anomalies.

3.2.5 Sidescan Sonar Survey

APTIM utilized an EdgeTech 4200 sidescan sonar system (Figure 29) for this project. This system uses full-spectrum chirp technology to deliver wide-band, high-energy pulses coupled with high-resolution and good signal to noise ratio echo data. The sonar packages included a portable configuration with a laptop computer running EdgeTech's Discover® acquisition software and dual frequency towfish running in high-definition mode. This sonar system consists of dual frequency towfish operating at 300/600 kHz, with maximum range scales of 754 ft (230 m) to either side of the towfish (300 kHz), and 393 ft (120 m) to either side of the towfish (600 kHz). These range scales are the maximum manufacturer recommended ranges for the frequencies listed above. However, geophysicists in-the-field based the recorded ranges on the field conditions and may not have utilized the maximum range scales. For data acquisition during this survey, frequencies and range scales were at 300 kHz/230 m and 600 kHz/120 m with the operation range set to high-definition mode. The sidescan sonar data were merged with positioning data from DGPS via HYPACK 2020®, video displayed, and recorded to the acquisition computer's hard disk for post-processing and/or replay. The location of the fish tow point (as referenced to the DGPS antenna), together with the length of cable deployed from the tow point, were entered into HYPACK 2020® to account for the fish layback and provide accurate positioning of the sidescan towfish during the survey. The sidescan system was operated by the Edgetech Discover® software program. All sidescan sonar data were collected in the default EdgeTech. jsf file format. The purpose of the sidescan sonar survey was to detect the presence of any surficial geomorphological features, potential underwater wrecks, submerged hazards, or other features that would affect borrow area delineation and dredging activities.

Figure 29. EdgeTech 4200 Sidescan Sonar Towfish

3.2.6 Seismic Reflection Profile Surveys

An EdgeTech 3200 X-STAR with a SB-512i towfish was used to conduct the sub-bottom profile surveys (Figure 30). The X-STAR Full-Spectrum Sonar is a versatile wide-band FM sub-bottom profiler that collects digital normal incidence reflection data over many frequency ranges. Throughout the duration of the survey, operational parameters for the seismic system were a pulse frequency of 0.7-12 kHz, power of 40 % ping rate of 7.0 Hz and acquisition depth of 40 m (131.2 ft) This instrumentation generated cross-sectional images of the seabed (to a depth of up to 50 ft [15.2 m] in this survey). The X-STAR SB-512i transmits an FM pulse that was linearly swept over a full-spectrum frequency range (also called a "chirp pulse"). The tapered waveform spectrum resulted in images that have virtually constant resolution with depth. The Chirp systems have an advantage over 3.5 kHz and "boomer" systems in sediment delineation because the reflectors are more discrete and less susceptible to ringing from both vessel and ambient noise. The full-wave rectified reflection horizons were cleaner and more distinct than the half-wave rectified reflections produced by older analog systems. Chirp sub-bottom/seismic reflection data were used to show sedimentary stratigraphy and identify potential project-compatible sediment resources. The use of chirp sub-bottom data allowed common stratigraphic layers to be mapped throughout the study area while determining the thickness and extent of potential project-compatible sediment.

Figure 30. EdgeTech X-STAR SB-512i Sub-Bottom Profiling System

In order to minimize noise related to the survey vessel and sea conditions, the sub-bottom towfish (which operated as both the source and receiver for the sub-bottom system) was deployed and towed behind the research vessel. The sub-bottom data were merged with positioning data from DGPS system via HYPACK 2020®, video displayed, and recorded to the acquisition computer's hard disk for post-processing and/or replay. The location of the fish tow point (as referenced to the DGPS antenna), together with the length of cable deployed from the tow point, were entered into HYPACK 2020® to account for the towfish layback and provide accurate positioning of the sub-bottom towfish during the survey. The sub-bottom system was operated by the Discover-SB® software program. At the start of the sub-bottom profiling survey, the sweep frequencies of the outgoing pulse together with the different gain settings available within Discover-SB® were adjusted to obtain the best possible resolution for the survey. The data were continuously bottom-tracked to allow for the application of real-time gain functions in order to have an optimal in-the-field view of the data. Automatic Gain Control (AGC) was used to normalize the data by strengthening quiet regions/soft returns while simultaneously reducing/eliminating overly strong returns by obtaining a local average at a given point. A Time-Varying Gain (TVG) was used to increase the returning signal over time in order to reduce the effects of signal attenuation. During the seismic data collection process, APTIM geophysicists were constantly monitoring the incoming data for areas where the subsurface stratigraphy was indicative of potential sand resources. When these were observed, targets were made in HYPACK and/or notes were taken and reviewed.

As part of this project, the seismic data collected were shared with the University of Texas Institute for Geophysics (UTIG) for additional high level data processing to maximize image quality. Additional information on this step is provided in Section 4.4 and Appendix F.

3.3 Mitigation Efforts to Minimize Potential High-Resolution Geophysical Impacts to Protected Species

3.3.1 Mitigation

While impacts to marine mammals were not expected, the following mitigation protocols were implemented to reduce the already small chance of high-resolution geophysical (HRG) survey impacts to marine mammals. These protocols reflected the most recent federal regulatory coordination document to address HRG systems, the Final Environmental Assessment on Sand Survey Activities for BOEM's Marine Mineral Program (MMP) produced by BOEM (May 2019), specifically Appendix B: Survey Requirements and Mitigation Measures.

The GLO and APTIM submitted a written Request for Mitigation Exemptions to BOEM on June 25, 2020. The GLO and APTIM requested exemptions from two mitigation measures, (1) Passive Acoustic Monitoring (PAM), and (2) Sea Turtle Frequency Modulation Requirements for Nighttime Operations. The written Request for Mitigation Exemptions provided information on the proposed geophysical survey equipment, the regulations for mitigation measures, proposed mitigation measures, as well as supporting documentation and reasoning for the mitigation exemption request. The mitigation exemption request was granted (via email) by BOEM on July 30, 2020. On October 21, 2020, prior to commencing field operations, BOEM issued project specific "Survey Requirements and Mitigation Measures for all Marine MMP G&G" describing the necessary survey requirements. This document confirmed that nighttime PAM operation and the nighttime frequency modulation mitigation requirements were waived.

3.3.2 Seismic Survey Mitigation and Protected Species Observer Protocols

Geophysical surveys may have an impact on marine wildlife, although HRG surveys are the least impactful when compared with surveys utilizing airguns. Non-airgun HRG acoustic sources with frequencies greater than or equal to 180 kHz do not require mitigation because the frequency is outside the general hearing range of marine mammals (National Marine Fisheries Service [NMFS] 2020). The magnetometer produces no acoustic noise whatsoever, while the echosounder and the sidescan sonar utilize a higher frequency than 180 kHz; therefore, no mitigation plan was necessary for these three (3) systems. Since the EdgeTech 3200 512i chirp sub-bottom profiler operates at a frequency below 180 kHz, the survey implemented mitigation protocols consistent with Final Environmental Assessment on Sand Survey Activities (EA) for BOEM's MMP produced by BOEM (May 2019), specifically Appendix B: Survey Requirements and Mitigation Measures.

An Acoustic Clearance Zone (ACZ) of 328-ft (100 m) was monitored during all sand survey activities. All survey operations were monitored by a NMFS approved, trained PSO. One NMFS approved and trained PSO was always on duty during survey operations. Startup and shut-down requirements were followed every time the survey began. Nighttime operations did not require the use of PAM or any frequency modulation above 2 kHz (see Section 3.3.1). This exemption was supplemented with the nighttime PSO utilizing night vision goggles to monitor the ACZ, as well as the use of a thermal imaging camera system. These proposed nighttime mitigations provided the same visual monitoring standards proposed by the EA for daylight hours.

During the survey operation, there was only one PSO shut-down due to a pod of dolphins entering the exclusion zone during ramp up on September 23, 2022. Once the dolphins were clear of the exclusion zone the area was re-cleared by the PSO and ramp up was completed. Throughout the duration of the survey several pods of dolphins were observed in the ACZ, however no shut-down was required.

3.3.3 Vessel Strike Avoidance and Injured/Dead Aquatic Protected Species Reporting Protocols

All efforts were made by the vessel operators and crew to avoid striking any aquatic protected species. A visual observer (e.g., captain and PSO) aboard the vessel monitored a vessel strike avoidance zone around the vessel to ensure the potential for strike was minimized. Vessel speeds were reduced to 10 knots (18.5km/h) or less when mother/calf pairs, pods, or large assemblages or any marine mammals were observed near the vessel. The vessel maintained a minimum separation distance of 100 m (328.1 ft) from sperm whales, and 500 m (1,640.4 ft) from any baleen whale to specifically protect the Gulf of Mexico

Bryde’s whale. The vessel maintained a minimum separation distance of 50 m (164 ft) from all other aquatic protected species, including sea turtles, with an exception made for those animals that approach the vessel. If aquatic protected species were sighted while the vessel was underway, the vessel acted as necessary to avoid violating the relevant separation distance. If aquatic protected species were sighted within relevant separation distance, the vessel reduced speed and shifted engine to neutral, and did not engage the engines until animals were clear of the area. This did not apply to any vessel towing gear (e.g., geophysical towfish). The above stated requirements did not apply 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.

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. No injured or dead aquatic protected species were observed during this survey.

3.3.4 Gulf of Mexico Marine Trash and Debris Awareness and Elimination Survey Protocols

Marine trash and debris pose a threat to fish, marine mammals, sea turtles, and potentially other marine animals, cause costly delays and repairs for commercial and recreational boating interests, detract from the aesthetic quality of recreational shore fronts, and increase the cost of beach and park maintenance. In order to mitigate this threat to the environment and marine animals, all personnel involved in conducting the HRG survey had Marine Trash and Debris Awareness Training. The program is conducted on an annual basis. All offshore employees and contractors actively engaged in offshore operations are required to view the Bureau of Safety and Environmental Enforcement YouTube™ video entitled “Keep the Sea Free of Debris. A look at preventing marine debris and some best practices” and review NTL 2015-G03. All policies and procedures outlined in this training were observed during vessel operations.

3.3.5 Navigation and Commercial Fisheries Operations Conflict Minimization Requirements

APTIM was required to file a Local Notice to Mariners with the appropriate U. S. Coast Guard (USCG) District. APTIM filed the Local Notice to Mariners prior to beginning the survey. Please see the USCG Published Local Notice to Mariners below.

TX - GULF OF MEXICO - Survey Operations

Continuing until October 31, 2022, M/V TERRY BORDELON will be conducting geophysical survey operations in the Gulf of Mexico, bound by the following approximate positions:
North East Corner: 29-00-49.0N 094-56-17.0W, to 15nm offshore;
South East Corner: 27-12-59.0N 097-10-19.0W, to 15nm offshore.
Operations will be conducted 24-hours a day, 7-days a week. M/V TERRY BORDELON will monitor VHF-FM Channel 16. M/V TERRY BORDELON is restricted in ability to maneuver and can be contacted on VHF-FM Channel 16.

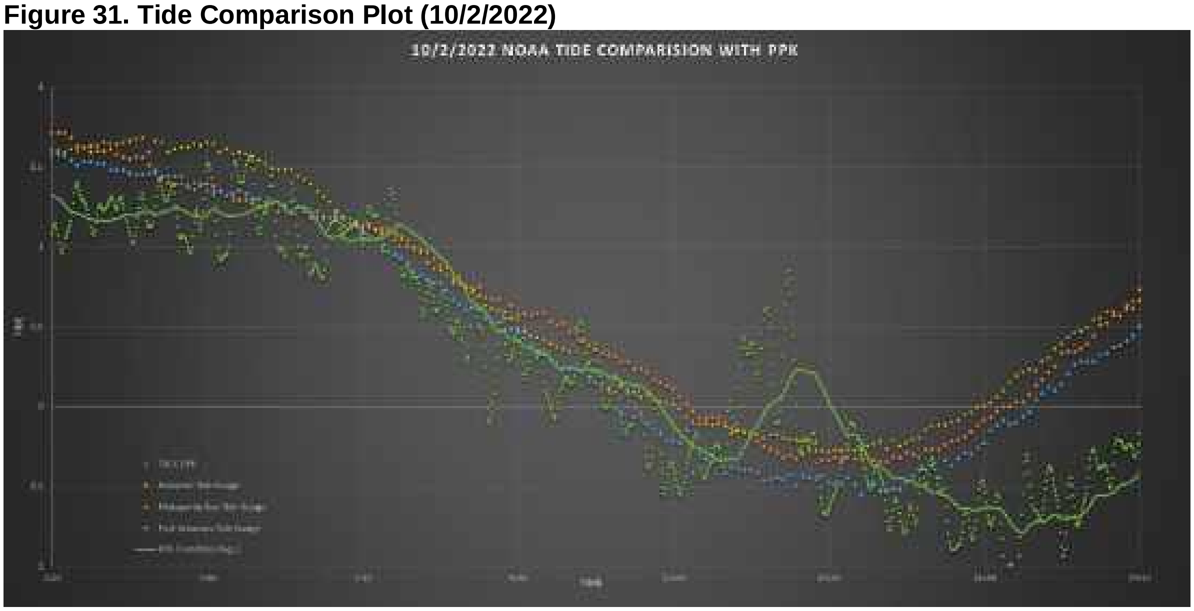
Charts: 411 1117A 11300 LNM: 37-22

4 Task 3 Data Processing and Data Interpretation

4.1 Bathymetric Survey

Upon completion of the field work, data were edited and reduced with APTIM's internal software programs, Trimble Business Center (TBC), and HYPACK 2022®. The logged GNSS data were processed using TBC to aid with water level corrections. The GNSS derived water level corrections were compared with local National Oceanic and Atmospheric Administration (NOAA) water level gauges for verification purposes. The NOAA recording gauges compared well with the GNSS derived water levels in most areas. It was observed that the NOAA recorded water levels were more stable than the GNSS derived water levels in areas of long GNSS base lines from the CORS station. The final water level solution was derived using the 8775241 Aransas, Aransas Pass, TX NOAA recording water level gauge, the 8773146 Matagorda City, TX NOAA recording water level gauge, and the 8772440 Freeport, TX NOAA recording water level gauge (Figure 31). All digitized soundings were scanned for noise with errant and false soundings removed. Water depths within the study area ranged from -148 to -54 ft (-45.1 to -16.5 m) (NAVD88). Bathymetric maps are presented in Appendix B.

Figure 31. Tide Comparison Plot (10/2/2022)

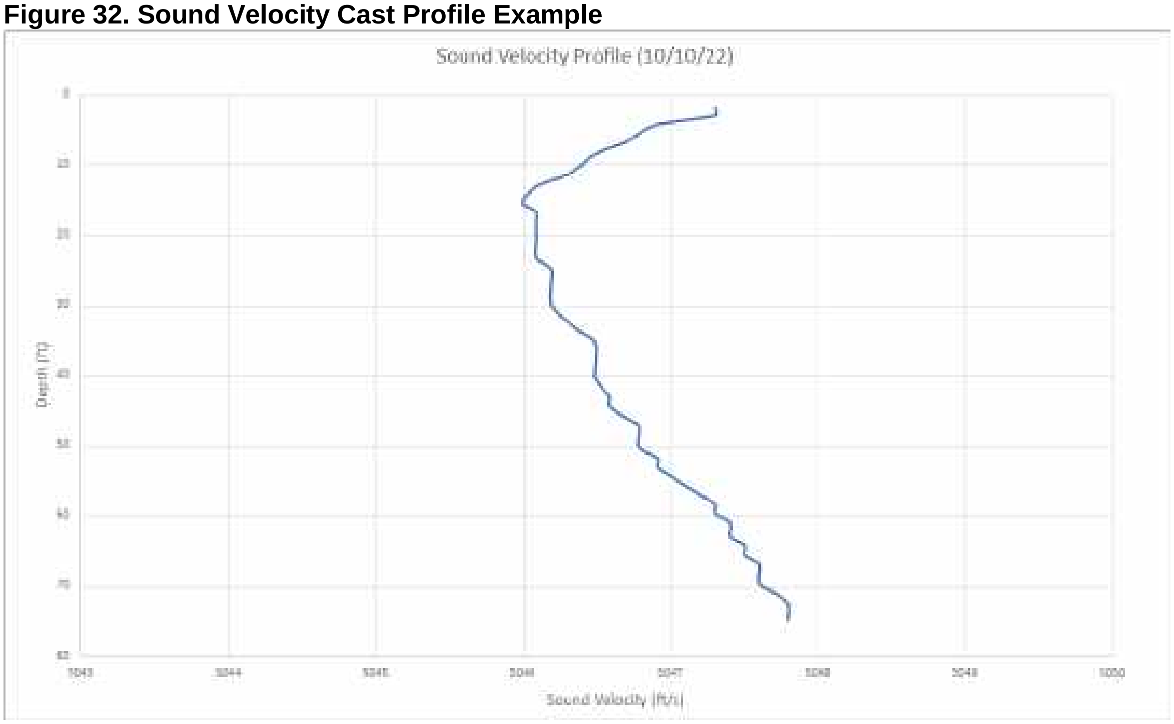


Data uncertainties were mitigated during both collection and processing phases using a range of instruments and procedures. Proper vessel mobilization, attentive and accurate data collection consistencies, as well as a stable processing method were used to ensure data quality and minimize uncertainties.

Prior to data collection, all instruments (including motion reference unit [MRU], GPS, and transducer) were mounted onto the vessel and offsets measured from the vessel center of mass. A vessel diagram depicting these offsets is presented in Appendix A. When installing the factory calibrated Teledyne TSS DMS-05 MRU, field calibrations were also performed. During the calibration routine, the instrument measures average roll and pitch angles over an extended period while the vessel is not in motion. These averages are applied to the raw MRU data, which accounts for any mounting angle bias that may be present.

The transducer draft was measured using conventional instruments after mobilization, and periodically throughout operations to ensure accurate depth determination. Bar checks were performed to verify draft/sound velocity corrections and to ensure proper echo sounder operation. Once draft/sound velocity measurements were taken, an acoustically reflective surface (bar) attached to a rope (or cable) is measured at a known distance from the waterline. Measurements are marked in five (5) ft (1.5 m) increments, allowing the bar to be placed at a maximum depth of 30 ft (9.1 m) from the waterline. Once lowered underneath the transducer at a specific depth, the echosounder reading is compared to that of the true depth of the bar and verified using the digitized depth reading. A factory calibrated Valeport SWiFT SVP was used to measure sound velocity during the survey and can collect sound velocity casts while underway (Figure 32). Sound velocity casts were collected at an interval of approximately 0.5 ft (0.15 m) throughout the entire depth range of the water column at least twice a day, once per 12-hour shift. Additional casts would be collected if deemed necessary (change in survey area, thermoclines observed, etc.). All casts were recorded for post-processing of the soundings. The average velocity is applied to the echosounder after each cast. Sound velocity profiles are applied to the processed data within HYPACK to account for changes from the average velocity at depth.

Figure 32. Sound Velocity Cast Profile Example

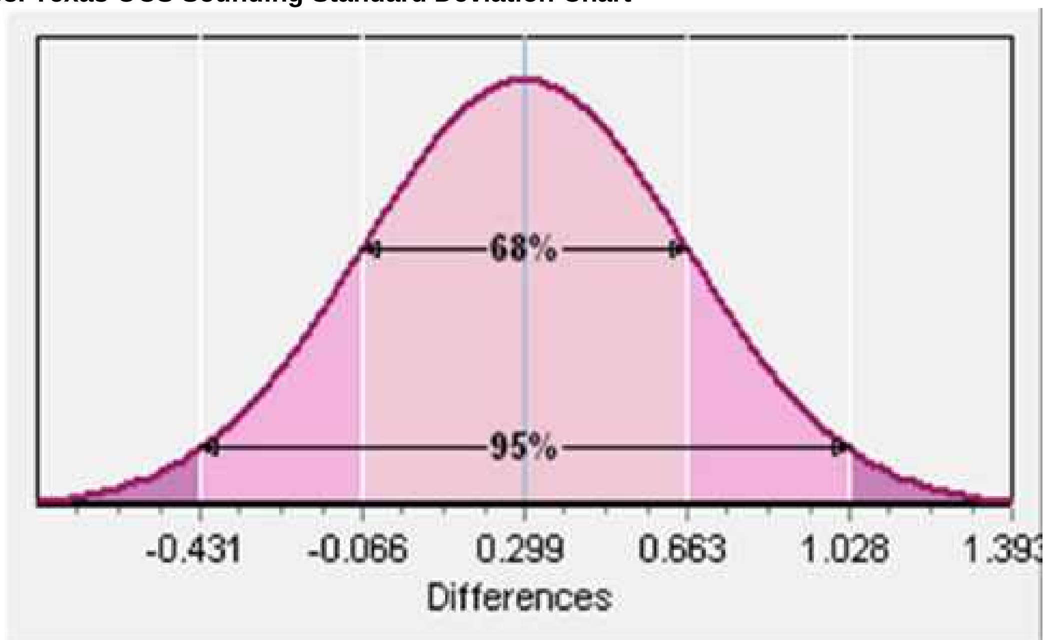


Following data collection, all data files were processed using HYPACK 2022® SBMAX64 program. A full sound velocity profile, tide adjustments and inertial measurement unit corrections were applied and analyzed for inconsistencies. Erroneous soundings were identified and removed within SBMAX64. HYPACK's SORT Program was used to reduce sounding data and export to an XYZ file used to create bathymetric maps presented in Appendix B. HYPACK's Cross Check Statistics program was used to identify potential sounding inaccuracies. Cross Check Statistics provides detailed information regarding differences between data on intersecting lines at a user-defined search radius. The program displays the number of intersections within the given radius, standard deviation, difference mean, arithmetic mean, and minimum/maximum difference between intersections. Table 3 below shows the Texas OCS Cross Check Statistical Report, generated using all main survey lines and tie lines. A graphical representation of sounding standard deviation is presented in Figure 33. Channels or large features within the survey area can have a major effect on minimum and maximum difference depending on the search radius used. These values are not always an accurate representation of uncertainties. Values such as standard deviation, absolute difference mean, and arithmetic mean are of greater importance when performing any quality assurance checks within a given dataset.

Table 3. Texas OCS Cross Check Statistical Report.

Number of Intersections	**82**
Theoretical Number of Intersections	1495966
Search Radius (ft/m)	25.0/7.6
Standard Deviation (ft/m)	0.365/0.111
Absolute Difference Mean (ft/m)	0.299/0.091
Arithmetic Mean (ft/m)	-0.022/-0.007
Minimum Diff (ft/m)	-0.861/-0.262
Maximum Diff (ft/m)	0.687/.210

Figure 33. Texas OCS Sounding Standard Deviation Chart



A Trimble SPS 461 DGPS was used for heading and positioning data during operations. A Trimble R8-4 Receiver was also aboard, allowing for PPK tide corrections. PPK data were processed using TBC and multiple survey days were compared to three of the nearest NOAA water level gauges (8775241 Aransas Pass, 8773146 Matagorda City, and 8772440 Freeport) to ensure accurate water level corrections.

The final tide corrections were derived using the centerline method from NOAA gauges 8775241 Aransas Pass, 8773146 Matagorda City, and 8772440 Freeport. A grid file was created with these xyz data using Surfer 21 to interpolate between the data points. A spacing of 150 ft x 150 ft (45.7 m x 45.7 m) was used. In the southwest portion of the project area, there are approximately 23 nm (42.6 km) between shore perpendicular lines, and five (5) nm (9.3 km) between the shore parallel lines. Since this is vastly different than the northeastern portion of the project area, there is far greater interpolation in the southwestern area. This has caused a slight “wave” effect of the contours in the southwest portion of the project area where the shore perpendicular lines cross the share parallel lines.

The grid file was opened in ArcCatalog 10.8.2 and was exported as a raster tagged image file (TIF) file so it can be viewed in ArcGIS PRO. The XYZ data and the TIF file were opened in ArcGIS PRO and a border shapefile was created, allowing interpolated raster data outside of the study area to be clipped out. The TIF file was then smoothed using the Focal Statistics tool, and a classified color ramp was applied to the raster file. Contours were created based on the elevation of the raster TIF file using the contours tool in ArcGIS. The contours can be observed in Appendix B.

4.2 Magnetometer Survey

The magnetometer data were processed with HYPACK 2022® software to locate magnetic anomalies. The raw data files were imported into and normalized manually to clean and remove any abnormal spikes or irregularities in the magnetic profile and to account for unwanted interference in the record, such as the survey vessel's effects or environmental and diurnal variations. Objects that possess any ferromagnetic mass (e.g., iron) can be detected with the magnetometer and are indicated by changes in magnetic intensity and visualized as monopoles, dipoles, and multi-component signatures in the profile view of the data. These varying signals distinguish the anomalies from the natural environment.

Each survey line was reviewed and interpreted in detail for the presence of magnetic anomalies. Upon completion of this review, anomalies were plotted and examined together with shapefiles of sidescan sonar contacts, known oil/gas pipelines, wells, and platforms, charted shipwrecks and obstructions, miscellaneous easements, artificial reefs, and buried transmission cables to find associations between the datasets. The Appendix C map series shows the extent of the magnetometer data coverage of the investigation area and the spatial distribution of anomalies.

The magnetometer survey data revealed 788 magnetic anomalies within the Central Coast OCS Region investigation area, as shown in Appendix C. Anomalies ranged from 4.49 to 17,207.07 nT in amplitude and from 6.66 to 3,626.45 ft (2.03-1,105.3 m) in duration. Anomaly signatures consisted of 455 monopolar, 206 dipolar, and 127 multi-component anomalies. None of the identified anomalies were potentially associated with, or representative of, side scan sonar contacts and 253 anomalies were potentially associated with, or representative of, features mapped in the aforementioned shapefiles.

Ideally, a close-order survey with multiple survey lines using a tighter line spacing would be implemented to refine the magnetic record.

4.3 Sidescan Sonar Survey

Sidescan sonar data was processed using Chesapeake Technologies, Inc. SonarWiz 7 software. The raw sidescan sonar data were imported into two (2) SonarWiz 7 projects, one (1) for low frequency and one (1) for high frequency data processing due to the large file sizes and data coverage over such a large area. Once the data were imported, they were bottom-tracked to remove the water column (nadir) recorded in the data. Bottom tracking was achieved by applying an automated bottom tracking routine that determined the first return signal in the data and provided an accurate baseline representation of the seafloor that eliminated the water column from the data. In some cases, manual bottom tracking was necessary when the automated bottom tracking cannot accurately determine the first return in the sidescan sonar record. For these cases, the APTIM geophysicist manually determined the first return in the data.

After bottom tracking, the data was processed to reduce noise effects and enhance seafloor definition. To do this, an Empirical Gain Normalization (EGN) table was built which sums and averages the sonar amplitudes of every ping in the imported files by altitude and range. The EGN is a gain function that can be considered a replacement for Beam Angle Correction. A given sonar amplitude sample is placed in a grid location based on the geometry of the ping, where the x-axis is range, and the y-axis is altitude. The resulting table quantifies the beam pattern of a sonar by empirically analyzing millions of data points. Due to the sea state and shallow water conditions observed in portions of the survey area, a small percentage of the sidescan sonar lines contain reduced data quality, resulting in noise and stripes. To mitigate this, a nadir and de-stripe filter were applied. The nadir filter is a special version of the AGC filter that runs only along the nadir stripe. It is designed to reduce the difference between the nadir pixel values and the values immediately outside the nadir. The de-stripe filter is used to reduce the effects of sonar 'pitching' that is characterized by a stripy pattern perpendicular to the direction of travel. This setting processes each ping by comparing the current ping brightness to a filtered version of the sonar file that has smoothed out the stripes.

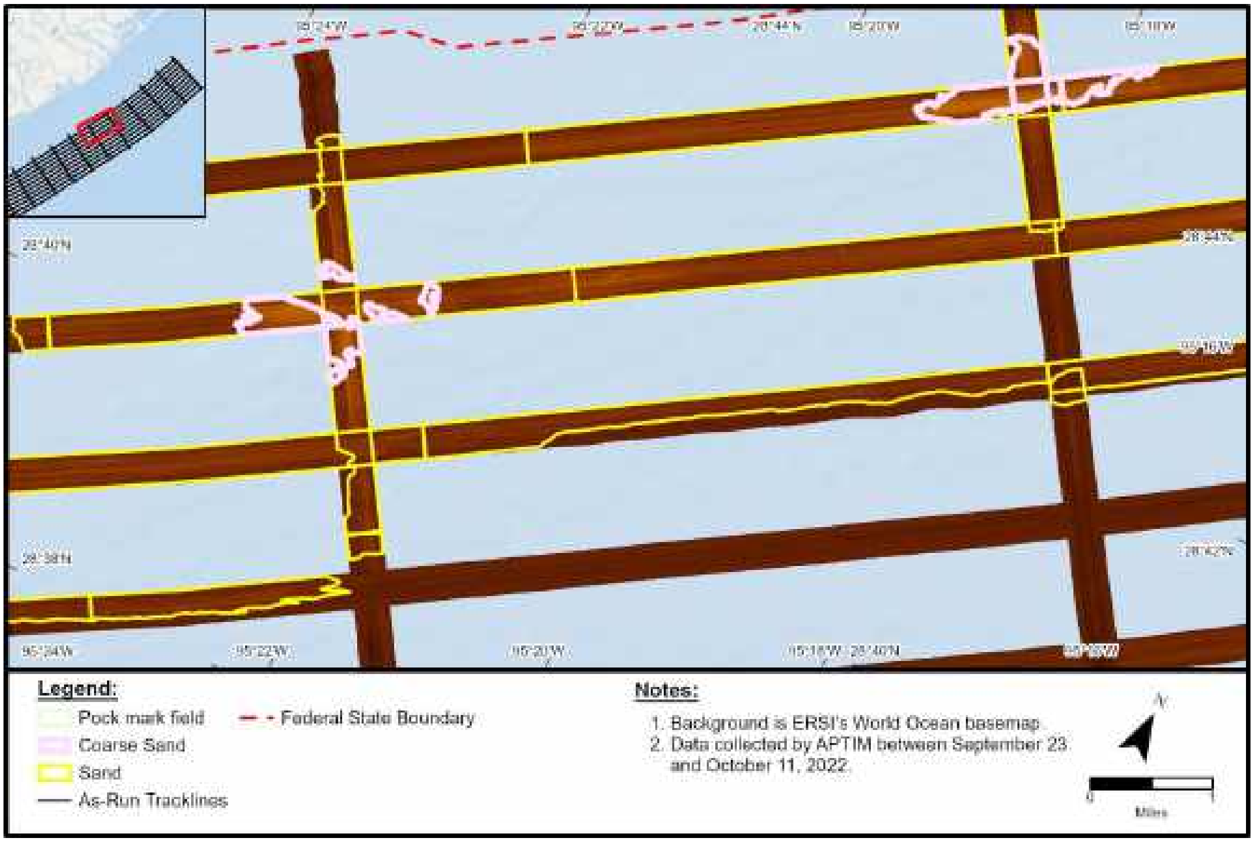
Following the processing phase, the data was interpreted to identify areas of potential seafloor hazards such as artificial reefs, submerged platforms, and the surficial geology of the seafloor. Potential areas of interest were digitized and categorized into subsection bottom types. APTIM geologists utilized backscatter intensity, distribution, and texture to make best professional interpretations of the features; however, these interpretations are based solely on the acoustic backscatter data and further ground truthing is recommend for confirmation of the acoustic interpretation.

The widely spaced survey lines collected throughout the survey area covering the Central Coast OCS Region were collected with the EdgeTech 4200 towfish which provided a limited image of the seafloor. The maximum range of the system was 230 m (754 ft) on each side, or 460 m (1,508 ft) swath, which was insufficient to allow for full seafloor coverage or interpretation between lines given the 1 nm (1.8 km) or 5 nm (9.2 km) tie line spacing of the survey. Therefore, the digitized features were “isolated” to individual lines but provide a general location and description of areas/features of interest. Identified sidescan sonar targets with magnetometer anomalies can be found in Appendix C. Interpreted maps with digitized features delineated from the sidescan sonar data can be found in Appendix D. The identified sidescan sonar targets were submitted separately as part of the digital deliverable for this project.

Based on the sidescan sonar interpretations, 145 contacts or targets were identified throughout the survey area. Contacts and targets include unknown debris and features, schools of fish and dolphins, fishing associated features (Shrimp Trawler Scour Marks), anchor scouring, exposed cables, and oil/gas infrastructure (Platforms, Wellheads, Associated Debris, and Exposed Pipelines).

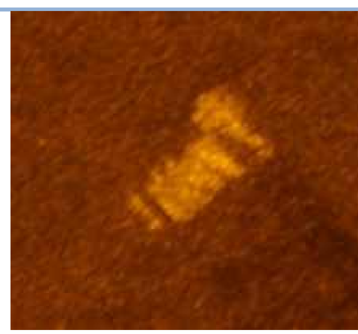
Several large areas of highly reflective coarse sands were identified near the federal boundary, roughly 11 mi (17.7 km) offshore Freeport. These sand banks present as shore parallel linear features extending seaward approximately 1.8 mi (2.8 km, Figure 34). A medium scale sand bank 12.5 mi (20.1 km) offshore the San Bernard National Wildlife Refuge was identified as running shore parallel and extending seaward roughly 1.4 mi (2.2 km). Large-scale sand features, less acoustically reflective than the aforementioned, were identified approximately 15-20 mi (24.1-32.2 km) offshore Brazoria National Wildlife Refuge and extend seaward around 15 mi (24.1 km). Northeast of Aransas National Wildlife Refuge another large-scale sand feature with moderate acoustic reflectivity is observed that extends 17-21 mi offshore (27.3-33.8 km). This feature runs shore parallel for roughly 20 mi (32.2 km) E-W. Most of the survey area consists of sandy bottom (mid to high-intensity backscatter) with large areas of very high-intensity backscatter material, indicative of coarse sandy sediments. Other prominent areas of high-intensity backscatter material with no visual ripples provide evidence to the presence of surface sands, remaining consistent with previously mapped shoals within the survey area (Figure 34). Pockmark fields are observed throughout the survey area (Table 4). Pockmarks are seabed depressions caused by the removal of seabed sediments by escaping fluids or gases; in most instances, this is related to hydrocarbon gases. They vary in size according to the nature of the seabed sediments and are generally between a few meters and a few hundred meters across, and from less than 3 ft (1 m) to about 66 ft (20 m) deep (Hovland and Judd 1988).

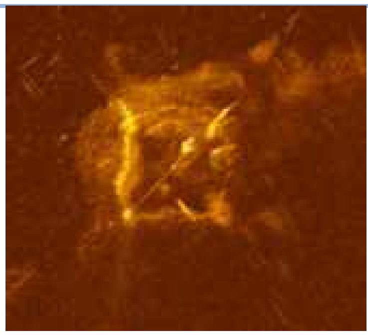
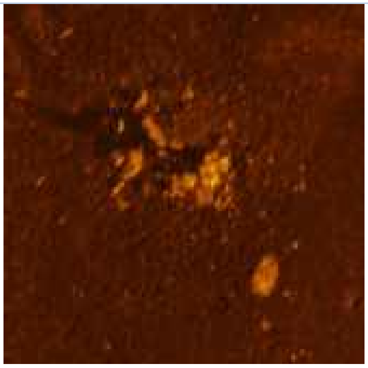
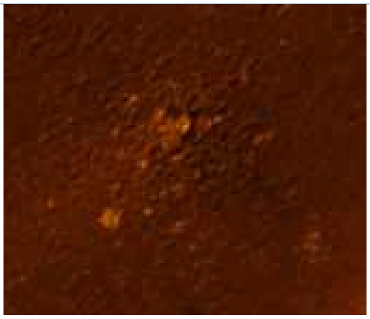
Figure 34. Highly Reflective Coarse Sand Bodies in the Sidescan Sonar Data

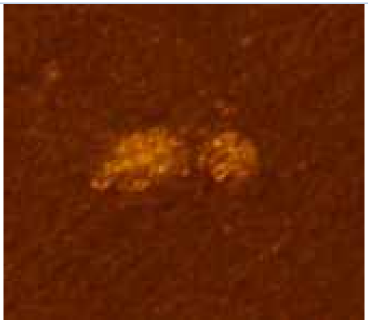
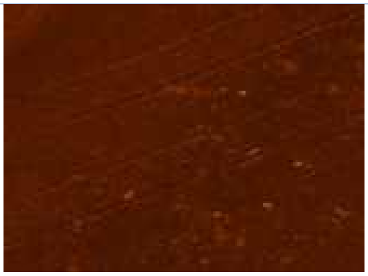
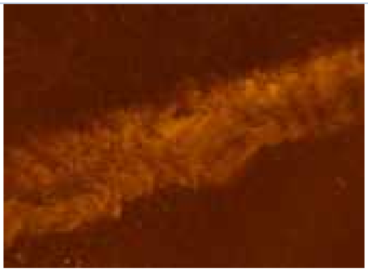
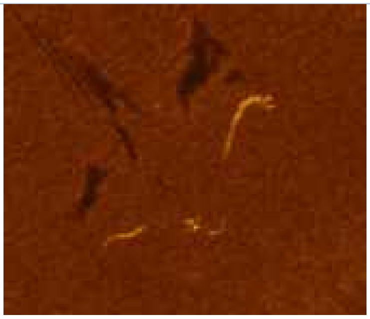


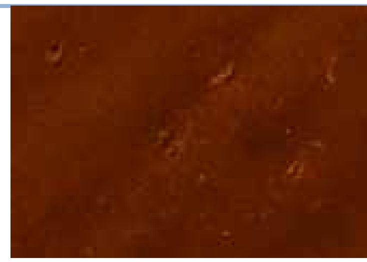
As part of the processing of the sidescan data, APTIM correlated the targeted contacts to shapefiles of hazards, features, magnetic anomalies, and historical structures to assist with the classification of the contacts and provide insight as to the general characterization of the seafloor.

Table 4. Sidescan Sonar Bottom Feature Classification

Bottom Feature/Description	Example
Oil and Gas Well Head E001 High-intensity backscatter feature correlated with known submerged well head	 Line 102.031
Exposed Pipeline/Cable medium-intensity backscatter linear feature	 Line 101.015

Bottom Feature/Description	Example
Oil and Gas Platform High-intensity backscatter feature correlated with known submerged oil platform	 Line 110.029
Potential Debris Obstruction High-intensity backscatter feature with irregular depositional formation correlating with known obstruction	 Line 105.011
Rubble Field High-intensity backscatter with irregular depositional formations	 Line 110.030
Coarse Sand Body High-intensity backscatter indicative of coarse sediments	 Line 110.005
Patch Sand Patches of high-intensity backscatter material surrounded by medium backscatter material	 Line 109.016

Bottom Feature/Description	Example
Anchor Scour Scouring formation consistent with anchoring	 Line 109.019
Bait Ball Medium-intensity backscatter with small shadow, consistent with schools of fish	 Line_110
Shrimp Trawl Marks Scouring consistent with shrimp trawls	 Line 110.002
Boat Wake Large, medium-intensity backscatter consistent with boat wakes	 Line 110.003
Dolphins Medium-intensity linear backscatter features consistent with dolphins	 Line 105.044

Bottom Feature/Description	Example
Pockmark Field Pockets of gas escaping the surficial sediment layer	 Line 105.024

4.4 Sub-bottom Profile Survey

Post collection processing of the sub-bottom data was completed using Chesapeake Technology, Inc.'s SonarWiz 7 software. This software allowed the user to apply specific gains and settings to produce enhanced sub-bottom imagery that were interpreted and digitized for specific stratigraphic facies relevant to the project goals.

The first data processing step was to calculate the approximate depth of the reflector below the sound source by converting the two-way travel time (the time in milliseconds that it takes for the "chirp pulse" to leave the source, hit the reflector and return to the source) to feet by utilizing an approximate value for the speed of sound through both the water and underlying geology. For this survey, a detailed hydrographic and geologic sound velocity structure was not available, so APTIM geophysicists used an estimated sound velocity of 1.6 meters per millisecond (m/ms [5.3ft/ms]) to convert two-way travel time to feet. This estimate of the composite sound velocity is based on several assumptions including the speed of sound through water which is typically 1.5 m/ms (4.9ft/ms) as well as on the speed of sound through the sediment which can vary from 1.6 m/ms (5.2 ft/ms) for unconsolidated sediment to >1.7 m/ms (5.6ft/ms) for limestone.

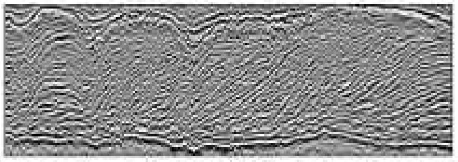
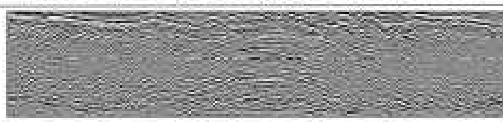
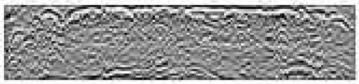
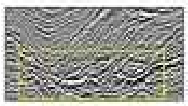
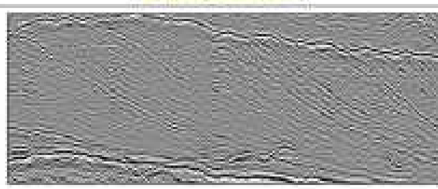
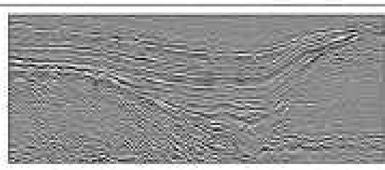
APTIM geophysicists then processed the imagery to reduce noise effects (commonly due to the vessel, sea state, or other natural and anthropogenic phenomenon) and enhance stratigraphy. This was done using the processing features available in SonarWiz AGC, swell filter, and a User-Defined Gain Control (UGC). The SonarWiz AGC is similar to the Discover-SB® AGC feature, where the data are normalized in order to remove the extreme high and low returns, while enhancing the contrast of the middle returns. In order to appropriately apply the swell filter and UGC functions, the sub-bottom data was bottom-tracked to produce an accurate baseline representation of the seafloor. Once this was done, through a process of automatic bottom tracking (based on the high-amplitude signal associated with the seafloor) and manual digitization, the swell filter and UGC were applied to the data. The swell filter is based on a ping averaging function that removes vertical changes in the data due to towfish movement caused by the sea state. The swell filter was increased or decreased depending on the period and frequency of the sea surface wave conditions, however, special care was taken during this phase to not remove, or smooth over geologic features that are masked by the sea state noise. The final step was to apply the UGC. The SonarWiz UGC feature allows the user to define amplitude gains based on either the depth below the source, or the depth below the seafloor. For this survey, the UGC was adjusted so that the gain would increase with depth below the imaged seafloor (and not the source), mimicking a TVG. The user was able to remove the noise within the water column, increase the contrast within the stratigraphy, and increase the amplitude of the stratigraphy with depth, accounting for some of the signal attenuation normally associated with sound penetration over time. A blank water column function was also applied to eliminate any features such as schools of fish under the chirp system which produce reflected artifacts within the water column.

The primary objectives of initial sub-bottom data interpretation were three-fold: 1) Indicate the Quaternary ravinement surface and its thickness throughout the survey area 2) identify paleochannels and/or paleosols that could contain accessible sediments and, if necessary, revise the regional geologic model/framework, and 3) identify localized features, contacts (such as pipelines, cables, etc.), and larger paleovalley systems.

Processed sub-bottom profiler data were interpreted within SonarWiz. Interpretation involved the identification of seismic reflection horizons that serve as boundaries for different seismic facies packages. These horizons can represent erosional unconformities such as the basal scour surface of a lateral migrating fluvial channel, or contacts representing a change in environment and associated lithology such as transgressive flooding leading to estuarine fine-grained sediment draping over a previously exposed floodplain (Figure 35, Reijenstein et al. 2011). The character of sub-bottom reflection horizons and geometries in continental shelf seismic stratigraphy can often be related to characteristics of silt, clay, sand, and the environment of deposition (Ravinement). These principles were used to interpret individual profiles that were combined to develop regional geologic conceptual models, such as defining the paths of paleo-river channels. These conceptual models helped to identify zones with potential sand-bearing sediment. It must be cautioned that interpretation of lithology using sub-bottom profiler data must always be “ground-truthed” using geologic cores, and in the absence of core data for validation, these interpretations are regarded as preliminary.

Upon completion of interpretation and digitization, the sub-bottom data were exported as a “Web” based project of HTML/JPEG files viewable in standard web browser software packages submitted to BOEM.

Figure 35. Example Classification of Sub-Bottom Profiler Data Based on Seismic Horizon Reflection Character and Geometry

2-D Seismic Facies	Reflection Character / Sedimentologic Interpretation
	**Convex-up lateral accretion surfaces, High-amplitude inclined seismic facies** Point-bar lateral accretion surfaces as seen in a dip-view cross section; Convex-up geometry with downdip increase in slope: 0.49° to 0.62° (point-bar tops) and 0.48° to 3.74° (basal point bar).
	**Convex-up bidirectional downlap; High-amplitude inclined seismic facies** Point-bar lateral accretion surfaces as seen in a strike-view cross section
	**Low-amplitude chaotic seismic facies** Reworked point-bar top deposits
	**High-amplitude channel lag seismic facies** Basal coarse-grained channel lag
	**Concave-up clinoforms; Low-amplitude inclined seismic facies** Clinoform deltaic mouth bar deposits; Concave-up geometry with downdip decrease in slope: 1.76° to 2.04° (clinoform tops) and 0.37° to 0.91° (basal section)
	**High-amplitude, confined, laterally continuous reflections; Seismic terminations onlap against valley walls** Early transgressive estuarine muddy facies
	**Low-amplitude (transparent), laterally continuous seismic facies** Open marine muddy facies

Note: The first four are representative of sandy fluvial channel belt deposits, and the last three (3) represent deltaic, estuarine, and marine deposition. Modified from Reijenstein et al. 2011.

The seismic data collected as part of this project was also submitted to UTIG for additional processing using their proprietary signal deconvolution method. Additional information on the methods used and steps taken as part of this process are presented in Appendix F. The goal of further processing the data utilizing this method, is to provide the user with an additional dataset that could better highlight the detailed stratigraphy in some areas, which would augment the understanding of specific features. This dataset is intended to be used in conjunction with the unprocessed data in order to further assist in the identification and interpretation of some of the depositional environments observed in the region.

UTIG has developed a robust workflow for processing chirp data, aiming to optimize image quality and interpretability utilizing both envelope and full waveform data. UTIG's chirp processing workflow includes bottom picking (bottom tracking) to remove any heave artifacts by identifying the return associated with the seafloor, followed by the processing of the envelope and real data by applying static corrections (to account for recording delay, towfish depth, tides, and heave compensation), followed by signal processing for image clarity and layback navigation correction (Saustrup et al. 2018).

As outlined in Saustrup et al. 2018, UTIG has developed an iterative bottom picking process which utilizes a threshold algorithm in conjunction with automated and manual methods for the refining of the seafloor reflector. Once the seafloor reflector has been identified, corrections are applied to the data to assist in the final signal processing. Static corrections such as towfish depth, heave compensation and tide corrections are applied to the data. The seismic data then undergoes several signal processing methods, such as frequency filtering, deconvolution, gain correction and water column muting to improve the image quality. The low frequency noise normally associated with towing is removed from the data utilizing a bandpass-filtering process. The data then undergoes a predictive deconvolution process (outlined in Saustrup et al. 2018 as well as Baradello 2014). Final processing steps include the application of an AGC gain, removal of water column noise (water column muting) and layback correction.

4.4.1 Ravinement

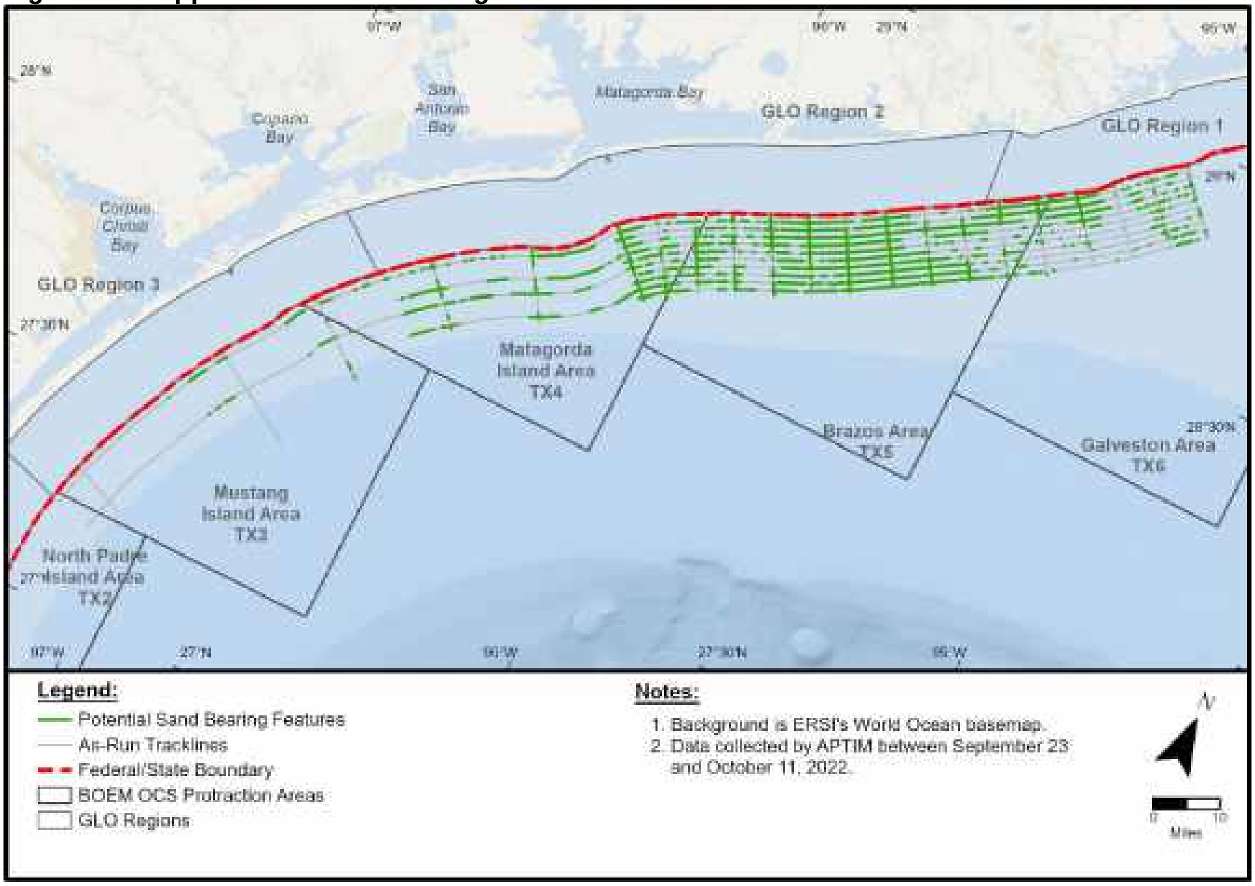
As part of the scope of work, the APTIM team were tasked with identifying the most recent transgressive ravinement surface evident in the Central Coast OCS Region. The ravinement surface is indicative of an erosional unconformity, where the dominant force was either wave or tidal which caused the removal of the antecedent deposits as the Gulf shoreline migrated across the shelf leaving behind coastal, estuarine, and marine stratigraphic units above the ravinement.

The most recent Holocene/Pleistocene unconformity ravinement was mapped throughout the entire study area. In some locations the most recent ravinement is absent above pre-existing Pleistocene deposits indicating that the modern seafloor is coincident with the ravinement surface. This stratigraphic reflector was digitized by manually identifying this reflector within SonarWiz to create a color-coded boundary. This boundary (where visible) was used within SonarWiz to compute the thickness from the bottom of the most recent depositional unit (i.e., erosional surface) to the seafloor in order to generate an isopach of the most recent sediment wedge. The thickness (XYZ) of this sediment unit was imported into Surfer 13 and gridded to create an interpolated surface depicting the general trend of deposits above the ravinement surface within the area (Appendix E). This area's ravinement was subsequently compared to GLO Regions 1, 2, and 3. While Region 1 has variable ravinement thickness throughout, the ravinement in Regions 2, 3, and within the Central Coast OCS Region trends thickening toward the southwest.

4.4.2 Interpretation of Paleochannels, Potential Sand-Bearing Features, and Development of the Regional Geologic Model

Chirp sub-bottom data were collected in a 1 nm x 5 nm (1.8 x 9.2 km) grid across Central Texas OCS waters offshore of the Brazos River to Matagorda Bay in protraction areas TX2-6 (Figure 36). Line spacing decreased to the southwest, ranging from 2.5-5 nm (4.6- 9.2 km) between shore parallel lines and 10-14 nm (18.5-25.9 km) between tie lines. The data were processed in SonarWiz following the procedures outlined in Section 4.4 above. The resulting data were systematically interpreted to outline the locations of potential sand-bearing stratigraphy with a maximum of 20 ft (6.1 m) of overburden (the overlying non-compatible sediment between the potential sandy deposit and the seafloor). Seismic reflector horizons marking the top and bottom of the potential sand feature were digitized within SonarWiz to generate 2-D surfaces and isopach (unit thickness). The sections below provide examples of these features within the sub-bottom data and are loosely organized by regions as follows. 1) OCS Galveston and Brazos (protraction areas TX5, TX6); 2) OCS Matagorda, Mustang, and North Padre Island (protraction areas TX2, TX3, TX4). Isopach maps for each potential sand-bearing feature where the top and bottom of the feature could be clearly mapped are included in Appendix E. Several features are presented due to their importance to the regional geologic model but are not viable potential sand resources due to the presence of excessive overburden or inferred fine-grained composition. Section 4.4.8 contains a summary of the viable potential sand resources identified in this reconnaissance investigation.

Figure 36. Mapped Subsurface Geologic Features within Central Texas OCS

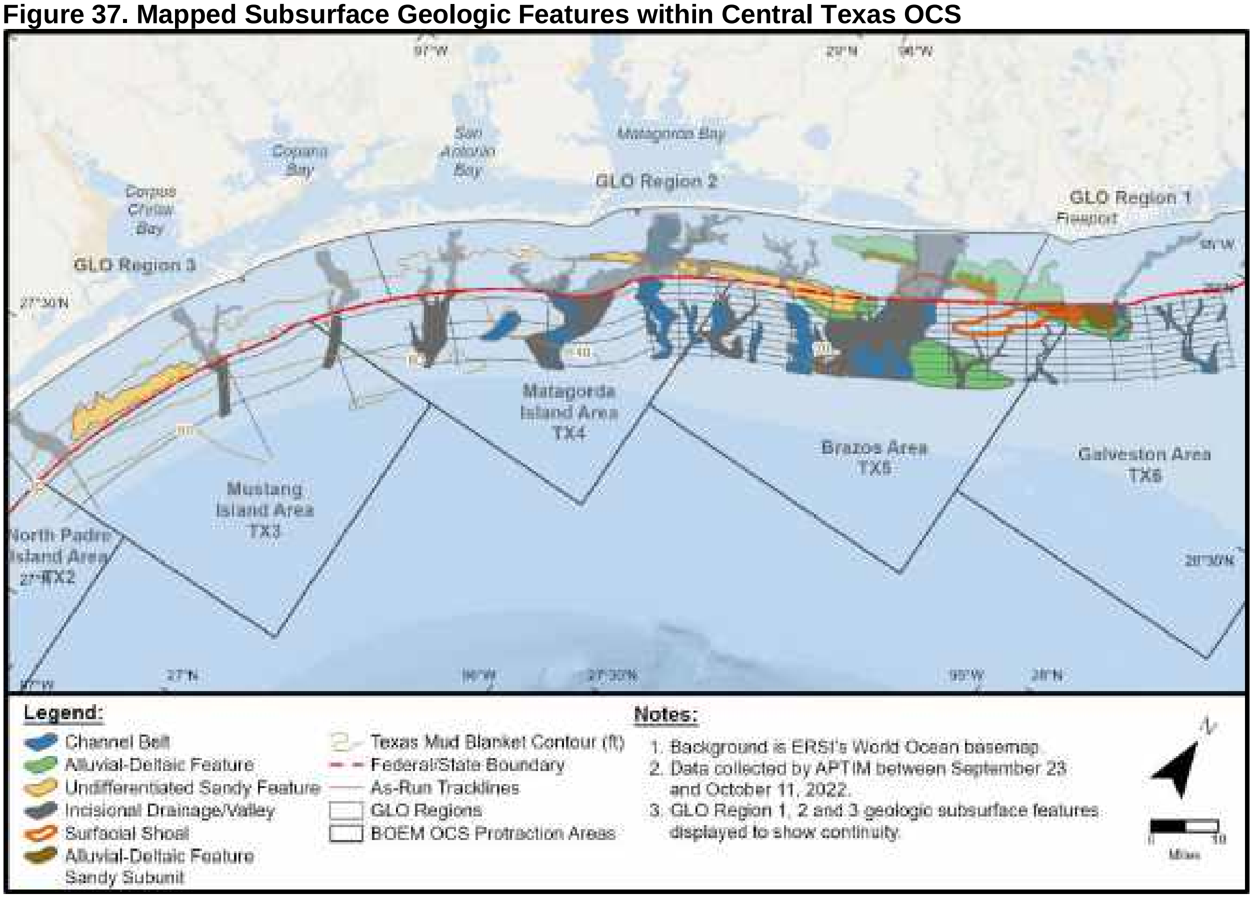


This effort focused on identifying the stratigraphic record of major regional incisional fluvial valley systems such as the Colorado, Lavaca, San Antonio/Guadalupe, Nueces River Valleys and potential tidal/estuarine/alluvial, deltaic fill, as well as potential shoreface systems. Incised valley fill is shown to contain mostly thick fine-grained sediment overlying fluvial sands and not considered potential viable sand resources. However, the Colorado and Lavaca Incised Valleys exhibit potentially viable sand resources in the form of fluvial sands within 20 ft (6.1m) of the seafloor, demonstrating the complexity of these systems in this investigation area. The interfluvial areas (outside the incised valleys) contain potentially viable sand resources in the form of channel belts and other sand-rich features with minimal overburden similar to findings in GLO Region 1 (APTIM and TWI 2021). The regional geologic model is built by mapping the location, extents, and characteristics of these large-scale features and can be used to identify areas which are likely to contain sand-bearing stratigraphic elements and nomination as potential sediment resource areas.

In tandem with mapping these features, regional surfaces were correlated where possible to inform the preliminary regional geologic model. Aside from the latest transgressive ravinement surface (the erosional surface generated as sea level approached current levels), which is present in nearly all the Central Coast OCS study area, there was not one conformable surface or marker evident across the entire study area. Most of the features identified incise existing older subsurface stratigraphy and the cross-cutting or overprinting nature of the multiple transgressive and regressive episodes in the slowly subsiding Texas shelf (Anderson et al. 2016) add too much complexity to create a confident stratigraphic surface without more age constraining data. Archival stratigraphic framework studies demonstrate Holocene deposits may overlie Pleistocene deposits dated to 20,000 years to 90,000 years or older before present (Simms et al. 2009).

Overall, the Central Coast OCS Region contains a significant number of potential sand-bearing units located within Texas federal waters in the form of surficial shoals, fluvial deposits, alluvial and/or deltaic deposits, as well as other more enigmatic elements (Figure 37). The features range in scale from 1.5-mi (2.4 km)-wide and 10-mi (16.1 km)- long continuous fluvial channel belts and channel belt complexes to small discrete subunits. Importantly, potential sand resource units are interpreted with less than 20 ft (6.1 m) of overburden across the entirety of the Central Coast OCS, some of which have never been previously identified. A major limiting factor in the study area is related to a thick, muddy deposit deemed the TMB that overlies and affects many potential sediment features in the southwest. The TMB, discussed in greater detail in the next section, will likely constrain sand resource units to be preferentially constrained to the northeast portion of the study area where the TMB is not as thick. The following sections summarize the main findings for each sub-region and presents its viability as a sand resource.

Figure 37. Mapped Subsurface Geologic Features within Central Texas OCS



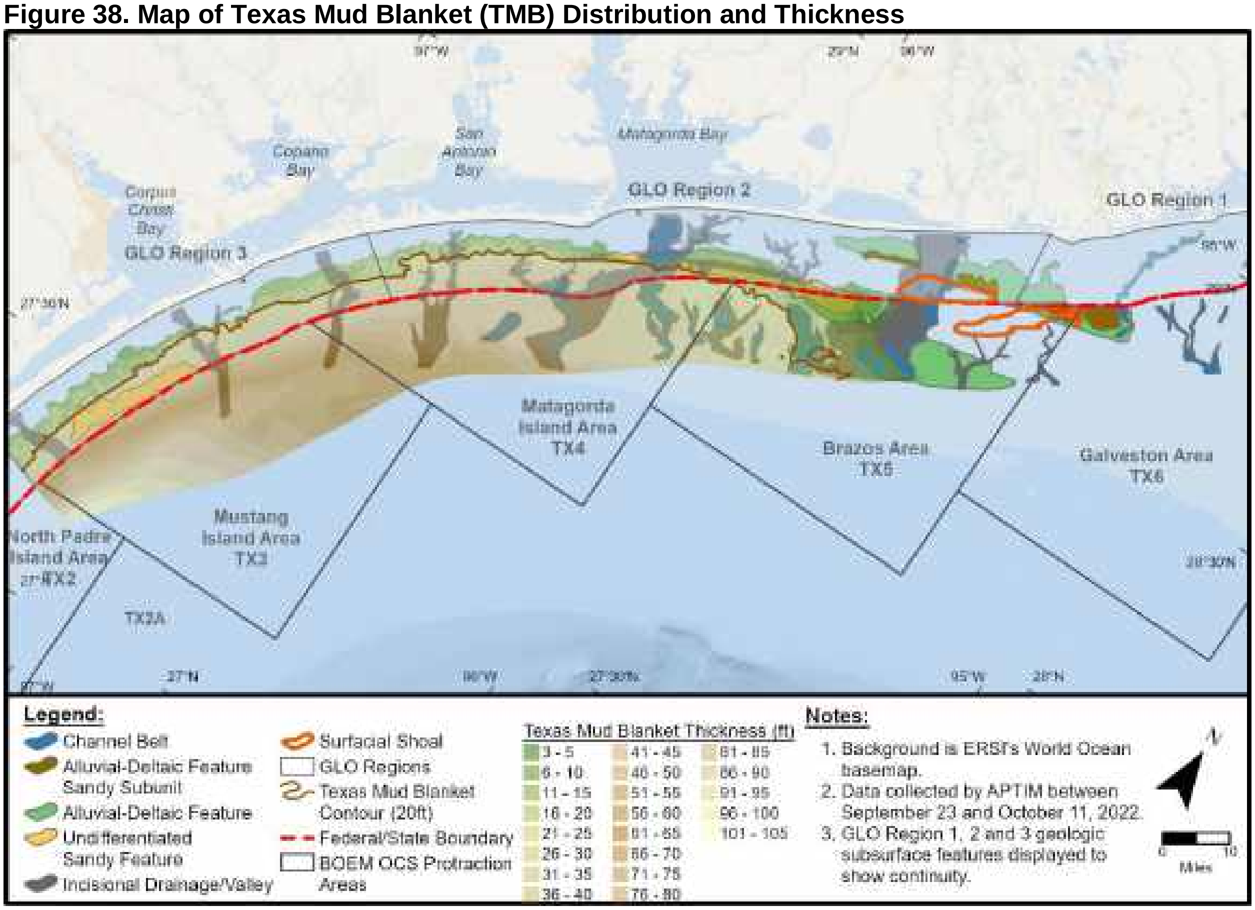
Note: Regionally mapped features and localized features. Southwestern units may be excluded from potential sand resource viability due to overburden but presented as part of the regional geologic framework. Features mapped in the GLO Region 1, 2, and 3 are shown to provide regional continuity context.

4.4.3 Texas Mud Blanket (TMB)

This study identifies and delineates a regional unit that extends across GLO Regions 2 and 3 (APTIM and TWI 2024), the Central OCS, and likely continues into GLO Region 4 and the Lower OCS. The TMB is defined here as the uppermost depositional unit resolved in the chirp data. The TMB is bounded by the transgressive ravinement surface and the modern seafloor, except where overlain by modern coastal deposits (lower shoreface or tidal deltas). Its full spatial extent is not constrained by the data collected as a part of this investigation as it extends to the west, and south according to archival studies (Weight et al.

2011). Its seismic character includes draping horizontally laminated, to slightly wavy, laterally continuous reflectors of varying amplitudes, and is interpreted as a fine-grained deposit. The reflector sets downlap seaward and onlap landward. This unit thickens up to 100 ft (30.5 m) seaward and to the southwest within the investigation area (Figure 38). The TMB is described as being Holocene age based on radiocarbon samples presented in Weight et al. (2011) and references within Weight et al. 2011; and others. The TMB represents river plume fine-grained material as well as locally reworked shelf edge delta material that accumulated in the central Texas shelf embayment during the last transgression (Weight et al. 2011). Based on seismic data from this investigation it is a highly continuous feature. Historical geological data show grey to red clays and interbedded clays and silts with sand lenses and shelly mud intervals (Weight et al. 2011). Depositional ages range from 9,000 years ago to present, representing both terrestrial to marine sedimentation (Weight et al. 2011).

Figure 38. Map of Texas Mud Blanket (TMB) Distribution and Thickness



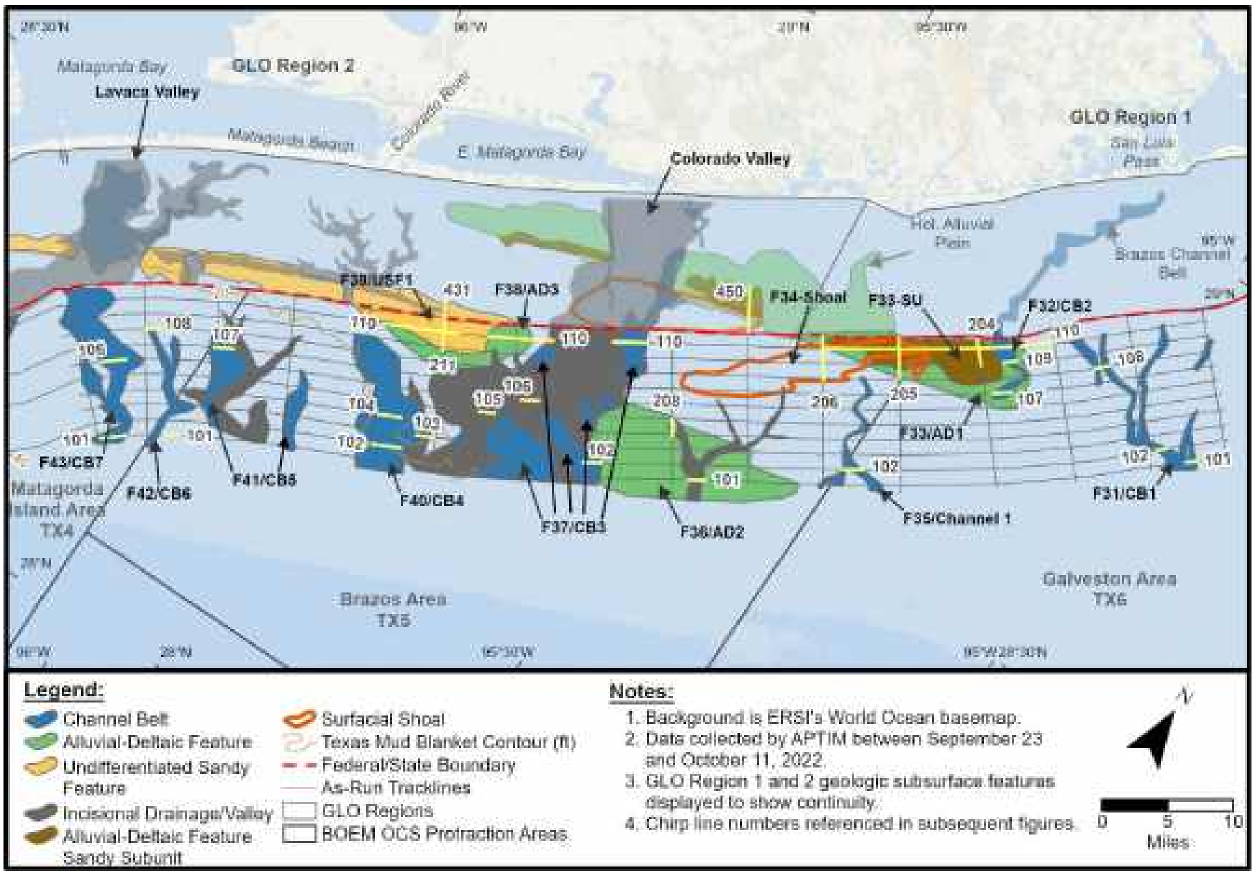
Note: TMB is classified as overburden to any underlying potential sand-bearing geologic features. An overburden threshold of 20 ft (6.1 m) is used to characterize viable and non-viable sand-bearing features from reconnaissance-level sand resource quantification.

The TMB does not represent a potential sand resource but understanding its distribution is critical to identifying the limiting overburden that may constrain the utility of any underlying potential sand-bearing sediment resources. This investigation uses a threshold of 20 ft (6.1 m) or greater of TMB to exclude underlying features from consideration as a viable sand resource target. However, these excluded features are identified and mapped due to their importance for the regional geologic framework. Potential sand-bearing deposits displaying massive or transparent acoustic facies were found in much of the central portion of the investigation below the TMB and transgressive ravinement surface but was not mapped due to poor seismic imaging at depth. This could correlate to a preserved FS coastal shoreline or wave dominated delta 80,000 years old underlying the TMB identified in previous research (Anderson et al. 2004; Eckles et al. 2004). However, these coastal deposits are overlain by greater than 20 ft (6.1 m) of TMB overburden and were excluded as a potential sand resource.

4.4.4 Galveston Area (TX5) and Brazos Area (TX6) Protraction Areas

The Galveston and Brazos protraction areas (TX5 and TX6), broadly bounded by the modern Brazos River delta and Matagorda Bay, contain numerous potential sand-bearing stratigraphic features that are potentially related to alluvial plain construction from fluvial avulsions and deposition during the Holocene (Anderson et al. 2016) and Pleistocene (Blum and Aslan 2006), preserved alluvial-deltaic features of unknown age, and modern surficial shoals (Figure 39). Below we present the characteristics and initial interpretation of each identified regional geologic feature. These features tie into mapping results from investigations in the state waters GLO Region 1 (APTIM and TWI 2021) and GLO Region 2 (APTIM and TWI 2024).

Figure 39. Map of Potential Sand-Bearing Geologic Features of the Central Coast OCS in Brazos and Galveston Protraction Areas



Note: Regionally mapped features in Galveston and Brazos protraction areas. Features mapped in GLO Region 1 and 2 state waters are shown to provide regional continuity context. Location and line of subsequent seismic examples shown in white.

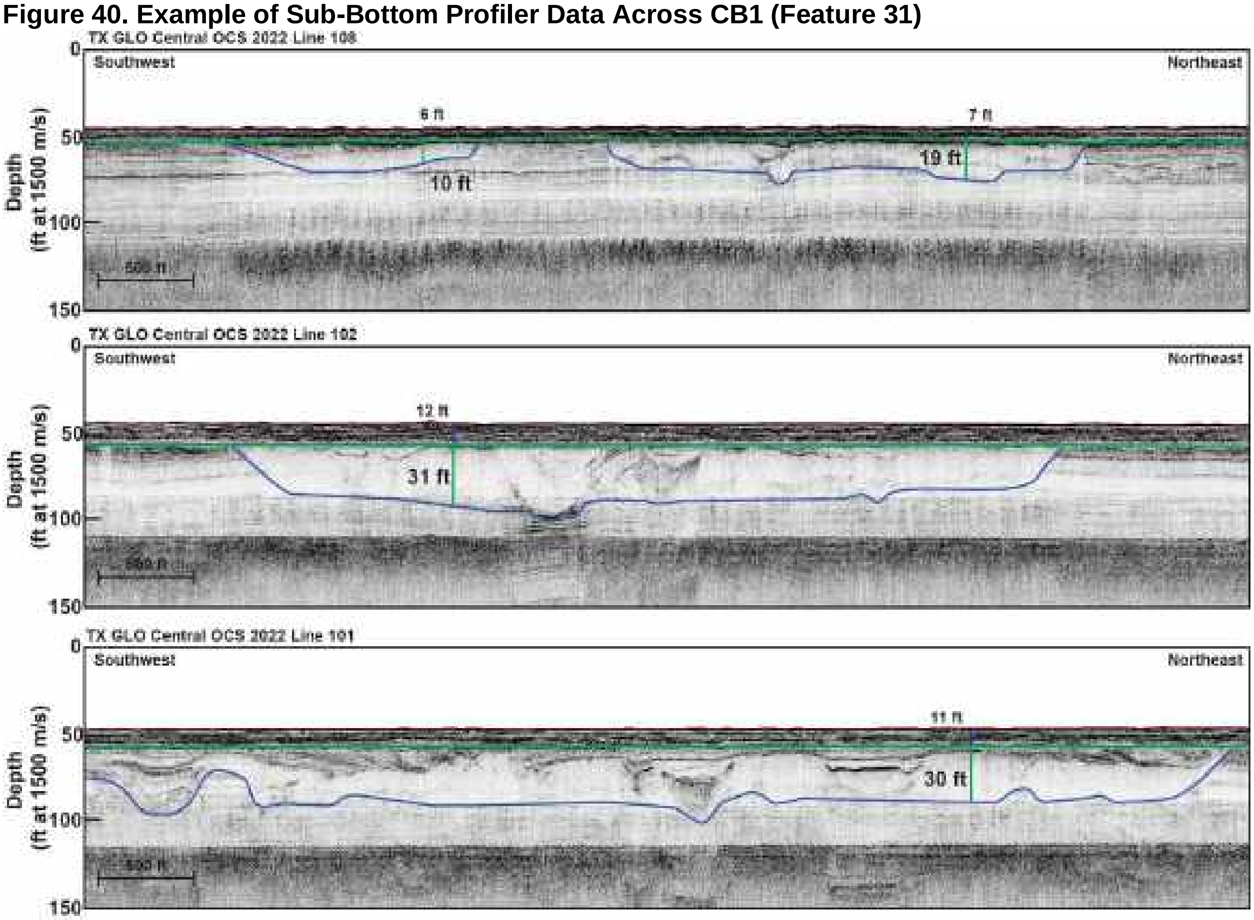
4.4.4.1 Feature 31 Channel Belt 1

The Channel Belt 1 (CB1) system is an elongated, narrow set of features that trend generally north to south and show higher preservation moving offshore with greater amounts of ravinement landward. These features are characterized by steeply dipping clinoforms, with transparent to chaotic acoustic facies near the base, and a basal erosional unconformity when resolved on the sub-bottom profiler record. The potential channel bar unit thickens seaward from 6-30 ft (1.8- 9.1 m), with overburden ranging between 6-11 ft (1.8- 3.3 m). The feature was not mapped in GLO Region 1 (APTIM and TWI 2021), and with the exhibited decreasing preservation of the channel belt in landward, it is possible it was truncated by transgressive ravinement in the state waters area.

The channel belt transitions into a large incisional feature further seaward, with compounded generations of fluvial activity (Figure 40). Due to survey line spacing, the geometry of these channel belts was difficult to discern. The apparent amalgamation of an accretional channel belt form and an incision drainage is potentially a stratigraphic signature of the nature of accommodation generation within this portion of the Texas shelf (e.g., Cardenas et al. 2023; Speed et al. 2022).

The inferred sand-rich sediment composition of this feature and minimal overburden warrants further investigation as a potentially viable sand resource and is included in Section 4.4.7.

Figure 40. Example of Sub-Bottom Profiler Data Across CB1 (Feature 31)



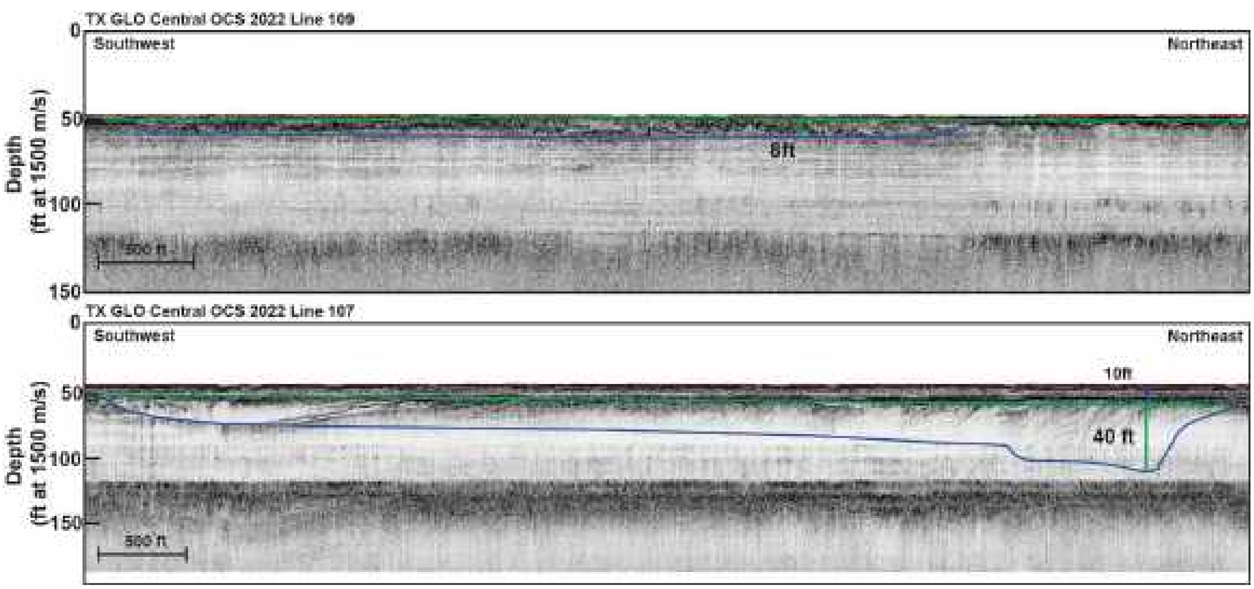
Note: The blue horizon marks the basal unconformity of the dipping clinoforms and variable transparent/chaotic seismic reflectors. The green horizon is the transgressive ravinement surface. Profiles progress further offshore. Refer to Figure 39 for seismic line number and location.

4.4.4.2 Feature 32 Brazos Pleistocene Channel Belt 2

The Brazos Pleistocene Channel Belt 2 (Figure 39) is an elongate, narrow feature that originates in the northeast and crosses GLO Region 1 state waters (APTIM and TWI, 2021) to the southwest and continues for 5 mi (8 km) into the Central OCS region (Figure 41). It is inferred as Pleistocene in age since its orientation does not align with the trend of onshore Holocene channel belt equivalents following the interpretations in APTIM and TWI (2021). In seismic profiles, it is characterized by steeply dipping clinoforms with variable acoustic amplitude. The basal erosional unconformity incises into layered Beaumont stratigraphy and is capped by laminated seismic facies. The Brazos Pleistocene Channel Belt width varies between 0.5-2.0 mi (0.8-3.2 km), and ranges in thickness from 8-40 ft (2.4-12.2 m). It is capped with up to 10 ft (3 m) of overburden, although in local areas this may thin to less than a foot or the fluvial stratigraphy may be exposed at the surface. The variability in channel belt geometry is likely due to the amount of relative ravinement or preservation combined with variations in the original depth of fluvial incision in one area versus another. Within each line the laterally accretional dipping reflectors grade into a channel form infilled with draping, layered stratigraphy characteristic of a channel abandonment facies or mud plug. These geometries and successions are typical of a laterally migrating fluvial channel belt that was abandoned through avulsion (Mohrig et al., 2000; Reijenstein et al. 2011; Cardenas et al. 2023). The dipping clinoforms that comprise most of the channel belt are likely to contain a significant proportion of coarse-grained material, like terrestrial equivalent Pleistocene and Holocene channel belts located on the modern coastal plain.

The inferred sand-rich sediment composition of this feature and minimal overburden warrants further investigation as a potentially viable sand resource and is included in Section 4.4.7.

Figure 41. Example of Sub-Bottom Profiler Data Across Brazos Pleistocene Channel Belt 2 (Feature 32)



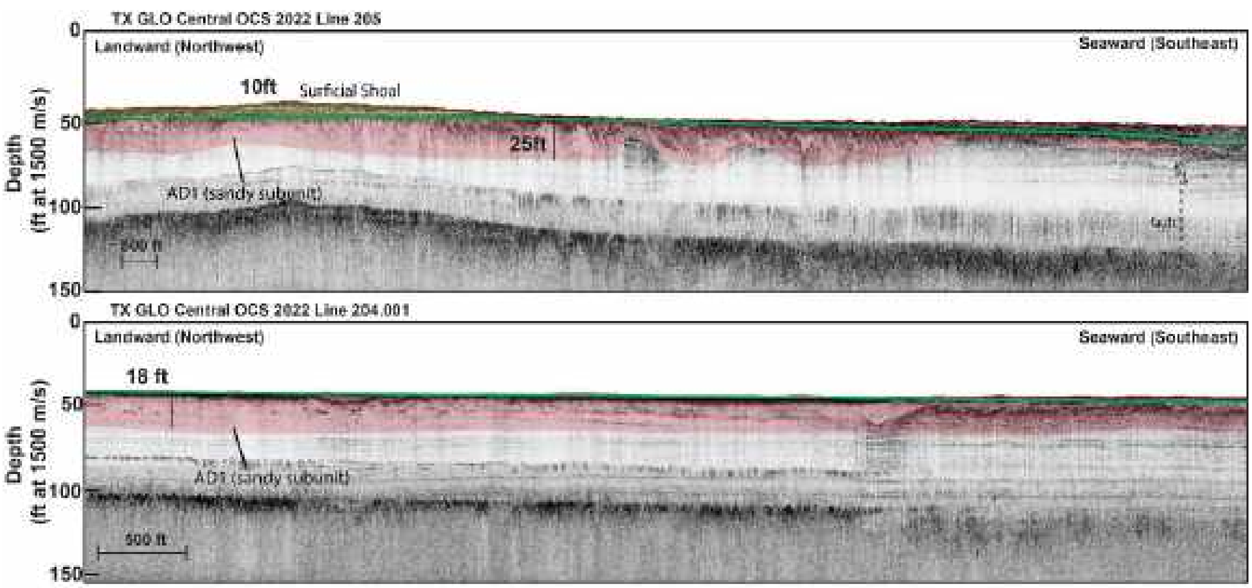
Note: The blue horizon marks the basal unconformity separated layered Beaumont stratigraphy from the above dipping clinoforms and variable transparent/chaotic seismic reflectors. The green horizon is the transgressive ravinement surface. Note the variable thickness of the channel belt and transition from dipping clinoforms to channel form at the edge of the feature. Refer to Figure 39 for seismic line number and location.

4.4.4.3 Feature 33 Alluvial-Deltaic Feature (AD1)

A series of mounded elongate to lobate features, generally interpreted as either alluvial or deltaic (AD) identified throughout the Galveston and Brazos Areas in the Central Coast OCS and in GLO Region 2 (APTIM and TWI 2024). They consist of highly variable seismic facies, with interpreted sand or mud-dominated subunits based on the reflector geometry (e.g., Reijenstein et al. 2011). The proposed sandy subunits (SU) are characterized by semi-transparent or chaotic seismic facies, with a speckled or mottled basal section and a high-amplitude top reflector displaying numerous incisions in some places (Figure 42). This central facies grades distally into a thinner semi-transparent to laminated facies, again with numerous small incisions. These features generally dip seaward and are occasionally onlapped by laminated mud-dominated facies. Unit AD1 displays an overall mounded external form with variable internal architecture. It is roughly 17 mi (27.3 km) by 3.5 mi (5.6 km) long, and generally lobate in shape. Internal reflector packages with the highest potential for sand composition display transparent to dipping reflector sets, ranging from 1-2 degrees to 4-7 degrees. In some instances, the dipping reflector packages grade laterally into an incisional channel form (Figure 42). Unit AD1 trends shore oblique, generally dips seaward where it pinches out and is overlain by onlapping laminated reflectors. There is a clear genetic link to truncated dipping reflector packages of AD1 and overlying modern shoal, suggesting coarse-grained material was sourced from the reworking of sandy pre-existing AD1 deposits.

Only the inferred sand-rich sediment composition of the Alluvial-Deltaic sandy subunits and minimal overburden warrants further investigation as a potentially viable sand resource and is included in Section 4.4.7.

Figure 42. Example of Sub-Bottom Profiler Across Alluvial-Deltaic Feature (AD1; Feature 33) and Surficial Shoal (Feature 34)

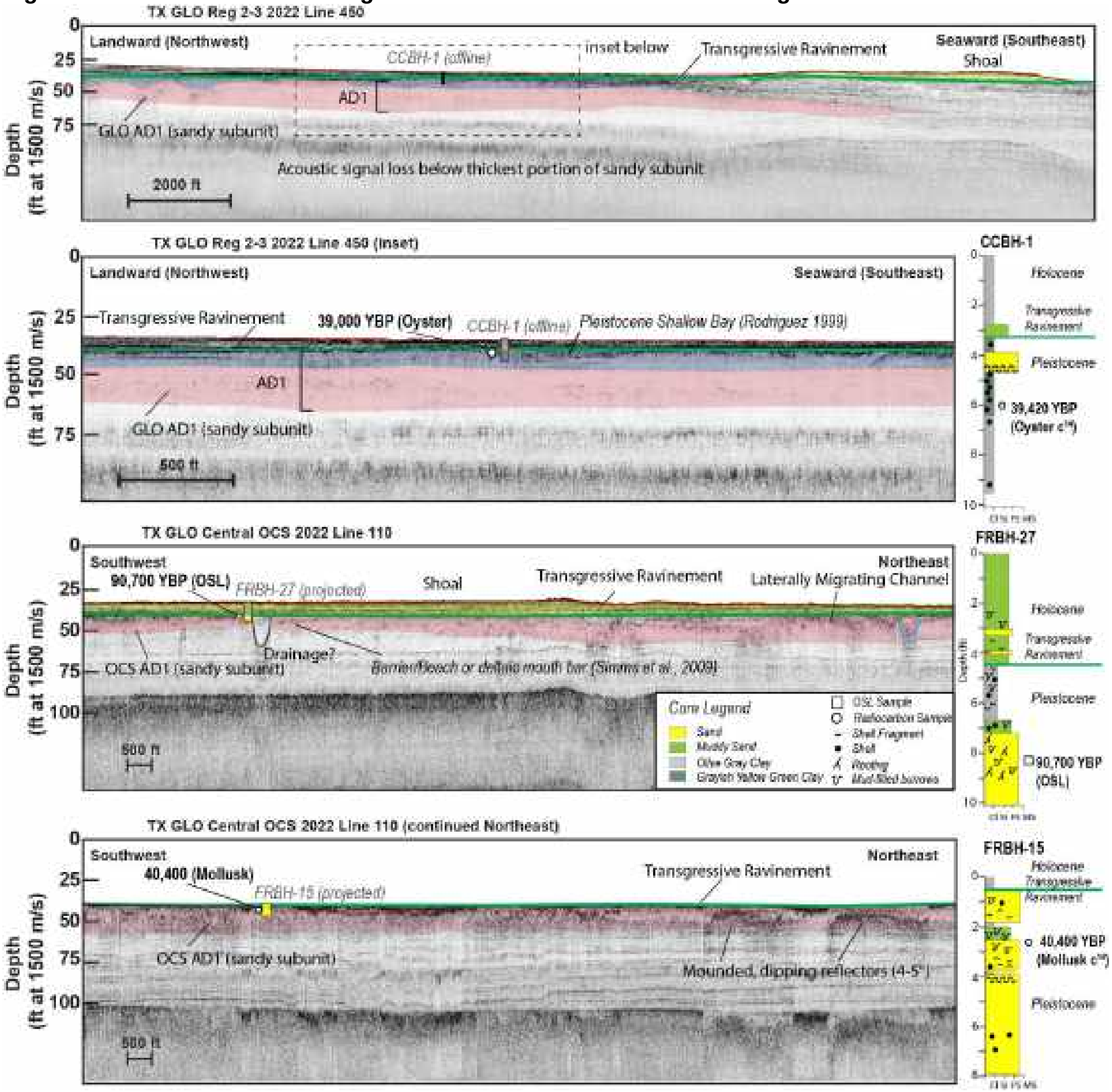


Note: The red package represents the AD1 sandy subunit. The green horizon transgressive ravinement surface. The transparent yellow facies denotes the surficial shoal. Note the minimal overburden and correlation to the surficial shoal and truncation of AD1. Refer to Figure 39 for seismic line number and location.

The overall package AD1 extends into the OCS from GLO Region 2 (APTIM and TWI 2024) and shows similarities to the Holocene Alluvial Plain mapped in GLO Region 1 (APTIM and TWI 2021). The feature in GLO Region 1 was originally interpreted as a partially preserved portion of the Brazos alluvial plain forming during the most recent transgression. Due to the complex stratigraphy and highly avulsive of the Brazos and Colorado systems, it is possible to have features of greatly different ages preserved at similar stratigraphic positions (APTIM and TWI 2021). Determining the absolute age of these deposits to aid in geologic framework understanding is only reserved to areas where previously published age constraints can be correlated to seismic data. Shallow archival cores in the Central OCS constrain the potential age of AD1, providing radiocarbon and optically stimulated luminescence dates targeting the Freeport Rocks Bathymetric High and underlying facies (e.g. Figure 43, Rodriguez 1999; Simms et al. 2009). Dates from those studies show 12,000-year-old Holocene muds overlie highstand 91,000-year-old sands separated by the transgressive ravinement surface. This demonstrates how much of the stratigraphic record is missing in this location. The sandy facies, found within 2 ft (1.8 m) of the seafloor, consists of clean, tan to grey, medium-grain size sand with mud filled burrows and shells in the upper portions with minor shells, rooting and organic material in the lower sections (Figure 43; Line 110). The correlative sediment facies of the sandy subunit of AD1 were interpreted as a barrier island/beach deposit or deltaic mouth bar deposit, seaward of estuarine muds by previous researchers (Simms et al. 2009).

Archival core CCBH-1 coincides with the location of the identified alluvial-deltaic deposit in GLO Region 2 investigation. The core samples an upper laminated seismic subunit of AD1 is composed of shelly, yellow-green, and grey clays truncated by a shell hash horizon (Figure 43; Line 450). An archival radiocarbon dated oyster shell was estimated to be ~40,000 years old (Rodriguez 1999). These radiocarbon dates are near the reliable limit that particular dating method (radiocarbon “dead”) and the original study suggested they were minimum, not absolute ages (Rodriguez 1999). Previous studies interpret this muddy laminated subunit as a Pleistocene shallow bay environment (Rodriguez 1999). Unfortunately, the underlying potential sand-rich subunit of AD1 was not sampled and no directed age constraints were found in archival studies, but both age constraint support the interpretation these are of Pleistocene age.

Figure 43. Archival Cores and Age Constraints within AD1 in GLO Region 2-3 and Central OCS



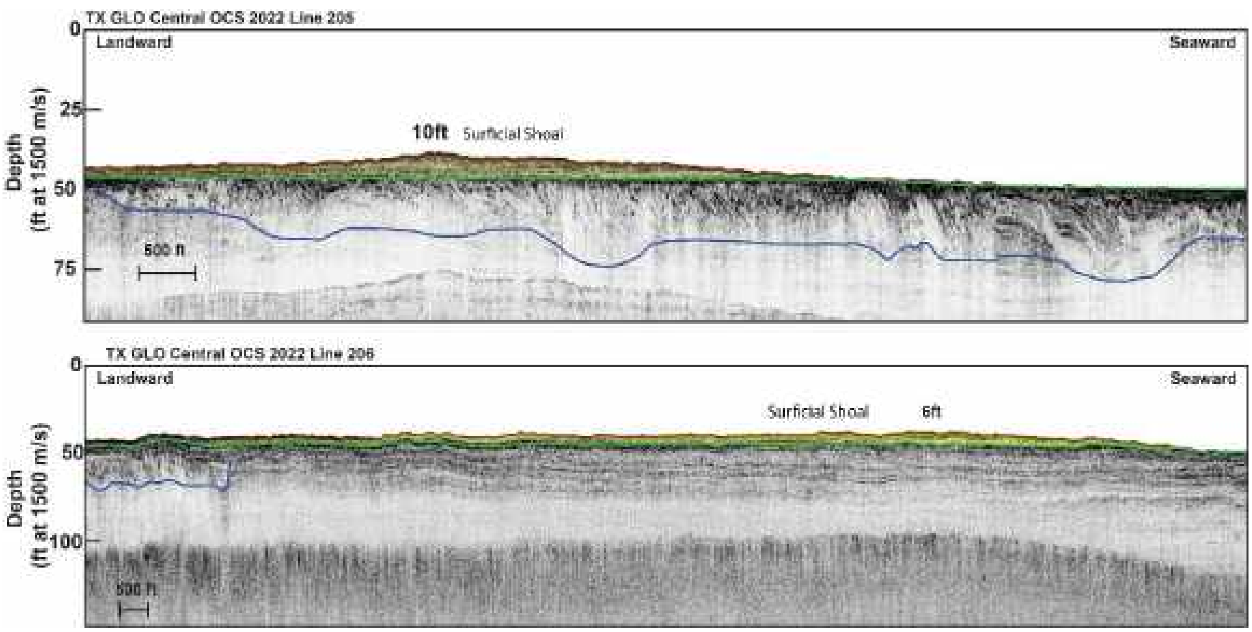
Note: Below the transgressive ravinement surface (green horizon), one archival Optically Stimulated Luminescence date (Simms et al. 2009) constrains the age of sandy subunit (red) of alluvial-deltaic feature AD1 (blue) to ~91,000 years old (Line 110). The Pleistocene age interpretation is further supported from archival radiocarbon mollusk and oyster shells estimated to be ~40,000 years old (Rodriguez 1999; Lines 450 and 110). These radiocarbon dates are near the reliable limit that particular dating method (radiocarbon "dead") and the original study suggested they were minimum, not absolute ages (Rodriguez 1999). Simms et al. (2009) interpreted the correlative deposit to AD1 as either a barrier/beach deposit or deltaic mouth bar with estuarine deposits overlying or landward. A modern shoal directly overlies areas of AD1 in the OCS. Refer to Figure 39 for seismic line number and location.

4.4.4.4 Feature 34 Surficial Shoal

A marine surficial shoal previously identified as the Freeport Rocks Bathymetric High (FRBH; Rodriguez et al. 2000; Simms et al. 2009), was mapped as part of this effort in both recently collected bathymetric and sub-bottom data surveys. The shoal is up to 10 ft (3 m) thick, elongate, oriented shore parallel, and overlies the transgressive ravinement surface. The thickest part of the shoal directly overlies truncated AD1 sandy subunit, displaying steeply dipping and transparent packages exposed at the seafloor at the seaward toe of the shoal (Figure 44). This correlation points to the genetic link of reworked sandy alluvial-deltaic facies supplying sediment for modern marine shoals by wave and currents as sea levels rose during the transgression. Archival core (FRBH-27) sampling this surficial shoal consist of dark grey sandy silt to silty sand with abundant mottling and sand filled borrows (Figure 43 Line 110; e.g., Simms et al. 2009).

The inferred sand-rich sediment composition of this feature and minimal overburden warrants further investigation as a potentially viable sand resource and is included in Section 4.4.7.

Figure 44. Example of Sub-Bottom Profiler Data Across the Surficial Shoal (Feature 34)



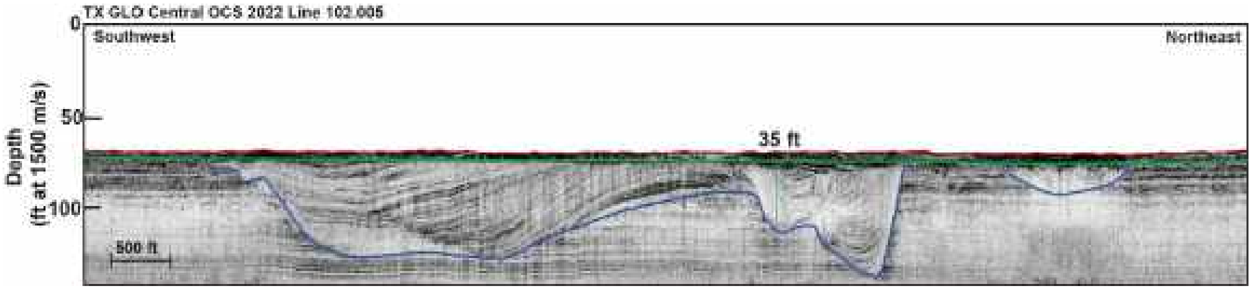
Note: Yellow body marks surficial shoal. Note thickness increases to the northeast where it overlies and truncates sandy portions of the AD1 sandy subunit. The blue horizon marks the basal unconformity separated layered stratigraphy from the above variable transparent/chaotic seismic reflectors of AD1 sandy subunit. The green horizon is a ravinement surface marking the top of the seismic reflector packages of the AD1 sandy subunit and base of the surficial shoal. Refer to Figure 39 for seismic line number and location.

4.4.4.5 Feature 35 Channel 1

A tributary channel system incises to depths up to 40 ft (12.2 m) and displays evidence of multiple generations of incision with little lateral accretion (Figure 45). The fill consists dominantly of finely laminated draping reflector fill with isolated laterally migrating more transparent facies. It seems only lower portions of the channel are preserved as the base of the channel form trends closer to the interpreted transgressive ravinement towards the modern coast. The channel is interpreted to bifurcate near the offshore portion of the survey extent, but denser line spacing would help resolve the feature geometry.

These features are not considered a potentially viable sand resource due to the inferred fine-grained composition but are important to the geologic framework understanding of the area.

Figure 45. Example of Sub-Bottom Profiler Data Across Channel 1 (Feature 35)



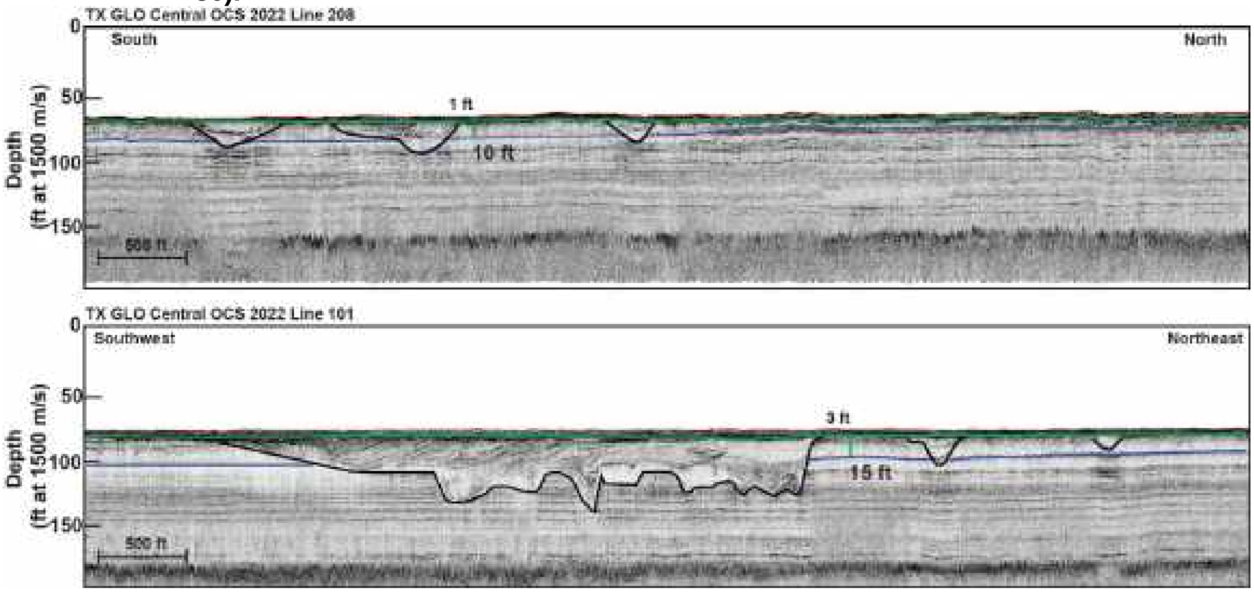
Note: The blue horizon marks the incisional basal unconformity separated layered stratigraphy from the above variable laminated draping reflectors. The green horizon is the top of the seismic reflector packages. The vertical green line marking channel thickness is an example of a small isolated laterally migrating, transparent and potentially sandy subunit compared to the dominantly muddy channel fill. Refer to Figure 39 for seismic line number and location.

4.4.4.6 Feature 36 Alluvial-Deltaic Feature (AD2)

AD2 is more lobate shape, is roughly 7 mi x 15 mi (11.2 x 24.1 km) across and thickens seaward, up to ~15 ft (4.6 m) thick with less than 5 ft (1.5 m) of overburden throughout the survey area. This mounded feature has variable internal seismic characteristics similar to AD1, although AD2 is much thinner and has much lower occurrence of dipping clinoform packages. Based on the strength of acoustic penetration below AD2 and internal architecture, it is inferred as having lower sand composition. AD2 is truncated by the Colorado Incised Valley to the west. A dendritic drainage system incises AD2 with main tributary widths of 1.3-1.8 mi (2.1-2.9 km) and is up to 35 ft (10.6 m) deep and has complex fill architecture and heterogeneous acoustic facies (Figure 46; Line 101).

This feature is not considered a potentially viable sand resource at this time due to the inferred fine-grained composition but is important to the geologic framework understanding of the area. Geologic sampling could help constrain its composition.

Figure 46. Example of Sub-Bottom Profiler Data Across Alluvial-Deltaic Feature 2 (AD2; Feature 36).



Note: The blue horizon marks the basal unconformity separated layered stratigraphy from the above variable transparent/chaotic seismic reflectors of AD2. The black represents drainage channels. The green horizon is the transgressive ravinement surface. Refer to Figure 39 for seismic line number and location.

4.4.4.7 Feature 37 Colorado Incised Valley and Channel Belt 3

The Colorado Incised Valley is a major stratigraphic feature offshore East Matagorda Bay within the Brazos Area (TX5). This aligns with valley orientation from GLO Region 2 (APTIM and TWI 2024) and the broader Colorado-Brazos alluvial valley (Figure 39). The boundaries or valley edges are generally well constrained by the chirp seismic data presented in this investigation and continues offshore from Region 2 into the Central Coast OCS Region and beyond. The incised valley maintains a fairly uniform width of 7.5 mi (12.1 km) wide. Where mappable, the regional valley is bounded by a basal erosional unconformity that incises into the layered Beaumont stratigraphy of the shelf and is capped by a transition to more layered seismic facies. Seismic data imaging reaches about 50-60 ft (15.2-18.3 m). below seafloor, however the base of the valley is not imaged with confidence. The valley incises and truncates the mapped alluvial-deltaic feature AD2 to the east.

This overfilled valley in the classification of Simms et al. (2006), is filled with fluvial and alluvial deposits generated by aggradation and avulsion of the ancestral Colorado River during Holocene transgression. The corresponding valley geometry and fill is complex with multiple channel belts with varying amounts of floodplain, deltaic and transgressive muddy shelf overburden (Figure 47, Line 110). Interpreted channel belts are characterized by steeply dipping clinoforms of variable acoustic amplitude as well as packages of chaotic and transparent seismic facies. Amalgamated fluvial channel belt stratigraphy is overlain by floodplain laminated reflectors with small channel forms creating small positive-relief alluvial ridges (Figure 47, Line 106). Larger channels found in GLO Region 2 display aggradational constructive trajectories demonstrating rapid rates of alluvial floodplain deposition and infilling (see Figure 44, Line 101 in APTIM and TWI 2024). This transition from amalgamated channel belts of the lower unit to the more isolated, aggradational channel belts of the middle-upper unit supports previous work detailing the styles of avulsion as the Colorado-Brazos valleys infill and the large sediment supply of these particular systems (Blum and Aslan 2006). This presents an interesting opportunity to selectively target fluvial sands or channel belts with minimal overburden or occurring at higher stratigraphic intervals in the Colorado Incised Valley compared to underfilled incised valleys, such as the

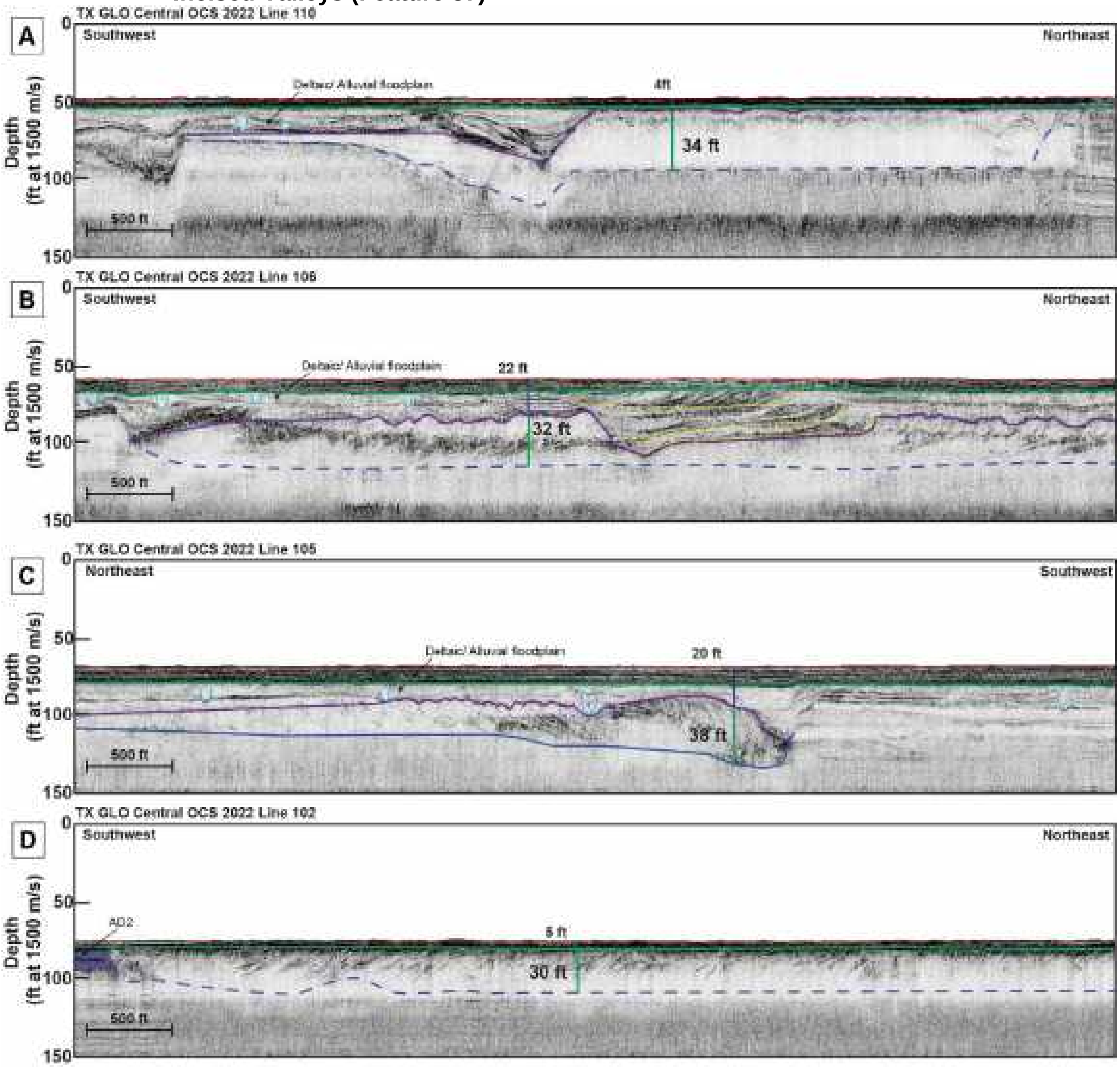
Trinity Incised Valley, presented in GLO Region 1 (APTIM and TWI 2021) whose fluvial sands are overlain by thick estuarine/marine mud packages that limit their viability as sediment resources.

Channel Belt 3 is fully contained within the larger Colorado Valley and represents selective portions of the basal amalgamated fluvial deposits that have less than 20 ft (6.1 m) of overburden and are thus mapped as a discrete potential sediment resource. The thickness of the dipping clinoform unit, interpreted as fluvial channel and point bar material and thus likely sand-bearing, ranges up to 38 ft (11.6 m) and is overlain by a maximum of 20 ft (6.1 m) of overburden. In some areas the amalgamated channel bar facies are exposed at the seafloor, with no overburden present (Figure 47, Line 102, 110). The lower unit fluvial stratigraphy is overlain by laminated reflectors with channel forms creating topographic high's such as leveed channels or small alluvial ridges (Figure 47, Line 110, 106, 105). A series of stacked cut and fill morphology, laterally accreting deposits are depicted in yellow, above fluvial sands in Figure 47; Line 106. These stacked channels mark a boundary between the interpreted deltaic/alluvial flood plain facies to the southwest from horizontally laminated reflectors to the northeast within the middle and upper unit. Further investigation is needed to determine its specific depositional setting within the larger valley fill. This middle-upper unit is capped by the transgressive ravinement surface and overlying laminated muds. The thickness of potential basal sands could vary since the base of the valley is not resolved confidently in this investigation. It should be emphasized that most of the basal fluvial sands within the Colorado Incised Valley are considered non-viable potential resource targets due to the overburden threshold criteria in this investigation and are excluded from volumetric analysis.

Previous work details steep, straight valleys adjacent to one another along the Texas continental shelf that eventually merge further offshore (Anderson et al. 2004; Abdulah et al. 2004; Abdulah 1995). The individual valley systems are difficult to distinguish since the valley base is rarely imaged in data collected for this effort. The Colorado Incised Valley has undergone a series of reoccupation and reorganization episodes in response to sea level fluctuations and high sediment discharge. The age of these fluvial deposits likely ranges from Late-Pleistocene to Holocene although it was very difficult to regionally map the basal unconformity or differentiate between older generations of fluvial channel belts. Due to high sediment load, the Brazos and Colorado rivers underwent a series of avulsions that resulted in a series of channel belts with up to 35 ft (10.6 m) of erosional relief yet do not correlate to a regional sequence boundary (Simms et al. 2006 and references within). The overfilled Colorado-Brazos valley (Simms et al. 2006) differs greatly from the underfilled Trinity-Sabine valley of GLO Region 1 that have a simple fill sequence of basal fluvial sands with thick deltaic and estuarine fill and well-defined valley edges (APTIM and TWI 2021), in that it has a much higher coarse-grained sands and gravels and is filled entirely of fluvial and floodplain or deltaic facies (Abdulah et al. 2004; Simms et al. 2006). The Colorado Incised Valley is expected to have a higher coarse-grained fraction since its drainage basin consists of granite and schist of the Llano Uplift, compared to the red clay beds that make up the majority of the Brazos drainage basin (Blum 1994). The general locations mapped in this reconnaissance study suggest this area contains significant sand resources and requires further detailed geological and geophysical investigation to determine the framework evolution and better delineate sediment resources.

The inferred sand-rich sediment composition of these features and minimal overburden warrants further investigation as a potentially viable sand resource and is included in Section 4.4.7. Additional fluvial sands are identified within the Colorado Incised Valley but have greater than 20 ft (6.1m) overburden.

Figure 47. Example of Sub-Bottom Profiler Data Across Features of Interest within the Colorado Incised Valleys (Feature 37)



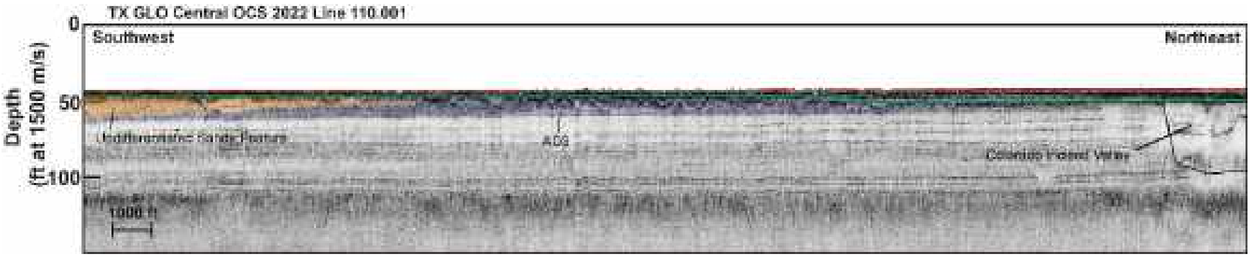
Note: The blue horizon marks the basal unconformity variable transparent/chaotic or dipping reflector seismic package. The purple horizon is the top of the seismic channel belt reflector packages. Light blue small channel features represent distributary levee channels or alluvial ridges. Yellow horizons denote cut and fill patterns of a laterally accreting channel. Green horizon marks the transgressive ravinement surface. Note the variable overburden covering the discrete channel belts. Dashed lines represent the interpreted base of the feature but could not be confidently resolved in sub-bottom. Profiles A-D progress further offshore. Refer to Figure 39 for seismic line number and location.

4.4.4.8 Feature 38 Alluvial-Deltaic Feature (AD3)

AD3 is lobate, roughly 4 mi (6.4 km) by 10 mi (16.1 km) across and up to 14 ft (4.3 m) thick with generally less than 5 ft (1.5 m) of overburden. This feature thins to the northeast and generally dips seaward. This slightly mounded features has numerous incisions and lacks the dipping reflector packages of AD1. The upper unit is transparent to chaotic with laminated facies below. It seems AD3 partially underlies the shore parallel undifferentiated sand feature (USF1) presented in the next section which is an extension of the USF1 of GLO Region 2 (see Figure 39 for location; APTIM and TWI, 2024). AD3 is capped by the transgressive ravinement surface and overlying Holocene muds. AD3 in interpreted as having low sand content and is not recommended as a sediment resource.

This feature is not considered a potentially viable sand resource at this time due to the inferred fine-grained composition but is important to the geologic framework understanding of the area. Geologic sampling could help constrain its composition.

Figure 48. Example of Sub-Bottom Profiler Data of the Alluvial-Deltaic Feature (AD3; Feature 38)



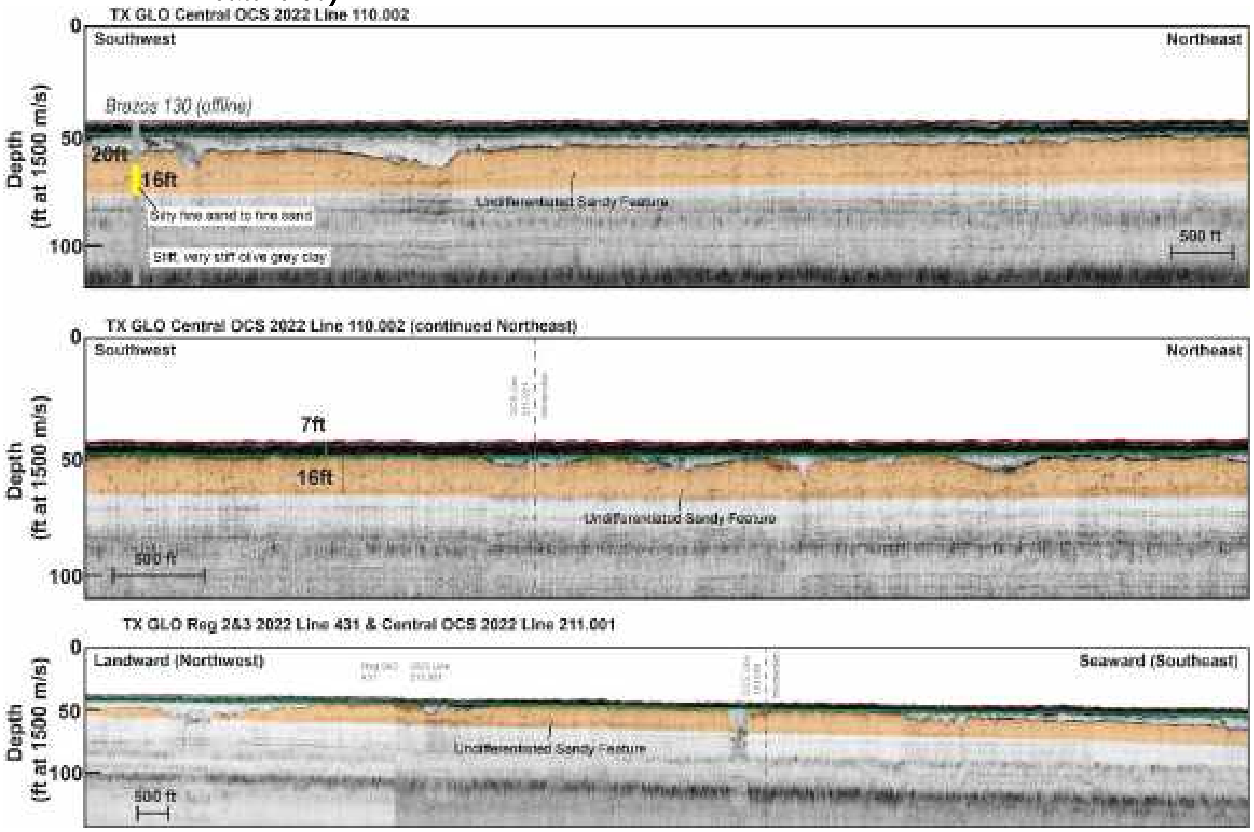
Note: The green horizon represents the transgressive ravinement surface. The blue package represents AD3 and the orange package represents USF1. Note this is deposit is inferred to have low sand composition. Refer to Figure 39 for seismic line number and location.

4.4.4.9 Feature 39 Undifferentiated Sandy Feature (USF1)

USF1, in the Brazos Area (TX5), and its extension in GLO Region 2 make up a linear feature that trends shoreline parallel for roughly 40 mi (64.3 km). The portion mapped in the OCS Brazos Area (TX5) is roughly 4 mi (6.4 km) by 10 mi (16.1 km) and roughly 16 ft (4.9 m) thick with generally less than 20 ft (6.1 m) of overburden. This feature dips seaward with increasing overburden. USF1 is characterized by transparent facies with transparent to speckled or mottled facies in its lower portions (Figure 49). The top of USF1 displays a strong amplitude reflector with considerable relief due to secondary incisions and reworking. The underlying stratigraphy is horizontally laminated reflectors of variable-amplitude. An archival platform boring, (Brazos 130) is projected onto seismic data collected in this investigation (Figure 49; Line 110). This boring displays 16 ft (4.9 m) of silty fine sand to fine sand with 20 ft (6.1 m) of overlying muds. USF1 has variable overburden packages of partially channelized features which are truncated by the transgressive ravinement surface.

The inferred sand-rich sediment composition of this feature and minimal overburden warrants further investigation as a potentially viable sand resource and is included in Section 4.4.7.

Figure 49. Example of Sub-Bottom Profiler Data of the Undifferentiated Sandy Feature (USF1; Feature 39)

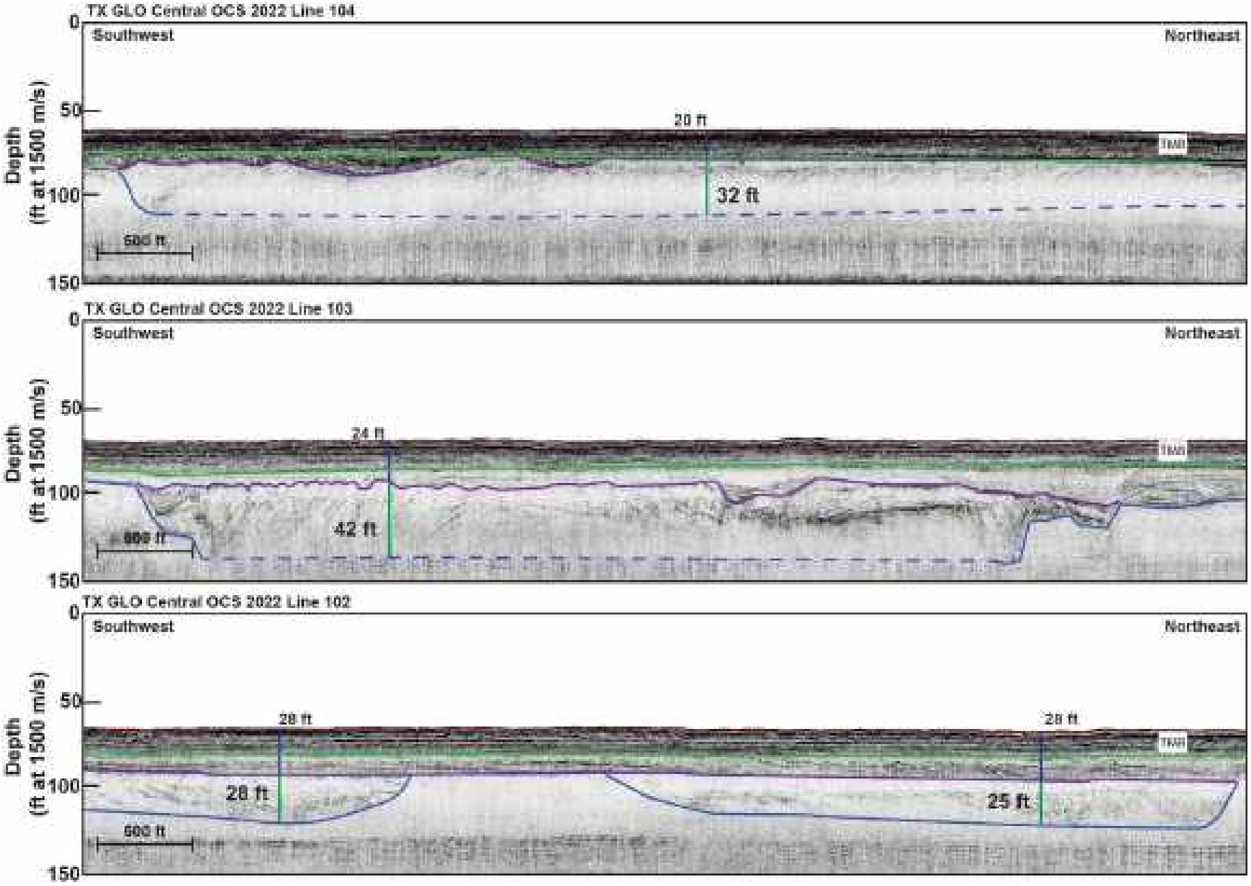


Note: The orange package represents USF1. The green horizon represents the transgressive ravinement surface. Note the variable overburden. Refer to Figure 39 for seismic line number and location.

4.4.4.10 Features 40, 41, 42 (Channel Belts 4, 5, 6)

Several potential sand-bearing channel belt complexes were interpreted and mapped in addition to smaller channel forms and potential sand-bearing deposits that could not be correlated with the density of sub-bottom data. However, none of these features are considered potentially viable resources due to the amount of overburden related to the westward thickening of the TMB. These channel belts are characterized by variable-amplitude, steeply dipping clinoforms and occasional areas of semi-transparent to chaotic acoustic facies and a basal erosional unconformity, when resolved on sub-bottom profile. The upper portion of these units is characterized by either a transition to a more horizontally laminated seismic facies, indicating fine-grained deposits, or are truncated by transgressive ravinement. It should be noted that poor seismic penetration of underlying units below the ravinement surface made interpreting and mapping individual channel belts and other features of interest difficult to resolve. The easternmost channel belt complex (Channel Belt 4) exhibits a potential sand-bearing unit of up to 42 ft (12.8 m) thick with overburden ranging from 20-28 ft (6.1-8.5 m) thick (Figure 50) The channel belt complex is 2-3.5 mi (3.2-5.6 km) across.

Figure 50. Example of Channel Belt 4 (Feature 40)

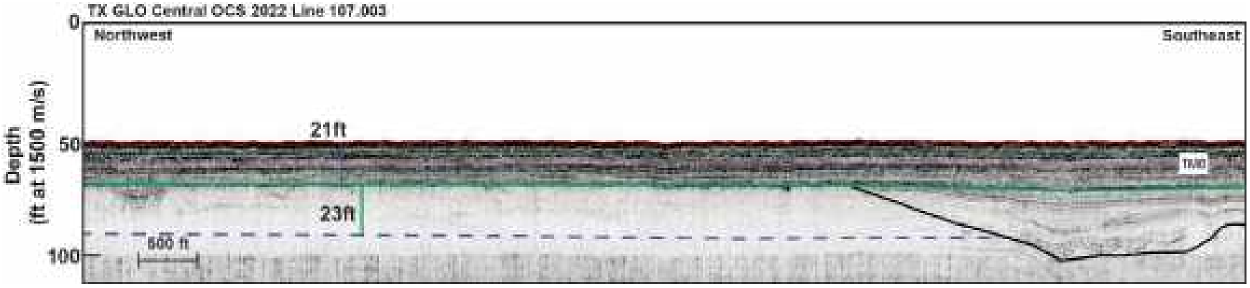


Note: The blue horizon marks the inferred basal unconformity of variable transparent/chaotic seismic reflector packages. The purple horizon is the top of the seismic reflector packages. The green is the transgressive ravinement surface. Note the poor acoustic penetration below the laminated facies. Dashed lines represent the interpreted base of the feature but could not be confidently resolved in sub-bottom. Refer to Figure 39 for seismic line number and location.

Channel Belt 5 is up to 25 ft (7.6 m) thick with 20-28 ft (6.1- 8.5 m) of overburden (Figure 51). The eastern portion of the channel belt is truncated by an incisional valley tributary, displaying laminated draping fill. Channel belt 6 maintains a width of ~0.75 mi (1.2 km) across and is about 21 ft (6.4 m) thick (Figure 52). Channel belts 4-6 all have greater than 20 ft (6.1 m) of overburden and had no landward extensions mapped in GLO Region 2 (APTIM and TWI 2024). A more detailed investigation in the Brazos Area (TX5) is required to link these various features in a stratigraphic context since there are potential isolated portions of the channel belt unit that could have less than the 20 ft (6.1m) overburden threshold (Figure 50; Line 104).

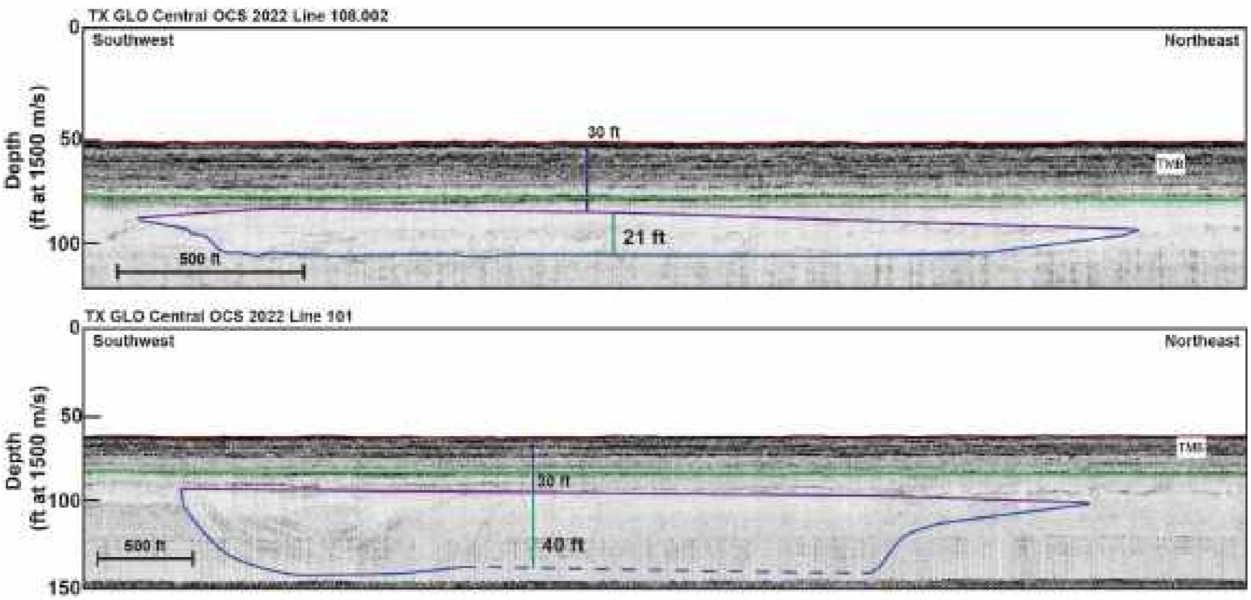
Although these features are inferred as having sand-rich sediment composition they are considered non-viable sand resources due to the amount of overburden within the investigation area. For this reason, they are presented solely to inform the geologic framework understanding and not included in potential sand resource target quantification for this investigation. Future surveys could explore if the channel belt features continue outside the current investigation area. It is possible they exist in areas of less overburden and could be considered potentially viable sand resources.

Figure 51. Example of Channel Belt 5 (Feature 41)



Note: The blue dashed horizon marks the inferred basal unconformity of variable transparent/chaotic seismic reflector packages. The green horizon is the transgressive ravinement surface and marks the top of the seismic reflector packages. The black horizon marks the basal unconformity of the incisional feature. Note the poor acoustic penetration below the laminated facies. Refer to Figure 38 for seismic line number and location.

Figure 52. Example of Channel Belt 6 (Feature 42)



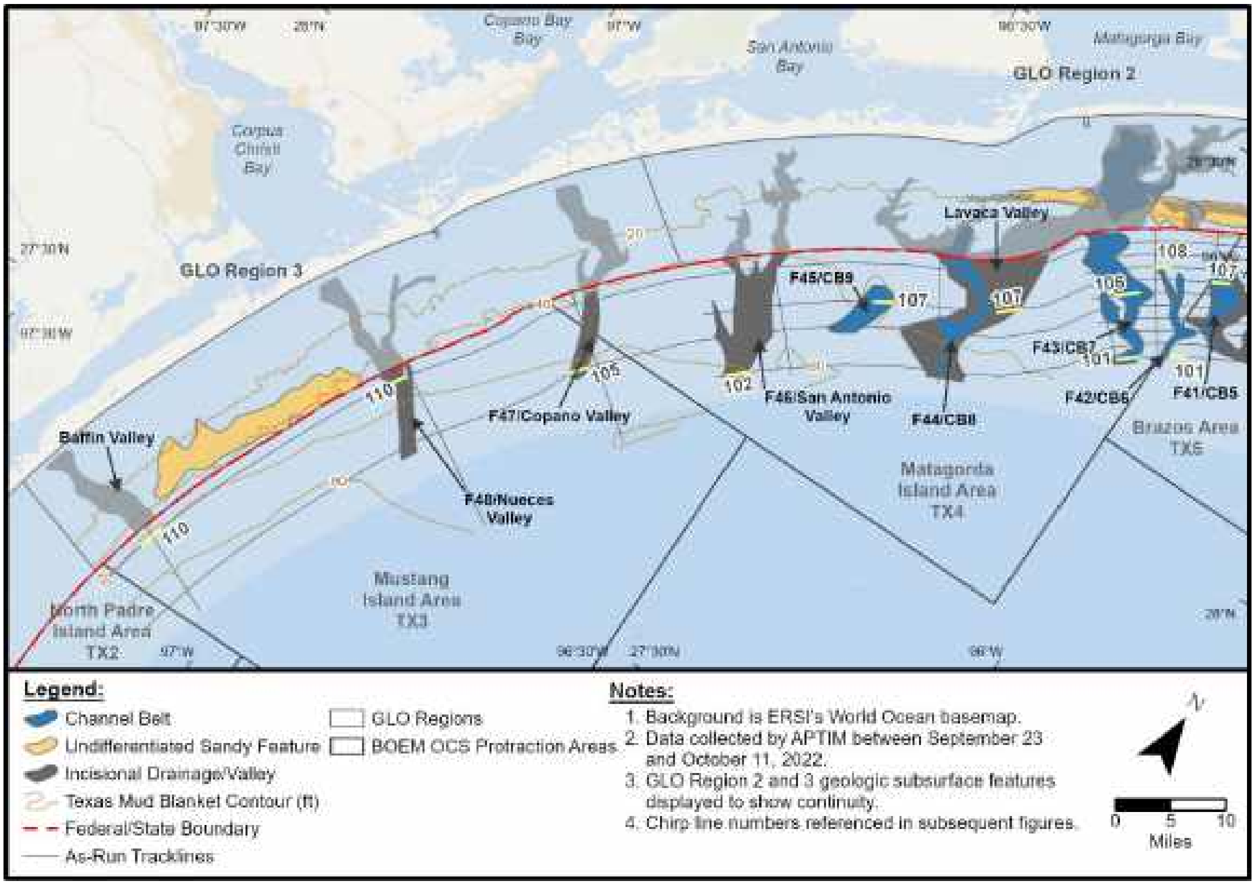
Note: The blue horizon marks the inferred basal unconformity of variable transparent/chaotic seismic reflector packages. The purple horizon is the top of the seismic reflector packages. The green horizon is the transgressive ravinement surface. Note the poor acoustic penetration below the laminated facies. Dashed lines represent the interpreted base of the feature but could not be confidently resolved in sub-bottom. Refer to Figure 38 for seismic line number and location.

4.4.5 Matagorda Island Area (TX4), Mustang Island Area (TX3), and North Padre Island Area (TX2) Protraction Areas

The Matagorda, Mustang, and portions of the North Padre Island protraction areas (TX4, TX3, TX2) of the Central Coast OCS are broadly bounded by Matagorda Island and Baffin Bay. This area contains very few potential sand-bearing features, and all are excluded as potential sediment resources due to the thick overburden related to the TMB. Features in the area are difficult to discern due to their depth below seafloor, and homogenous nature of the seismic unit underlying the TMB. Features that were identified from seismic interpretation alone are related incisional drainage and valley systems from a time of lower sea level during the Late Quaternary (Figure 53). Note these valley or drainage systems may have been incising at different time periods and related to separate sea level cycles, and although they are all exist below the most recent transgressive ravinement surface, no other evolutionary correlations were made at a regional scale.

All features in this section are not considered potentially viable sand resources due to the thick, muddy overburden related to the TMB and are presented solely to inform the geologic framework understanding of the investigation area.

Figure 53. Map of Potential Sand-Bearing Geologic Features within the Central Coast OCS Along Protraction Area TX2, TX3, and TX4



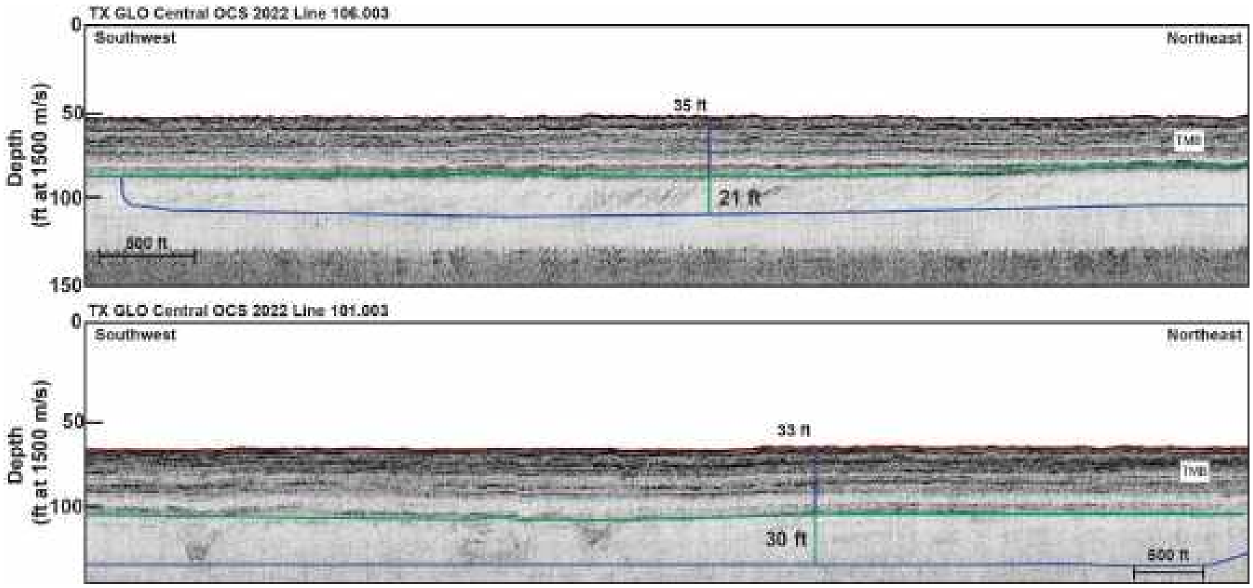
Regionally mapped features in Matagorda Island, Mustang Island, and North Padre Island protraction areas. Features mapped in GLO Region 2 and 3 state waters are shown to provide regional continuity context. Location and line of subsequent seismic examples shown in white.

4.4.5.1 Feature 43 Channel Belt 7

Channel Belt 7 is between 1-3 mi (1.6-4.8 km) wide and mapped for 12 mi (19.3 km) in the current data extent. The channel belt package, represented by dipping clinoform packages range from ~20 to 30 ft (6.1- 9.1 m) thick, with greater than 30 ft (9.1 m) of TMB overburden (Figure 54). The reflectors below the TMB are very faint, possibly due to the homogenous nature of the underlying stratigraphy, making mapping this feature difficult at the current data density. The Lavaca Incised Valley from GLO Region 2 (APTIM and TWI 2024) truncates Channel Belt 7 from the northeast.

Although these features are inferred as having sand-rich sediment composition they are considered non-viable sand resources due to the amount of overburden within the investigation area. For this reason, they are presented solely to inform the geologic framework understanding and not included in potential sand resource target quantification for this investigation. Future surveys could explore if the channel belt features continue outside the current investigation area. It is possible they exist in areas of less overburden and could be considered potentially viable sand resources.

Figure 54. Example of Channel Belt 7 (Feature 43)



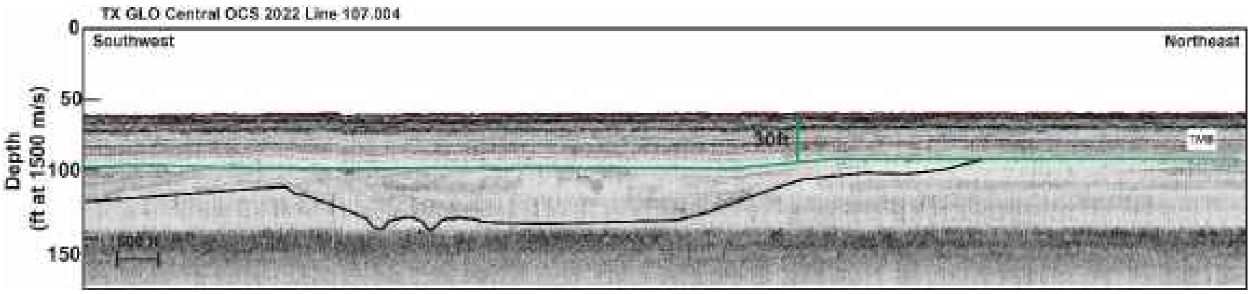
Note: The blue horizon marks the inferred basal unconformity of the dipping clinoform package. The green horizon is the transgressive ravinement surface. Note the poor acoustic penetration below the laminated facies. Refer to Figure 53 for seismic line number and location.

4.4.5.2 Feature 44 Lavaca Valley and Channel Belt 8

The Lavaca Incised Valley tributaries from the Region 2 state waters (APTIM and TWI 2024) converge in the Central Coast OCS Mustang Island Area (TX4). The incised valley narrows from roughly 7 mi (11.2 km) across to 5 mi (8 km) further seaward. Its valley edges are not well constrained due to faint seismic imaging at depth, but where imaged the erosional unconformity boundary incises into a faintly laminated reflector stratigraphy. The complex valley fill displays laterally migrating channel belts, prograding gently dipping reflector sets, and horizontally laminated reflector draping fill (Figure 55). The valley is capped by the transgressive ravinement surface and overlying laminated reflector packages of the TMB.

These features are not considered a potentially viable sand resource due to the inferred fine-grained composition and amount overburden but are important to the geologic framework understanding of the area.

Figure 55. Example of the Lavaca Valley Extension in the Central Coast OCS (Feature 44)



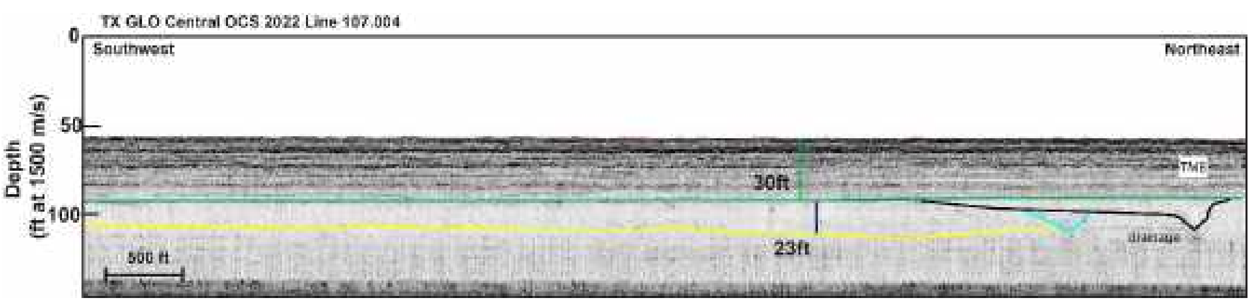
Note: The green horizon marks the transgressive ravinement surface and black marks the inferred basal unconformity of the incisional valley. TMB is the Texas Mud Blanket. Refer to Figure 53 for seismic line number and location.

4.4.5.3 Feature 45 Channel Belt 9

Channel Belt 9 in the Mustang Island Area (TX4) is roughly 1.5 mi (2.4 km) wide, and averages about 20 ft (6.1 m) thick. It is characterized by transparent to faintly dipping reflectors grading into an incisional channel form. It is located on the interfluve area between incised valleys and is capped by the transgressive ravinement surface and overlying 30-40 ft (9.1-12.2 km) of TMB (Figure 56).

Although these features are inferred as having sand-rich sediment composition they are considered non-viable sand resources due to the amount of overburden within the investigation area. For this reason, they are presented solely to inform the geologic framework understanding and not included in potential sand resource target quantification for this investigation. Future surveys could explore if the channel belt features continue outside the current investigation area, it is possible they exist in areas of less overburden and could be considered potentially viable sand resources.

Figure 56. Example of Channel Belt 9 (Feature 45)



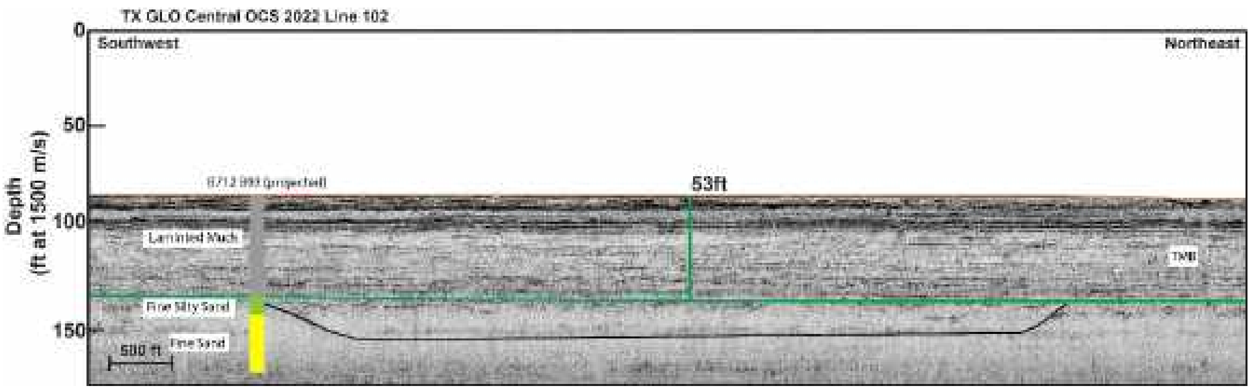
Note: The green horizon marks the transgressive ravinement surface and yellow marks the inferred basal unconformity channel belt facies. The light blue horizon marks the channel form associated with the dipping clinoform package. Black horizon shows a secondary drainage incision. TMB is the Texas Mud Blanket. Refer to Figure 53 for seismic line number and location.

4.4.5.4 Feature 46 San Antonio Valley

The San Antonio Valley is much smaller than other major stratigraphic features such as the Colorado and Lavaca Valleys. Its valley edges are not well constrained due to faint seismic imaging, but where imaged the erosional unconformity boundary incises into faint laminated reflectors to the northeast and a transparent unit mostly found to the south and southeast. The deepest, mappable, incisions of the valley reach roughly 80 ft (24.3 km) below seafloor and maintain a width of roughly 1 mi (1.6 km) across. The two major tributaries continue and coalesce in the Central OCS region (Figure 53). Valley fill is mostly transparent to faintly laminated reflectors (Figure 57). The valley is capped by the transgressive ravinement surface, and seaward thickening laminated reflectors related to the TMB. The interfluvial areas may contain sand-rich deposits inferred from archival core B712 B93 (Figure 57), however they are located roughly 50ft (15.2m) deep below the seafloor.

These features are not considered a potentially viable sand resource due to the inferred fine-grained composition and amount overburden but are important to the geologic framework understanding of the area.

Figure 57. Example of San Antonio Valley (Feature 46)



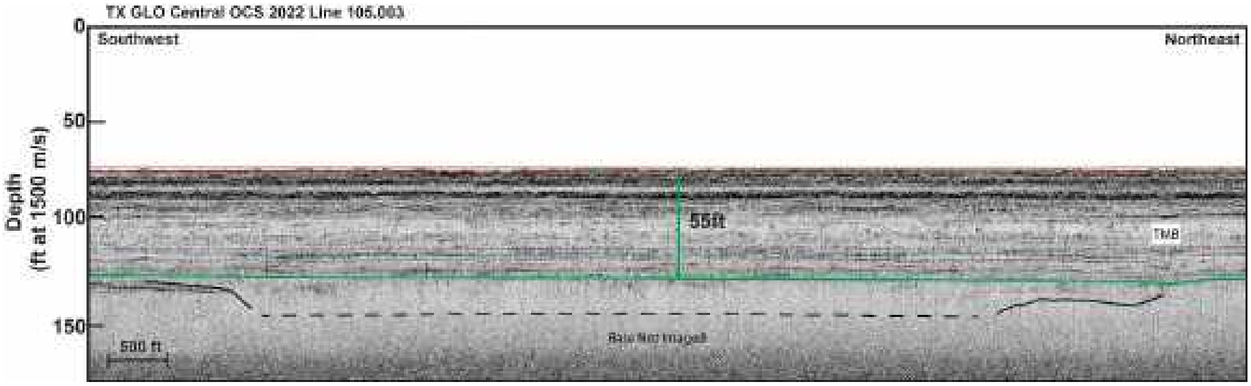
Note: The green horizon marks the transgressive ravinement surface and black marks the inferred basal unconformity of the incisional valley. TMB is the Texas Mud Blanket. Archival platform boring B93 modified from (Abdulah 1995). Refer to Figure 53 for seismic line number and location.

4.4.5.5 Feature 47 Copano Bay Valley

The Copano Bay Valley maintains a width of roughly 3 mi (4.8 km) and incises to 75 ft (22.9 km) deep where mappable in the Central OCS region. Its valley edges are not well constrained due to faint seismic imaging at depth, but where imaged the erosional unconformity boundary incises into faint laminated reflectors landward and a transparent unit mostly found further seaward. The valley is capped by the transgressive ravinement surface, and seaward thickening laminated reflectors related to the TMB (Figure 58). Previous studies within Copano Bay show the valley incises to a depth of 65 ft (19.8 km) with basal bayhead delta and overlying tidal and estuarine deposits (Troiani et al. 2011). Age constraints show the deltaic deposition transitioned to estuarine around 9,600 years ago and a major bayhead delta backstepping event occurred at 8,200 years ago (Troiani et al. 2011). Three separate tributaries extending from the Aransas, Mission Rivers and Copano Creek in the upper bay coalesce at Live Oak Peninsula. This represents a dendritic drainage system that incises through the 120,000-year-old highstand Ingleside Shoreline. This could be an analogue to the shore parallel undifferentiated sand feature (USF1) found offshore of Matagorda Bay in concurrent investigation in GLO Region 2 (APTIM and TWI 2024).

These features are not considered a potentially viable sand resource due to the inferred fine-grained composition and amount overburden but are important to the geologic framework understanding of the area.

Figure 58. Example of the Copano Bay Valley Extension (Feature 47)



Note: The green horizon marks the transgressive ravinement surface and black marks the inferred basal unconformity of the incisional valley. TMB is the Texas Mud Blanket. Refer to Figure 53 for seismic line number and location.

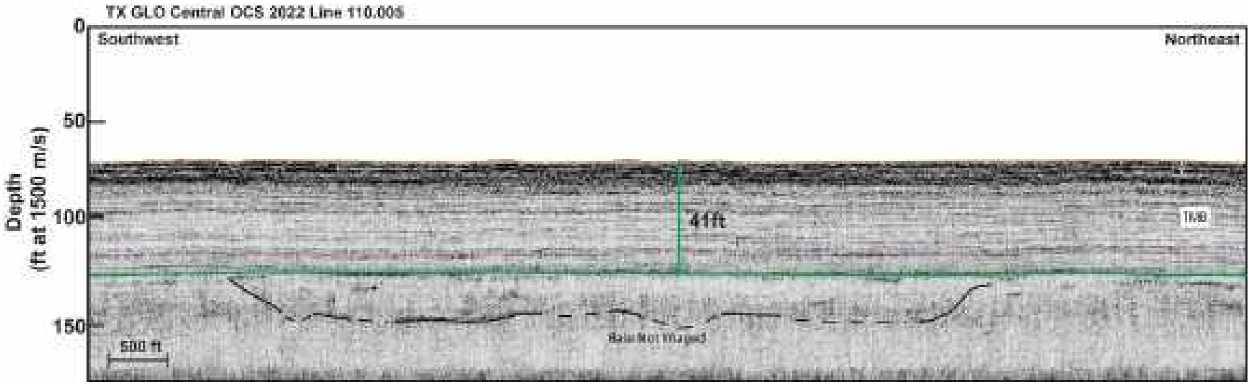
4.4.5.6 Feature 48 Nueces Valley

The Nueces Valley, offshore of Corpus Christi Bay, is about 1.5 mi (2.4 km) across, incises to depths of about 50 ft (15.2 km) below sea floor where imaged and continues from the Region 3 area. A narrow steeply incised drainage tributary trends towards Port Aransas and coalesces with the main valley about 8.5 mi (13.7 km) offshore. Its valley edges are not well constrained due to faint seismic imaging at depth, but where imaged the erosional unconformity boundary incises into faint laminated reflectors landward and a transparent unit mostly found further seaward. The valley is capped by the transgressive ravinement surface, and seaward thickening laminated reflectors related to the TMB (Figure 59).

Archival coring efforts along Mustang Island show two main valleys that incise to roughly 100 ft (30.5 km) below sea level, similar to the portions mapped offshore. The valley fill succession follows the basal fluvial sands, backstepping bayhead delta, estuarine and tidal deposits (Simms et al. 2008) similar to other underfilled flooded valleys in Texas (Anderson et al. 2016). Initial flooding of the bay occurred 9,700 years ago based on age constraints, with major backstepping events again occurring at 8,200 years ago.

These features are not considered a potentially viable sand resource due to the inferred fine-grained composition and amount overburden but are important to the geologic framework understanding of the area.

Figure 59. Example of the Nueces Valley Extension in Region 3 OCS Area (Feature 48)



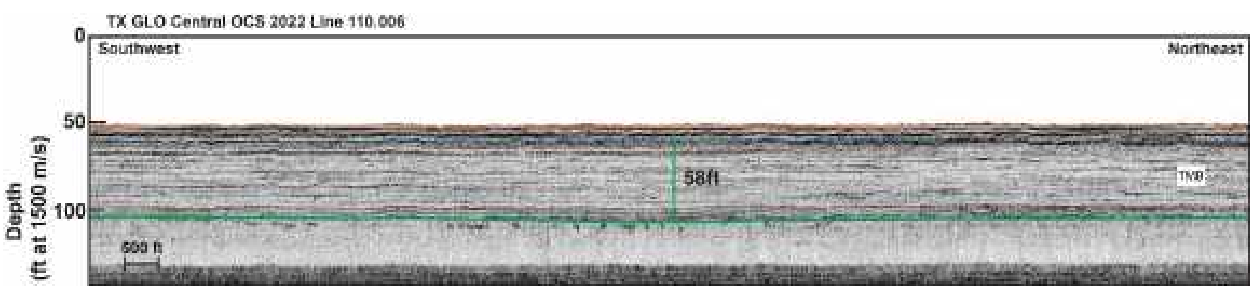
Note: The green horizon marks the transgressive ravinement surface and black marks the inferred basal unconformity of the incisional valley. TMB is the Texas Mud Blanket. Refer to Figure 53 for seismic line number and location.

4.4.5.7 Offshore Extension of Baffin Bay Valley

The Baffin Bay Valley is roughly 1.5 mi across (2.4 km), incises to depths of 60 ft (18.3 m) below sea floor where imaged in GLO Region 3 but was not confidently mapped in the Central Coast OCS. The valley edges were difficult to constrain in Region 3 and in the Central Coast OCS, with very sparse line spacing, there were no clues to determine the valley boundaries. An example of seismic line in the Central Coast OCS offshore of the Region 3 Baffin Bay Valley (APTIM and TWI 2024) is shown below (Figure 60).

Archival coring and geophysical efforts within Baffin Bay show valley fill consists of basal fluvial sands with overlying bayhead delta and estuarine or bay deposits. Initial flooding occurred around 8,000 years ago (Simms et al. 2008). The drainage basin is considered semi-arid with relatively small fluvial input throughout the Holocene from the several feeder creeks (Anderson et al. 2014). Baffin Bay is hypersaline due to its isolation from the Gulf, the semi-arid climate, and small freshwater input, which creates unique carbonate sedimentary units in the area. These evaporites, ooids, algal mats, and caliche deposits found onshore (Anderson et al. 2022 and references within) could be linked to the transparent, to mottled facies found in seismic in this investigation if they continue offshore.

Figure 60. Example Offshore of Baffin Bay in Region 3 OCS Area

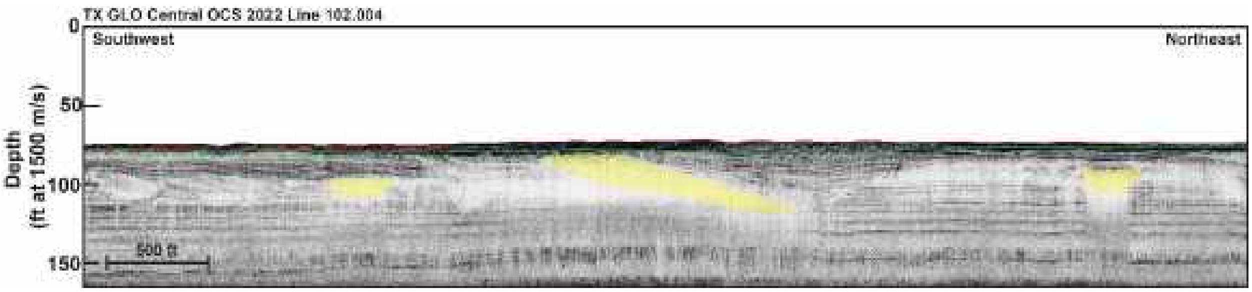


Note: Valley edges could not be mapped offshore, for example the thick TMB overlying Pleistocene deposits. Refer to Figure 53 for seismic line number and location.

4.4.6 Localized Features

Smaller localized features are scattered throughout the Central Coast OCS Region but are concentrated in the Galveston, Brazos and northern Matagorda Island protraction areas, within smaller channel belt type features, and some drainage/ paleovalley systems. These smaller features are normally isolated channels/sediment pockets which are indicative of potential resources or partially preserved channel belts. Due to the widely spaced grid, it is not possible to determine the overall extent of these features and correlate them to the larger sand-bearing regional deposits; however, based on the observed seismic characteristics, there is the potential for additional data collection to better delineate these features and determine their potential for sand. Localized features are characterized as typically having lateral accretionary deposits or transparent internal reflector packages (Figure 61). Other localized features may exist below the transgressive ravinement surface in Matagorda and Mustang Island protraction areas, but the thickness of the TMB and homogeneity of the underlying stratigraphy makes interpretation difficult.

Figure 61. Example of Localized Features. potential sand-bearing subunit marked in yellow that could not be correlated between seismic lines at the current line spacing



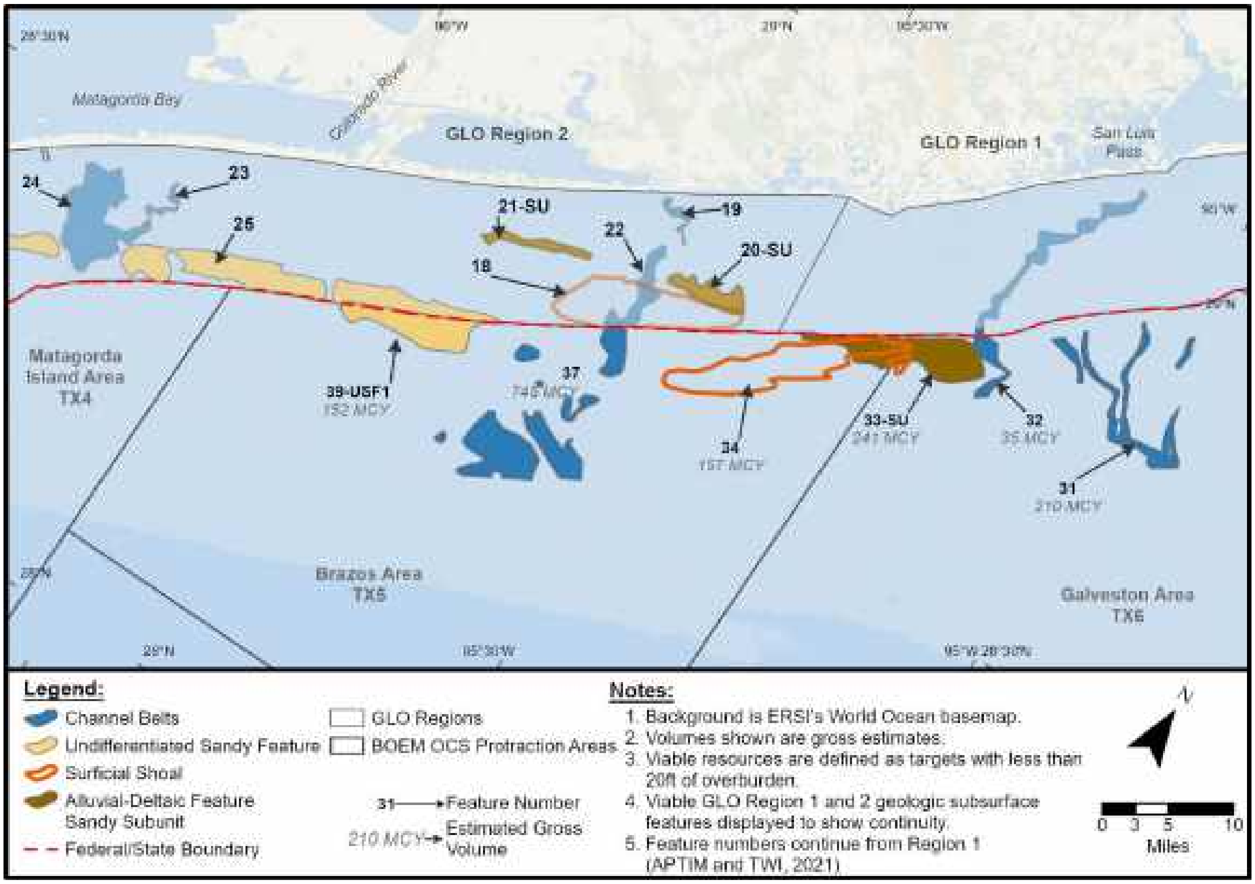
4.4.7 Potential Sediment Resource Quantity Estimates

Of the 19 regionally mappable features (including TMB) within the Central Coast OCS (TX2-6), one surficial shoal, three channel belts, one sandy subunit related to alluvial-deltaic features, and one undifferentiated sandy feature were identified as potentially viable sediment resources. These 6 potentially viable resource targets located within the Galveston and Brazos protraction areas are estimated to contain 1.54 BCY (1.17 BCM) of sand-rich sediment. The estimated resource volume is displayed alongside each potentially viable feature on the map in Figure 62, and in Table 5.

Channel Belt 3 (Feature 37) of the Colorado Incised Valley in the Brazos protraction area is the largest potential sand-rich feature in this investigation. This feature represents amalgamated channel belts with acceptable overburden and contains 745 MCY (million cubic yards [569.6 million cubic meters (MCM)]) of potentially sand-rich sediment. In the future if the overburden threshold was increased, other areas of channel belt sands found deeper in the Colorado Incised Valley could be expanded and considered for sediment resource exploration. Besides the one surficial shoal (Feature 34), estimated to contain 157 MCY (120.0 MCM) of potentially sand-rich sediment, all other features identified in this investigation are subsurface. Besides the channel belts related to the Colorado Incised Valley, two other channel belts (Feature 31 and 32) were identified containing 210 MCY (160.6 MCM) and 35 MCY (26.8MCM) of potentially sand-rich sediment. Two features were identified but their general origin will need to be further refined with geologic sampling. One sandy subunit related to an alluvial-deltaic deposit (Feature 33-SU) is estimated to contain 241 MCY (184.3MCM) of potentially sand-rich sediment and an undifferentiated sandy feature (Feature 39) contains 152 MCY (116.2MCM) of potentially sand-rich sediment. These are gross sediment volume estimates at the reconnaissance-level of which the exact sand percentage and amount will be highly variable and should be refined with geological sampling and further detailed geophysical and geological investigations. Note the reported volumes do not include volume of overburden, rather just the sand-bearing unit of interest. Some of these features continue into state waters within GLO Region 2 and were delineated as part of a concurrent investigation (APTIM and TWI 2024).

Other geologic subsurface features were potentially sand-bearing but were excluded in resource quantification estimates because the features have greater than 20 ft (6.1 m) of overburden (the overlying non-compatible sediment between the potential sandy deposit and the seafloor). In other instances, subsurface features were summarized in previous sections for their significance to the geologic framework understanding but their fine-grained sediment composition excludes them as potential sand resources.

Figure 62. Map of Viable Potential Sand Resource Targets within the Study Area



Note this is only viable potential sand resources with less than 20 ft (6.1 m) of overburden. Volumes do not include overburden. Volumes and feature numbers correlate with Table 5. GLO Regions 2 sediment resource targets (Features 18, 19, 20-SU, 21-SU, 22, 23, 24 and 25) from APTIM and TWI (2024).

Table 5. Summary of Regional Geologic Features in Central Coast OCS and Quantified Viable Potentially Sand Resources with less than 20 ft (6.1 m) Overburden

Feat. No.	Protract. Area	Viable Res. (Yes/ No)	Prelim. Interp.	Area (sq ft/m x 10^6)	Average Stat. Unit Thickness (ft/m)	Average Ovbn. Thk. (ft/m)	Gross Sed. Volume (MCY/ MCM)	Ex. Data Figure No.
31	TX6	Yes	Pleistocene Channel Belt/Drainage (1)	505/ 46.9	15/4.5	8/2.4	210/ 160.6	Figure 40
32	TX6	Yes	Pleistocene (Brazos) Channel Belt (2)	146/ 13.6	22/6.7	8/2.4	35/26.8	Figure 41
33	TX5, TX6	No	Alluvial-Deltaic (1)	NA	NA	NA	NA	NA

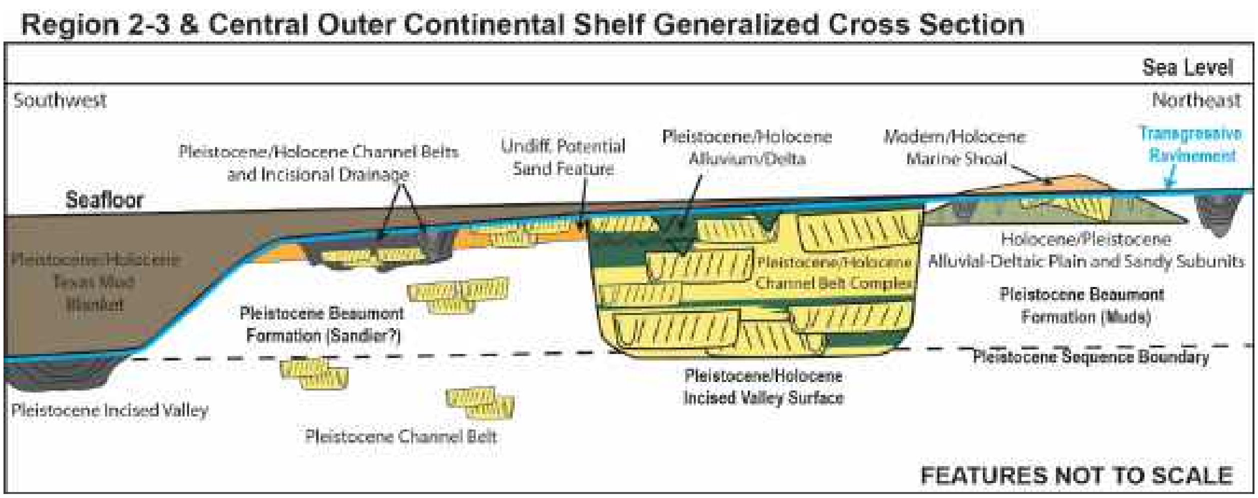
Feat. No.	Protract. Area	Viable Res. (Yes/ No)	Prelim. Interp.	Area (sq ft/m x 10^6)	Average Stat. Unit Thickness (ft/m)	Average Ovbn. Thk. (ft/m)	Gross Sed. Volume (MCY/ MCM)	Ex. Data Figure No.
33-SU	TX5, TX6	Yes	Alluvial-Deltaic Feature sandy subunit (1)	759/ 70.5	15/4.5	4/1.2	241/ 184.3	Figure 42
34	TX5	Yes	Holocene/ Modern Shoal	1,000/ 92.9	6/1.8	0	157/120	Figure 44
35	TX5, TX6	No	Quaternary Channel	NA	NA	NA	**	Figure 45
36	TX5	No	Alluvial-Deltaic Feature (2)	NA	NA	NA	**	Figure 46
37	TX5	Yes	Pleistocene/ Holocene Colorado Incised Valley & Channel Belt (3)	119/11	30/9.1	20/6.1	745/ 569.6*	Figure 47
38	TX5	No	Alluvial-Deltaic Feature (3)	NA	NA	NA	**	Figure 48
39	TX5	Yes	Undifferentiated Sandy Feature (1)	532/49. 4	10/3	10/3	152/ 116.2	Figure 49
40	TX5	No	Quaternary Channel Belt (4)	NA	NA	NA	**	Figure 50
41	TX5	No	Quaternary Channel Belt (5)	NA	NA	NA	**	Figure 51
42	TX5, TX4	No	Quaternary Channel Belt (6)	NA	NA	NA	**	Figure 52
43	TX4	No	Quaternary Channel Belt (7)	NA	NA	NA	**	Figure 54
44	TX4	No	Lavaca Valley & Channel Belt (8)	NA	NA	NA	**	Figure 55
45	TX4	No	Quaternary Channel Belt (9)	NA	NA	NA	**	Figure 56
46	TX4	No	San Antonio Pleistocene Valley	NA	NA	NA	**	Figure 57
47	TX3, TX4	No	Copano Bay Pleistocene Valley	NA	NA	NA	**	Figure 58
48	TX3	No	Nueces Pleistocene Valley	NA	NA	NA	**	Figure 59
TX Mud Blanket	GLO Reg. 2, 3, Central Coast OCS+	No	Holocene Texas Mud Blanket	NA	NA	NA	NA	Figure 38 Figure 60
TOTAL							**1,540**	

Note: *Gross volume estimates for the Colorado Incised Valley are for viable channel belt complexes where able to correlate with less than 20 ft (6.1 m) overburden, this should be considered a very conservative estimate. **Features not considered potential viable sand resource targets due to the amount of overburden and are presented for regional geologic framework understanding only. Note the reported volumes do not include volume of overburden, rather just the sand-bearing unit of interest. Volumes and feature numbers correlate with Figure 62.

4.4.8 Regional Geologic Summary

Region 2 and 3 and the Central Texas OCS contain several potential sand resources contained within regional scale geologic systems such as the Pleistocene and Holocene channel belt systems, potential alluvial-deltaic features, potential undifferentiated sand features and surficial shoals. Other significant potential sediment resources are found in localized features that are not regionally extensive due to survey spacing but are observed across the study area in the form of probable fluvial stratigraphy or paleo coastal strandplain deposits according to the literature. While all geologic interpretations based on sub-bottom geophysical data are preliminary until ground-truthed by geotechnical cores, these initial observations show the prominence of fluvial-related processes and stratigraphy across the central Texas inner shelf throughout the Pleistocene and Holocene. A generalized cross-section was developed from the mapping of regional depositional systems and localized features (Figure 63). A key observation of this investigation is the amalgamation of Pleistocene stratigraphy in the upper ~60 ft (18.3 m) record of this region which can lack clearly differentiated sequence boundaries separated by significant deposition as proposed in earlier work (Anderson, et al. 2016; Banfield and Anderson 2004) with the acknowledgment many of these boundaries could be below the seismic imaging of the chirp system.

Figure 63. Generalized Cross-Section of Major Features Observed in the Region 2-3 and Central Coast OCS



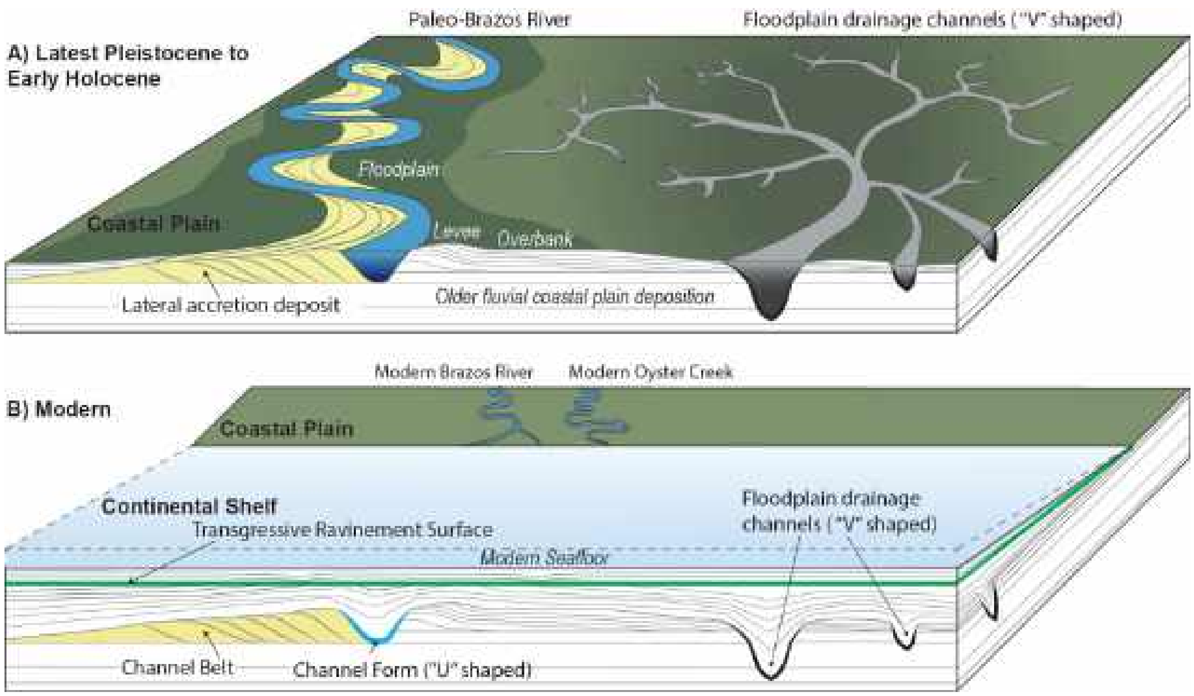
Note: Several cycles of incision, deltaic progradation, alluvial floodplain aggradation and coastal reworking, overprinted across the inner shelf of Region 2, 3, and Central Coast OCS. This complex stacking of facies requires better age control to constrain the absolute evolution of the investigation area.

The initial regional framework relies on archival cores to ground truth features and constrain their chronology where possible and demonstrates the complexity of coastal central Texas. The low-gradient, slowly subsiding inner shelf is composed of multiple cycles of fluvial and deltaic sedimentation and progradation, which is then reworked and redistributed during subsequent cycles of sea level rise and fall by coastal, marine, and alluvial processes (Anderson et al. 2016). The resulting deposits are further complicated by climatic shifts that alter sediment supply rates to the coast (Simms et al. 2008; Anderson et al. 2016). While this investigation could not confidently correlate the evolution of the inner shelf features without further geologic sampling and age control, based on the literature the features presented here are related to the last glacial cycle from 120,000 years ago to the most recent transgression starting about 20,000 years ago. Instead, this investigation focuses on the distribution and interplay between features from a sand resource perspective. Some observations relevant to these distributions include:

1) There are two dominant end member channel form types, "u" shaped channel forms related to laterally migrating channel belts with relatively uniform thickness and smooth bounding

surfaces throughout the deposit vs. incisional "v" shaped floodplain drainage features, similar to other studies in the Colorado-Brazos Area (Speed et al. 2022; Figure 64). The latter can exhibit many drainage incisions in a single feature creating a "sawtooth" basal unconformity. The drainage gullies can exhibit draping laminated reflectors or transparent packages, but predominantly consist of a minor coarse basal channel lag with mostly mud fill. The loss or weakening of seismic signal below features of interest may provide clues to sandier units if presented with transparent reflector packages. The differentiation between the two types of channels and their associated fill and presence of channel belt laterally accreting point bar deposits are crucial for geologic context and sediment resource exploration.

Figure 64. Conceptual Block Diagrams Demonstrating Brazos River Channel Belt and Floodplain Drainage Channel Evolution, (modified from Speed et al. 2022)



2) There is a wide gradational scale to the mentioned simplistic channel classification scheme. Along the axis of a single system or at convergence zones of incisional floodplain drainages or valleys may exhibit more complex fill architecture. If there is enough incisional accommodation, there is potential for stream occupation (e.g., Cardenas et al. 2023), which is interpreted in 2D seismic as occurrence of laterally migrating channel belts in the drainage system of the otherwise simple mud filled deposits up or down dip. An example can be found on the northeast portion of the Central Coast OCS, or the dendritic drainage features landward of USF1 in the Region 2 area.

3) The overfilled valleys of the Colorado and Brazos systems allow for unique sand prospecting strategies targeting stratigraphically shallower fluvial channel sands with minimal overburden, in contrast to the underfilled valleys that have very limited viable resource targets due to their fill architecture. These smaller underfilled systems, similar to the Trinity and Sabine valley systems of Region 1 (APTIM and TWI 2021) and central Texas in this investigation, had lower sediment supply relative to the rate of base level change. Fluvial sands are confined to the base of the valley and are overlain by thick, muddy deltaic, estuarine, and marine overburden (e.g., Simms et al. 2006; Anderson et al. 2004).

4) Pleistocene deposits below the thick TMB in Region 3 and Central OCS exhibit high amounts of truncation and/or very little basal incision. Mapping incisional valleys of central Texas was difficult in this investigation. The smaller fluvial systems (San Antonio/Guadalupe and Nueces Rivers and Copano and San Fernando Creeks) were identified as having lower sediment flux through the Late-Pleistocene, with no shelf lowstand deltas (Anderson et al. 2004). The seaward thickening overburden and relatively little incision and sandy valley fill offshore limits these systems' viability for future resource investigations and effort should be focused near the modern coast where there is greater preservation of sandy tidal deposits compared to the interfluve areas.

5) Future geological sampling should verify the interfluve transparent package surrounding the USF1 identified in the Central Coast OCS and the USF1 and USF2 identified within state waters as part of the GLO Regions 2 and 3 investigation, to determine its composition and depositional environment. Previous research based on seismic and boring data interpret a wave dominated deltaic shoreline underlying the TMB in the central Texas embayment. Efforts should focus in landward areas of acceptable overburden related to the TMB to determine its potential viability as resource material.

6) The size and geometries of these Pleistocene paleochannel belts/ paleo-channels found on the inner shelf in this investigation are orders of magnitude larger than Holocene or modern-day analogues, like previous investigations both onshore in the Colorado River drainage basin (e.g. Gutierrez & Sockli 2023; Blum and Aslan 2006) and offshore in Texas (APTIM and TWI 2021, 2022) suggesting periods of increased sedimentation and sediment input from higher in the drainage basins. We recommend targeting these specific Pleistocene paleochannel belts with minimal overburden as they represent one of the thickest potential resources.

5 Conclusions

This sand source reconnaissance geophysical investigation followed sequential survey procedures developed by APTIM. During Task I, a review of historical data found limited geologic data for marine sand resources offshore the Texas Central Coast OCS within the Galveston, Brazos, Matagorda Island, Mustang Island, and North Padre Island protraction areas (TX2-TX6). Based on this review, a Task 2 reconnaissance geophysical investigation collected 1,218 nm (2,256 km) of geophysical data at a combined grid line spacing of approximately 1 x 5 mi (1.6 x 8 km) grid. The geophysical data were used to determine potential sand deposits, assess major regional stratigraphic features located in the study area, and develop a regional geologic framework of major depositional systems that have the potential to contain accessible sand resources.

Interpretation of the reconnaissance geophysical survey was used to identify major regional stratigraphic features located within the Central Coast OCS along with the simultaneous Region 2 and 3 state waters investigation, as well as develop a regional geologic framework of major depositional systems that have the potential to contain accessible sand resources. Nineteen large-scale features were identified and loosely organized by regions as follows: 1) OCS Galveston and Brazos (protraction areas TX5, TX6) and 2) OCS Matagorda, Mustang, and North Padre Island (protraction areas TX2, TX3, TX4).

Within the Galveston and Brazos protraction areas of the Central Coast OCS, there are six regionally mappable geologic units that are likely sand-bearing and viable for further investigation and development since they were interpreted with less than 20 ft (6.1 m) of overburden. As part of this investigation, one surficial shoal, three channel belts, and one alluvial-deltaic feature with sandy subunits, and one undifferentiated sandy feature were identified.

The surficial shoal is up to 10 ft (3 m) thick with no overburden. The internal architecture consists of transparent to mottled packages with clear, horizontal bounding surfaces with some laminated packages. The base of the shoal is marked by the transgressive ravinement surface. There is a clear genetic link to reworking of underlying sandy material from one of the alluvial-deltaic features where the shoal is thickest. Archival cores confirm the shoal consists of silty sand and sandy silt. The gross volume estimate of the surficial shoal contains 157 MCY (120 MCM) of potentially sand and muddy sands.

Channel belts are characterized by variable-amplitude, steeply dipping clinoforms, and occasional areas of semi-transparent to chaotic acoustic facies grading into a channel form. These units are bounded by a basal erosional unconformity and its upper portion of these units show a transition to more layered seismic facies or are truncated by transgressive ravinement. Channel belts and channel belt complexes in the Brazos and Galveston protraction areas range in thickness of 15 to 40 ft (4.6-12.2 m), with average overburden varying from 8-20 ft (2.4-6.1 m), with some areas having less than 3 ft (0.9 m) of overburden. Channel Belt 3 within the larger Colorado Valleys could potentially have greater thicknesses since the base of this channel belt complex was sometimes difficult to discern in the chirp seismic data. The channel belts quantified represent a potential of ~990 MCY (756.9 MCM) of sand-rich sediment, with the Colorado Incised Valley channel belt complex representing the largest feature. Channel Belt 2 and 3 of this investigation extend from Regions 1 and 2 in state waters and Channel Belt 3 likely continues further seaward beyond the current coverage area informing future investigations. In the future, if the overburden threshold was increased, other areas of channel belt sands found deeper in the Colorado Incised Valley could be expanded and considered for sediment resource exploration.

The alluvial-deltaic feature is characterized by an overall mounded form, either lobate or elongate shape, and consists of highly variable internal seismic facies and therefore textural composition. The inferred sand dominant facies are characterized with clinoform packages or transparent to mottled facies. The mud dominant facies are characterized by more laminated facies that pinch out near its spatial boundaries. The overall alluvial feature displays incisions or depressions filled with draping fill where it is not truncated by the transgressive ravinement. Only the inferred sandy subunits were reported for potential sand resource quantification estimates, containing a potential 241 MCY (184.3MCM) sand-rich sediment. Both the overall alluvial-deltaic feature and sandier subunits continue into the Central Coast OCS from GLO Region 1 (APTIM and TWI 2021) and GLO Region 2 investigation areas (APTIM and TWI 2024).

The undifferentiated sandy feature is estimated to contain 152 MCY (116 MCM) of potentially sand-rich sediment. The linear feature is roughly 40 mi (64.3 km) long within the Brazos Area and extends into GLO Region 2. It is characterized by transparent facies with transparent to speckled or mottled facies in its lower portions with a strong amplitude upper reflect. Data from one archival boring within the feature displays up to 16 ft (4.9 m) of sand-rich sediment with less than 20 ft (6.1 m) of overburden. This could represent a significant sediment resource if confirmed with more geologic sampling in the future.

Within western Brazos, Matagorda Island, Mustang Island, and North Padre Island protraction areas, there are twelve regionally mappable units, with seven having high sand-bearing potential. All twelve features have greater than 20 ft (6.1 m) of overburden and were excluded from potential sand resource target quantification. One alluvial-deltaic feature did not display any subunit characteristic of the sandier portions mentioned above in this investigation area but could exist further seaward. Six channel belts with similar facies and thickness as described above exhibit 22-30 ft (6.7-9.1 m) of overburden. If these channel belts extend further seaward in future investigations to an area of less overburden, they could represent significant sediment resources. However, due to the southwestern thickening of the TMB, future efforts should focus on the northeastern extent of these discrete channel belts and alluvial-deltaic features. Four relatively small, incised valleys with variable fill types consisting of simple mud drape or more complex fluvial sands overlain by mud drape were associated with the Lavaca, San Antonio, Copano, and Corpus Christi Bay systems.

This investigation also delineated the TMB, a regional feature found in GLO Region 2 and 3 and the Central Coast OCS, and likely extends into Region 4 and the Lower OCS. This feature has been extensively researched in prior studies (see Weight et al. 2011). Its seismic character includes draping, horizontally-laminated, to slightly wavy, laterally continuous reflectors of varying amplitudes. The reflector sets downlap seaward and onlap landward. The unit thickens seaward and to the southwest, up to 100 ft (30.5 m) thick. This muddy to sandy mud unit does not represent a potential sand resource but understanding its distribution was critical to identifying the limiting overburden that may constrain the utility of any underlying potential sand-bearing sediment resources.

In addition to the large regional units, smaller, isolated features were also identified during data processing. These localized features are observed throughout the Central Coast OCS, and many are potentially sand-bearing deposits but are not observed on adjacent geophysical lines, making characterization and quantification of potential sand resources impossible at this resolution. These smaller features are normally isolated channels or sediment pockets, which are indicative of sand or mixed sediments.

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 sufficiently regionally extensive and contiguous to be confidently interpreted across the 1 nm x 5 nm (1.6 x 8km) spaced survey grid. The major geologic systems observed represent a cumulative gross volume of ~1.54 billion cubic yards (BCY) (1.17 billion cubic meters [BCM]) of sand-rich sediment. The precise composition of these deposits is likely highly variable and requires more detailed geological investigation. The majority of these large, depositional systems have never been previously observed and help to constrain areas of fluvial-deltaic activity of the Texas coastal rivers and reorganization by coastal processes throughout the Pleistocene and Holocene. The precise composition of these deposits is likely highly variable and requires more detailed geological investigation. As seen in previous investigations, offshore McFaddin Beach, the variability of sediment can be quite high, indicating that the actual volume of usable, shore-compatible fine-grained sands may be 10 percent or less of the gross volume.

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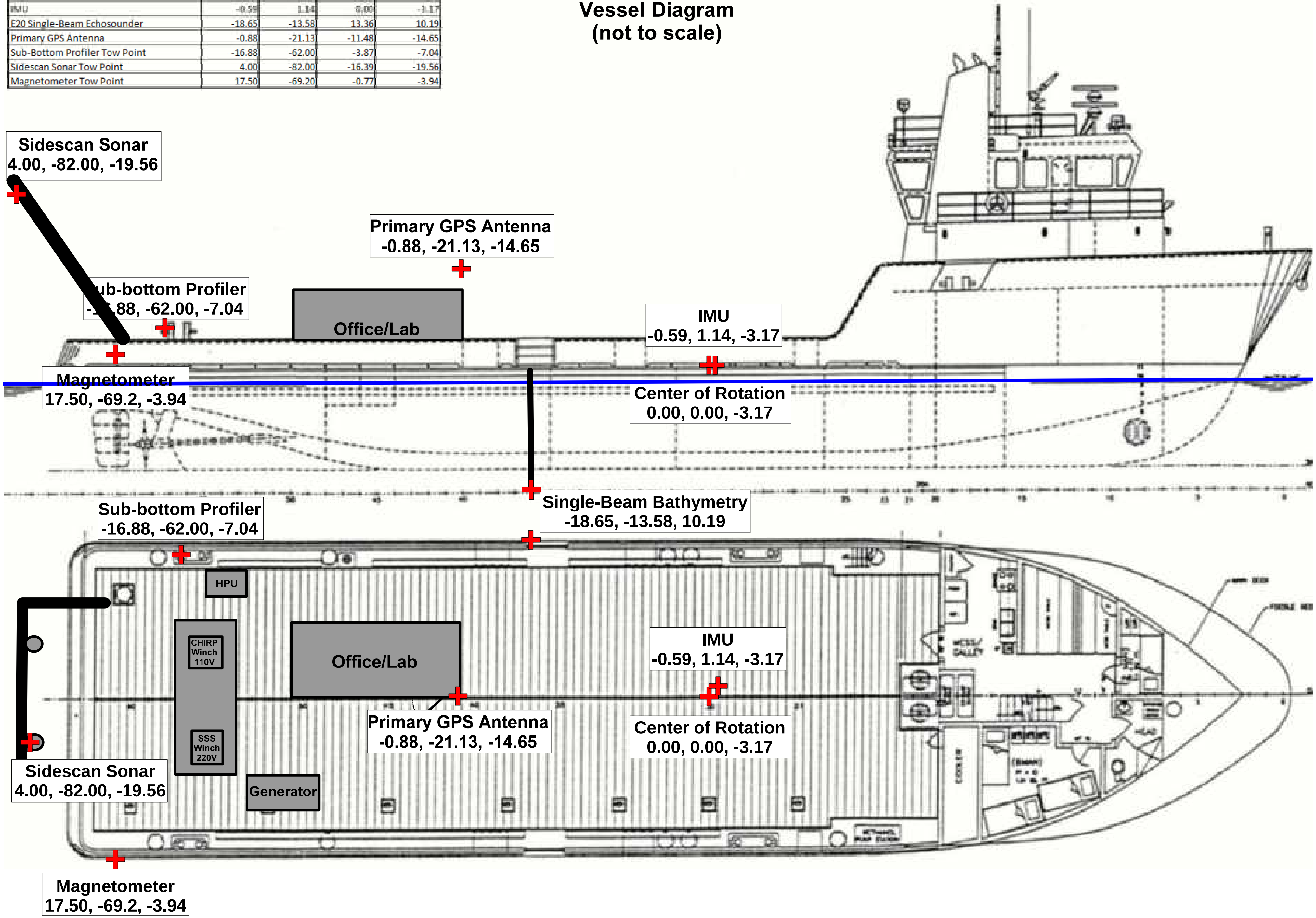
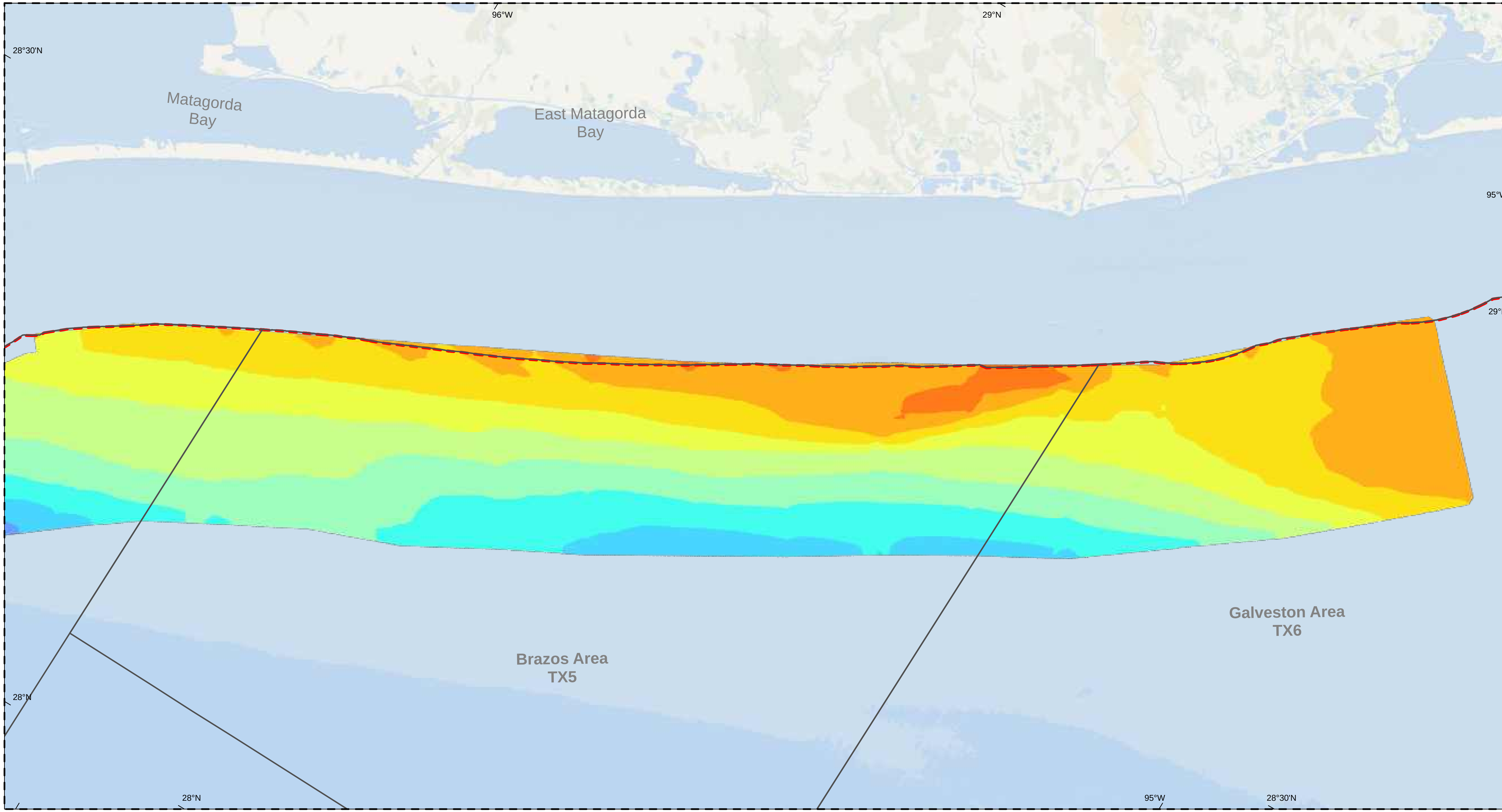
Appendix A: Vessel Diagram

M/V Terry Bordelon Offsets via Measured Relative to Permanent Shipboard Benchmarks. Offsets are relative to Reference Point (RP) or Waterline	Starboard Positive (ft)	Forward Positive (ft)	Down Positive w.r.t. RP (ft)	Down Positive w.r.t. Waterline (ft)
RP: Center of Rotation	0.00	0.00	0.00	-3.17
IMU	-0.59	1.14	0.00	-3.17
E20 Single-Beam Echosounder	-18.65	-13.58	13.36	10.19
Primary GPS Antenna	-0.88	-21.13	-11.48	-14.65
Sub-Bottom Profiler Tow Point	-16.88	-62.00	-3.87	-7.04
Sidescan Sonar Tow Point	4.00	-82.00	-16.39	-19.56
Magnetometer Tow Point	17.50	-69.20	-0.77	-3.94

Texas General Land Office
Offshore Sediment Inventory Central OCS
M/V Terry Bordelon
Vessel Diagram
(not to scale)



Appendix B: Bathymetry Map



Notes:

1. Background is ERSI's World Ocean basemap.
2. Data collected by APTIM between September 23 and October 11, 2022.

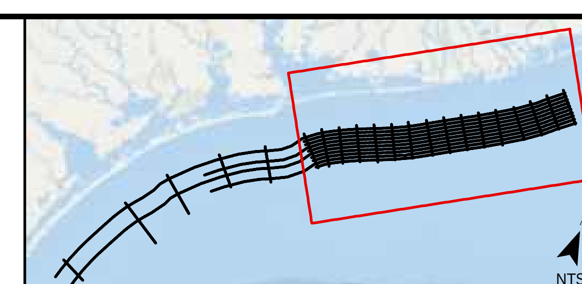
Legend:

- Federal/State Boundary
- BOEM OCS Protraction Areas

Elevation (ft, NAVD 88)

-54 - -50	-74 - -70	-94 - -90
-59 - -55	-79 - -75	-99 - -95
-64 - -60	-84 - -80	-104 - -100
-69 - -65	-89 - -85	-110 - -105

0 1 2 4
Miles



Title:
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Single-beam Bathymetry Surface

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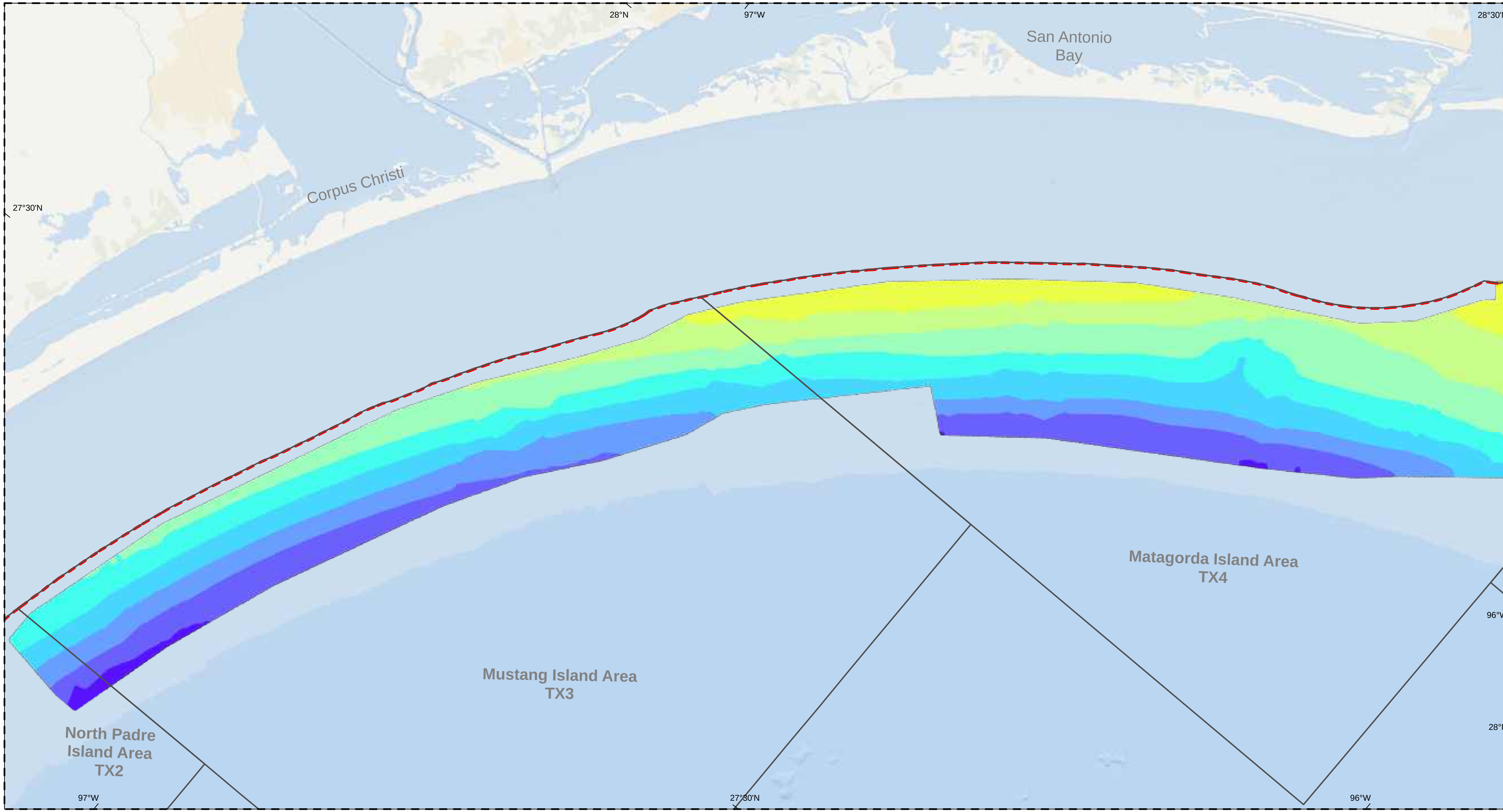
Date: 04/25/2024	Drawn By: AV	Commission No.:631021647	Appendix B Figure: 1



Notes:

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2. Data collected by APTIM between September 23 and October 11, 2022.

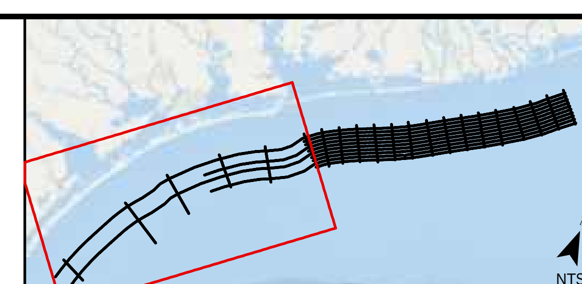
Legend:

- Federal/State Boundary
- BOEM OCS Protraction Areas

Elevation (ft, NAVD 88)

-54 - -50	-74 - -70	-94 - -90
-59 - -55	-79 - -75	-99 - -95
-64 - -60	-84 - -80	-104 - -100
-69 - -65	-89 - -85	-110 - -105

0 1 2 4
Miles



Title:
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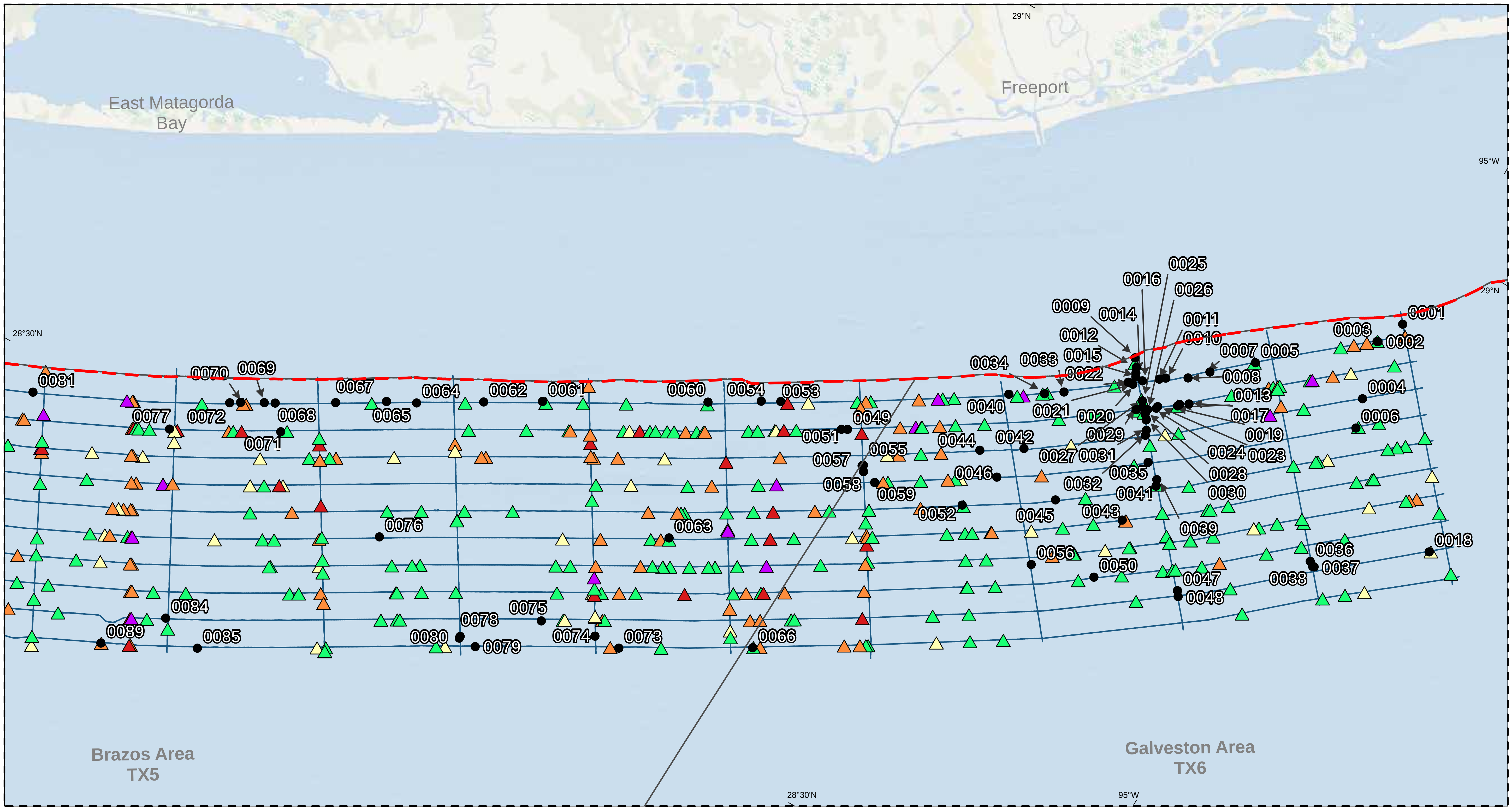
Appendix C: Magnetometer Map and Sidescan Sonar Contacts Map



Notes:

1. Background is ERSI's World Ocean basemap.
2. Data collected by APTIM between September 23 and October 11, 2022.

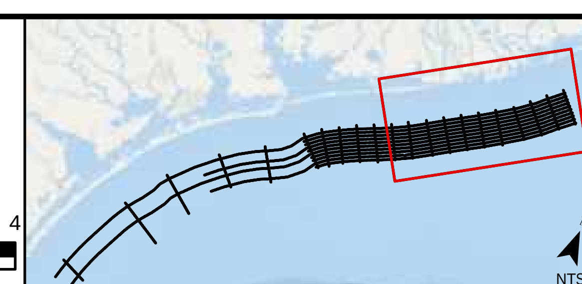
Legend:

- ● Sidescan Contacts
- As-Run Tracklines
- Federal/State Boundary
- BOEM OCS Protraction Areas

Magnetic Anomalies Amplitude (nT)

- 50 - 50
- 51 - 100
- 101 - 500
- 501 - 1000
- 1001 +

0 1 2 4
Miles



Title:
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Sidescan Sonar Contacts and Magnetometer Anomalies

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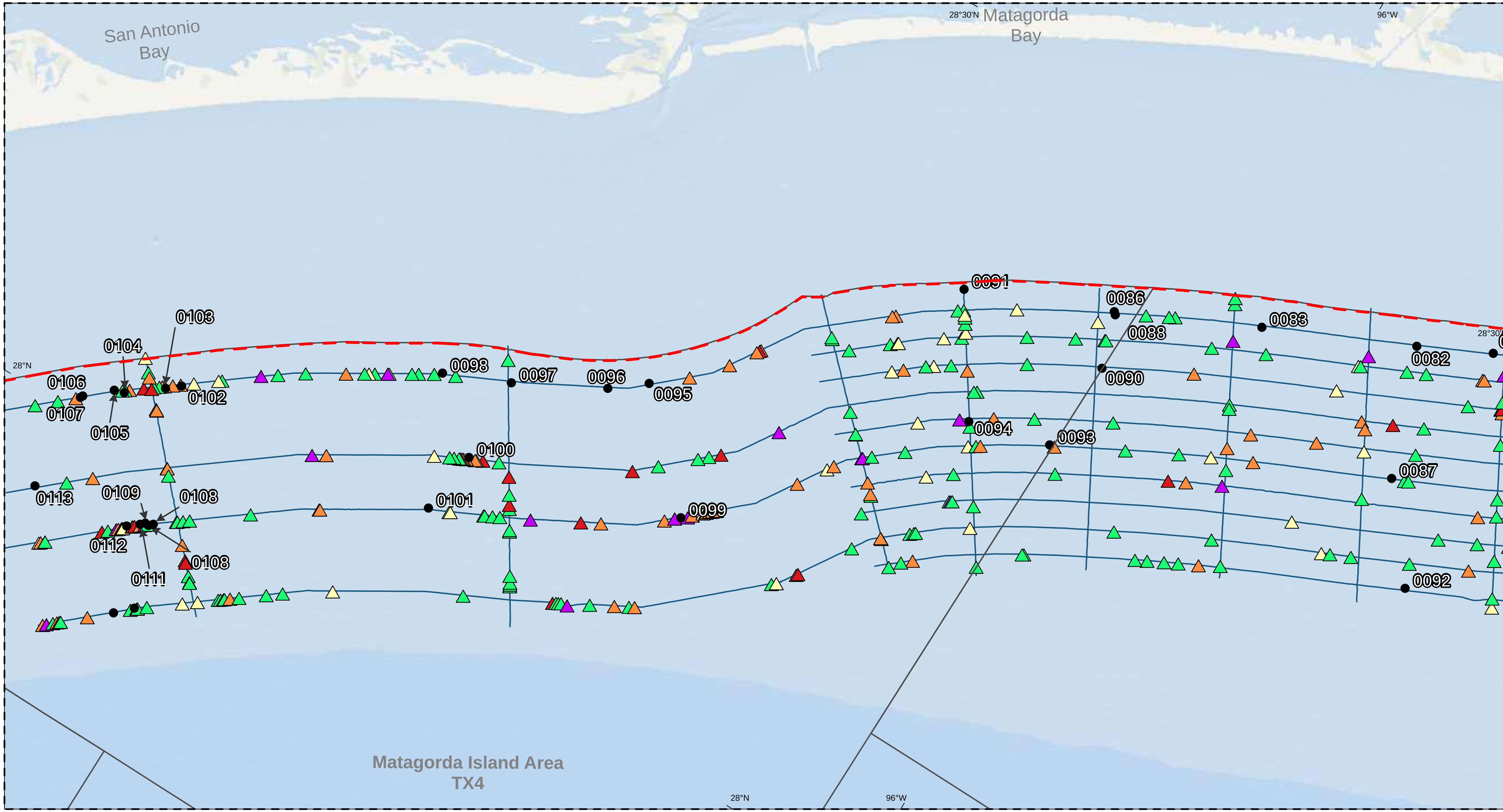


Notes:

1. Background is ERSI's World Ocean basemap.
2. Data collected by APTIM between September 23 and October 11, 2022.

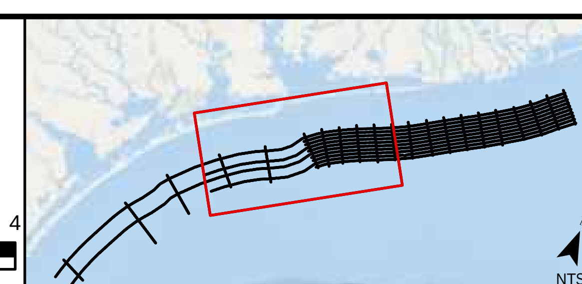
Legend:

- Sidescan Contacts
- As-Run Tracklines
- Federal/State Boundary
- BOEM OCS Protraction Areas

Magnetic Anomalies Amplitude (nT)

- 50 - 50
- 51 - 100
- 101 - 500
- 501 - 1000
- 1001 +

0 1 2 4
Miles



Title:
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Sidescan Sonar Contacts and Magnetometer Anomalies

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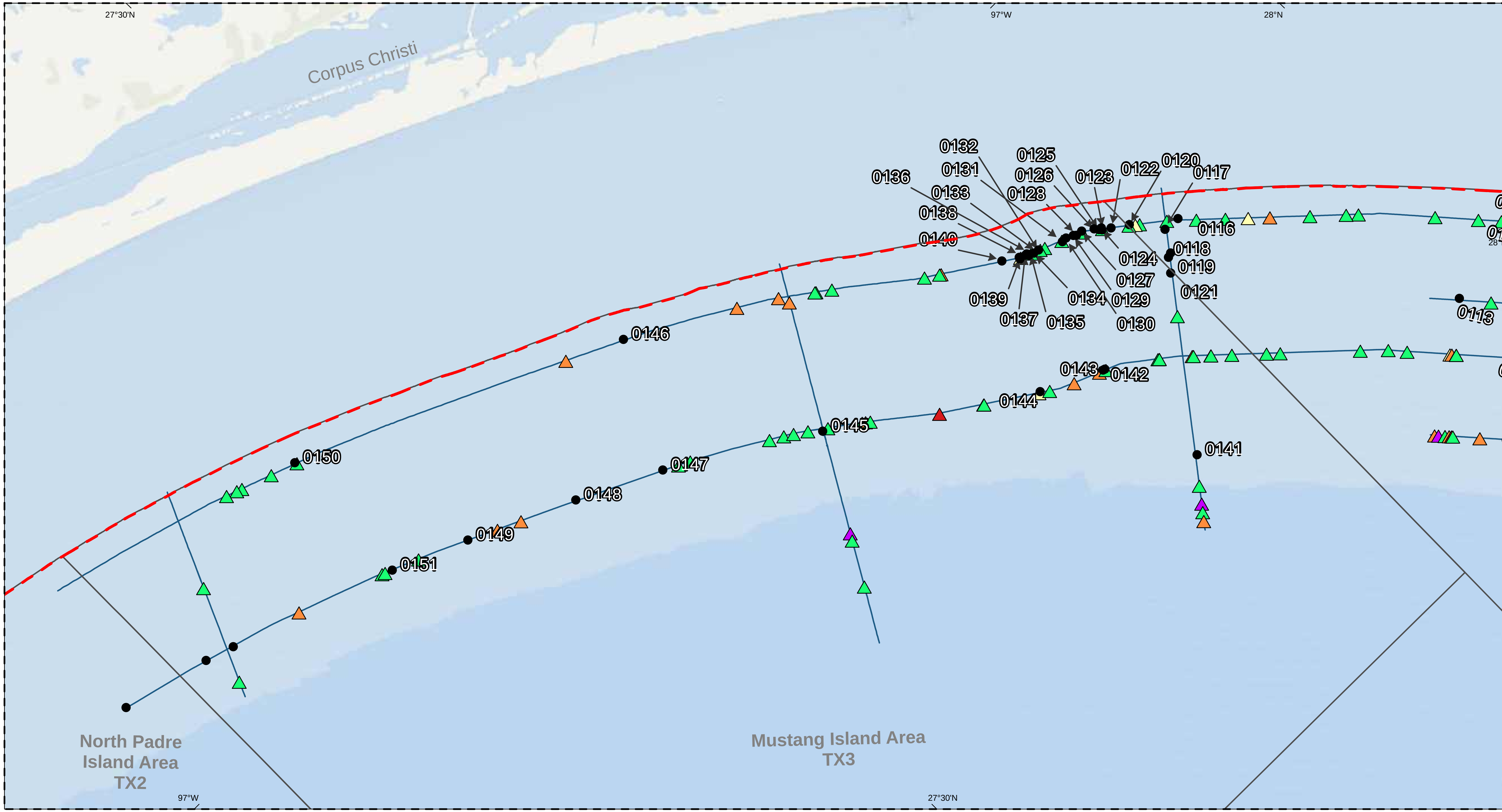


Notes:

1. Background is ERSI's World Ocean basemap.
2. Data collected by APTIM between September 23 and October 11, 2022.

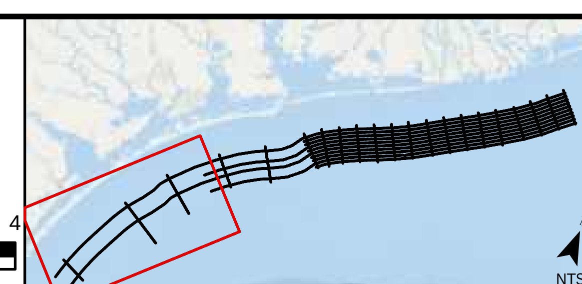
Legend:

- Sidescan Contacts
- As-Run Tracklines
- Federal/State Boundary
- BOEM OCS Protraction Areas

Magnetic Anomalies Amplitude (nT)

- 50 - 50
- 51 - 100
- 101 - 500
- 501 - 1000
- 1001 +

0 1 2 4
Miles



Title:
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Sidescan Sonar Contacts and Magnetometer Anomalies

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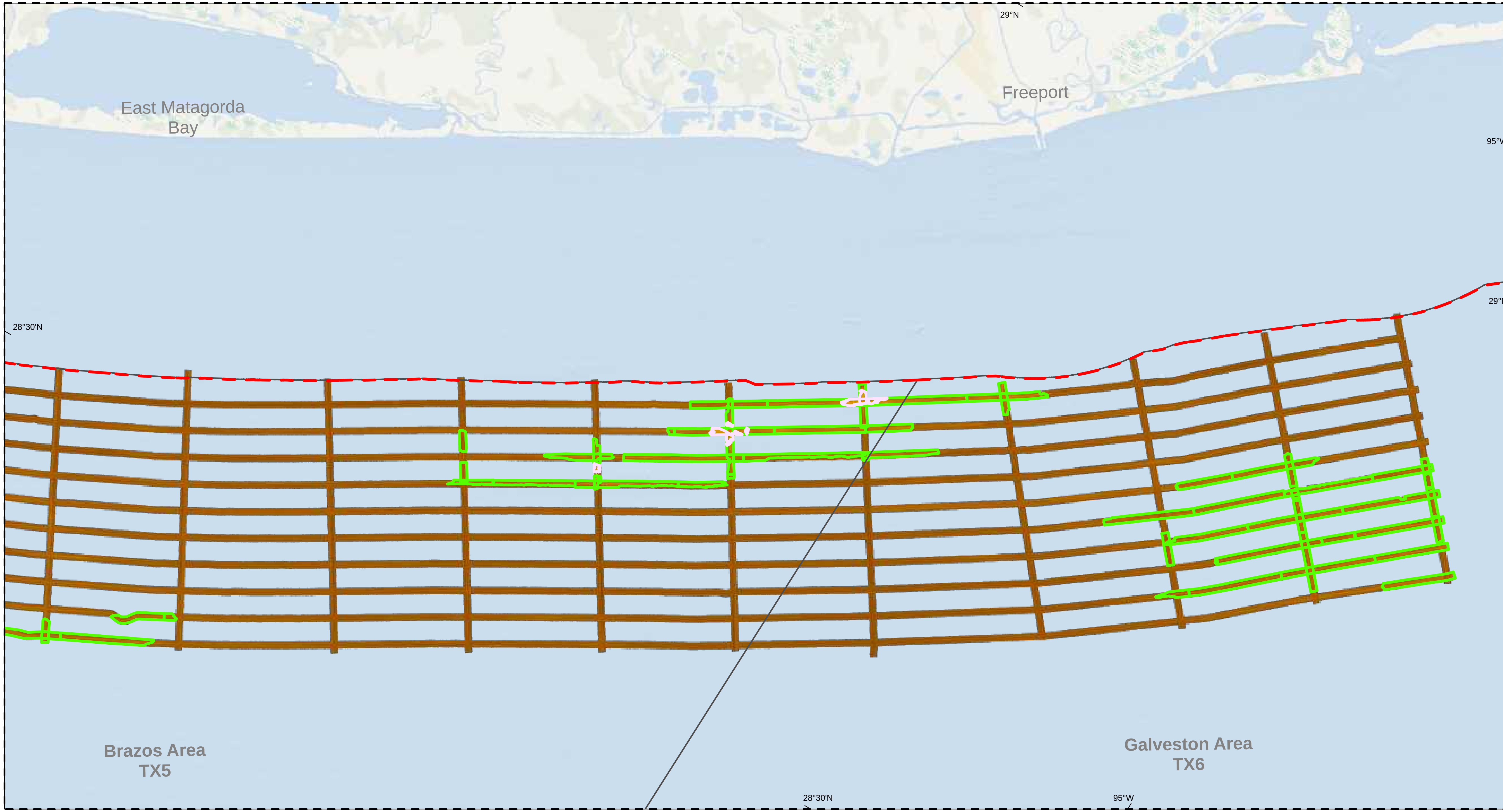
Date: 04/10/2024	Drawn By: PB	Commission No.:631021647	Appendix C Figure: 3

Appendix D: Sidescan Sonar Mosaic/Digitizations Map



Notes:

1. Background is ERSI's World Ocean basemap.
2. Data collected by APTIM between September 23 and October 11, 2022.

Legend:

- Pock mark field
- Coarse Sand
- Sand
- Federal/State Boundary
- BOEM OCS Protraction Areas

0 1 2 4
Miles

NTS

Title:
Texas General Land Office Central Outer Continental Shelf Sand Source Survey
Sidescan Sonar Mosaic and Digitized Features

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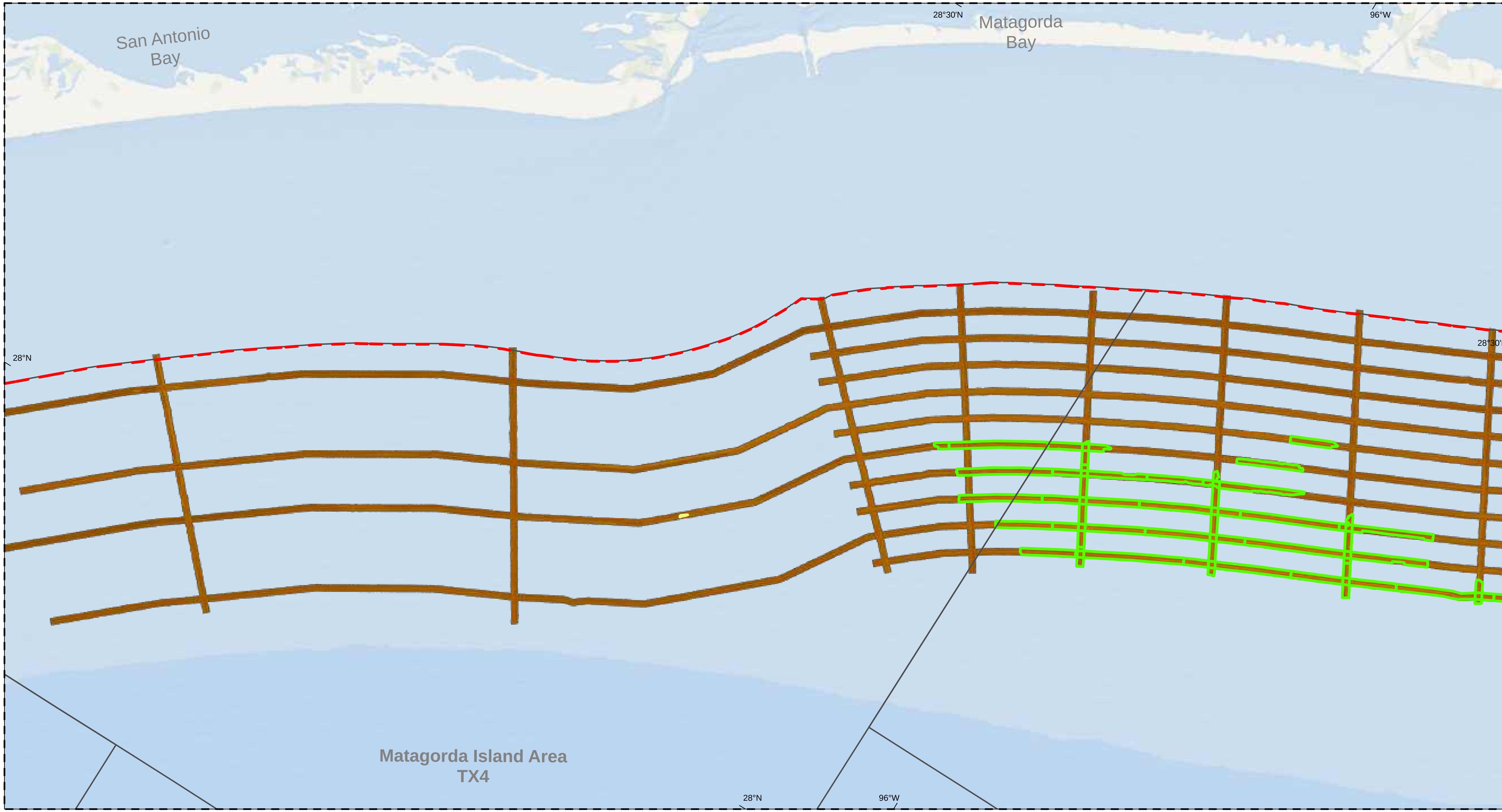


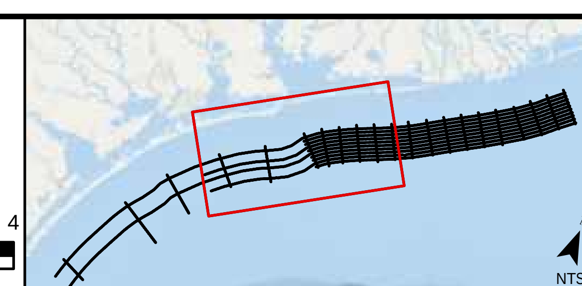
Notes:

1. Background is ERSI's World Ocean basemap.
2. Data collected by APTIM between September 23 and October 11, 2022.

Legend:

- Pock mark field
- Coarse Sand
- Sand
- Federal/State Boundary
- BOEM OCS Protraction Areas

0 1 2 4
Miles



Title:
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Sidescan Sonar Mosaic and Digitized Features

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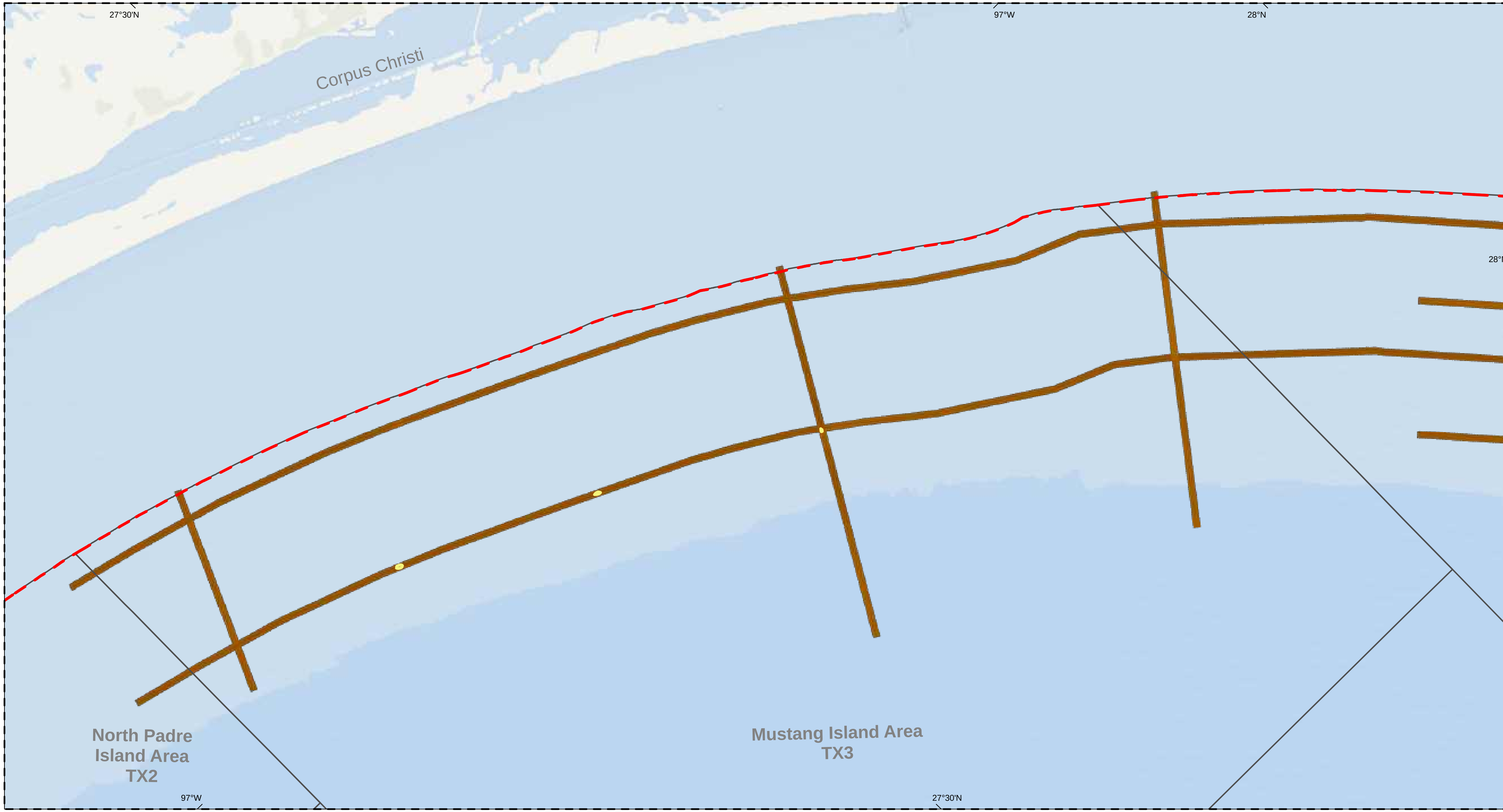


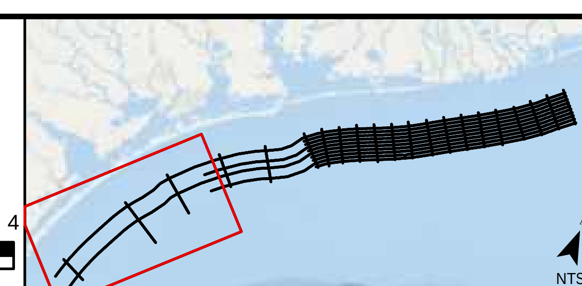
Notes:

1. Background is ERSI's World Ocean basemap.
2. Data collected by APTIM between September 23 and October 11, 2022.

Legend:

- Pock mark field
- Coarse Sand
- Sand
- Federal/State Boundary
- BOEM OCS Protraction Areas

0 1 2 4
Miles



Title:
Texas General Land Office Central Outer Continental Shelf Sand Source Survey
Sidescan Sonar Mosaic and Digitized Features

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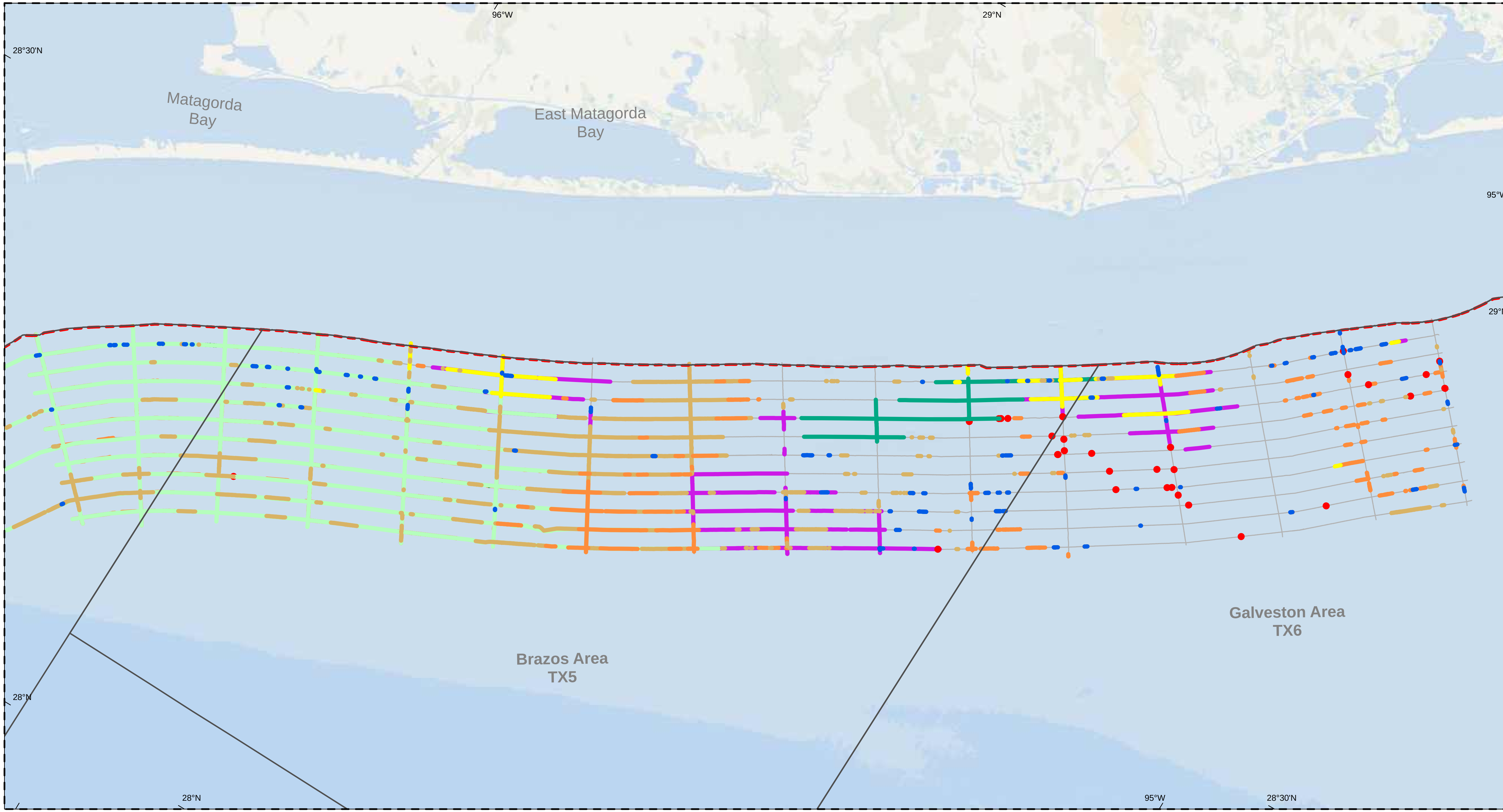
Appendix E: Seismic Maps (Features, Deposits, and Ravinement Isopach)



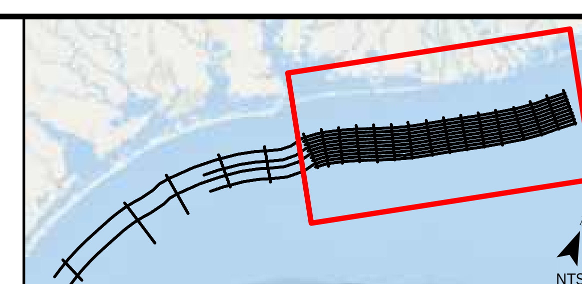
Notes:

1. Background is ERSI's World Ocean basemap.
2. Data collected by APTIM between September 23 and October 11, 2022.

Legend:

- As-Run Tracklines
- Localized Features
- Alluvial Delta
- Channel
- Mound
- Shoal
- Undifferentiated Sand feature
- Paleovalley
- Fault
- Texas Mud Blanket
- Federal/State Boundary

0 1 2 4
Miles



Title:
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Seismic Digitized Features

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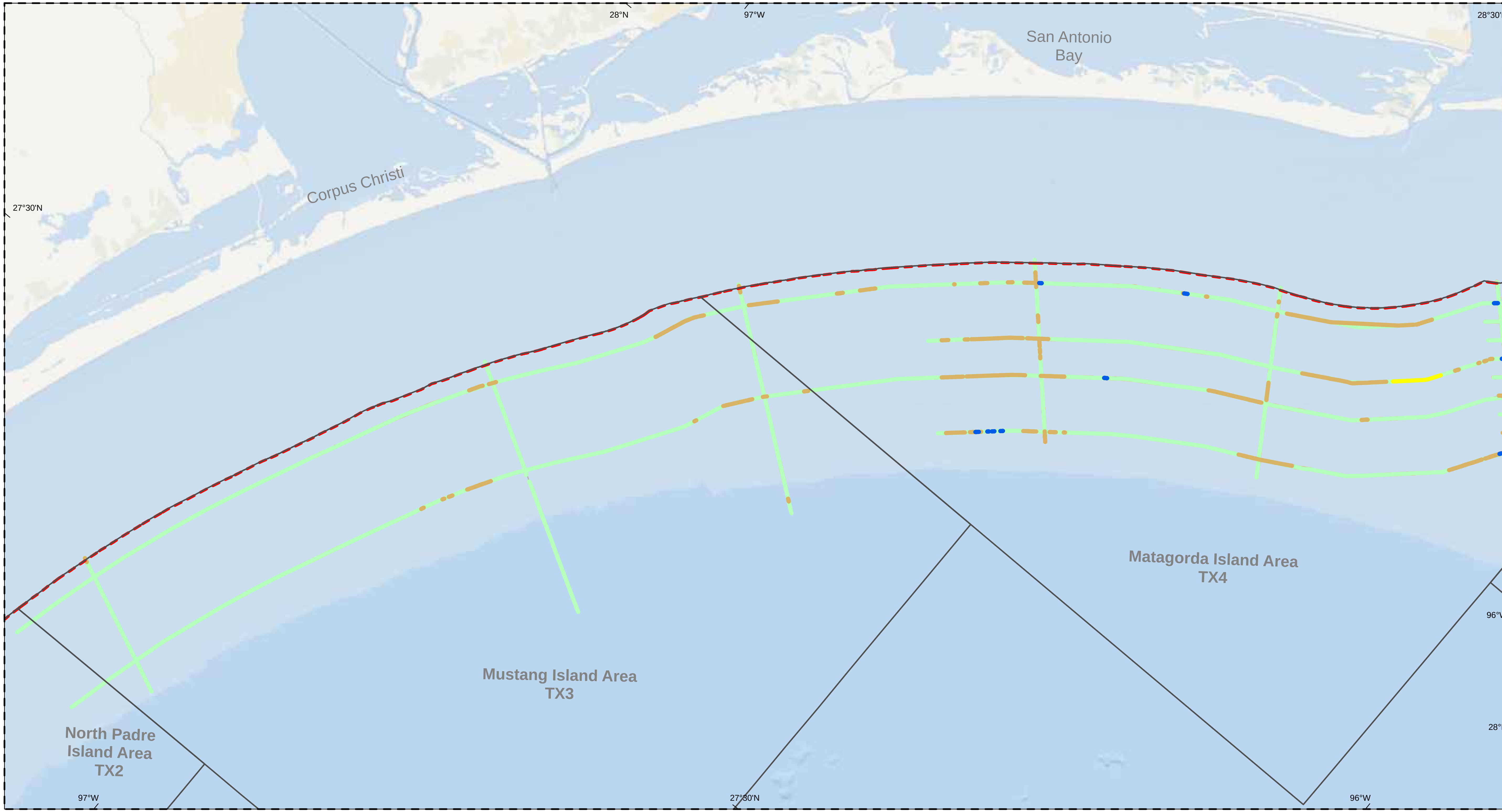
Date: 04/10/2024	Drawn By: AV	Commission No.:631021647	Appendix E Figure: 1a



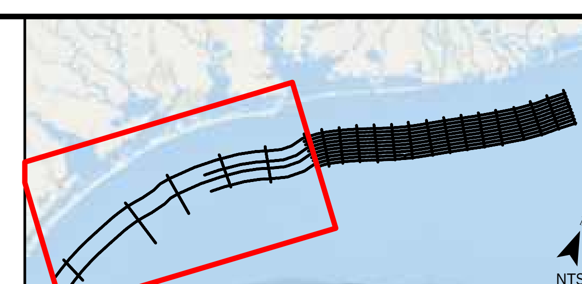
Notes:

1. Background is ERSI's World Ocean basemap.
2. Data collected by APTIM between September 23 and October 11, 2022.

Legend:

- As-Run Tracklines
- Localized Features
- Alluvial Delta
- Channel
- Mound
- Shoal
- Undifferentiated Sand feature
- Paleovalley
- Fault
- Texas Mud Blanket
- Federal/State Boundary

0 1 2 4
Miles



Title:
Texas General Land Office Central Outer Continental Shelf Sand Source Survey
Seismic Digitized Features

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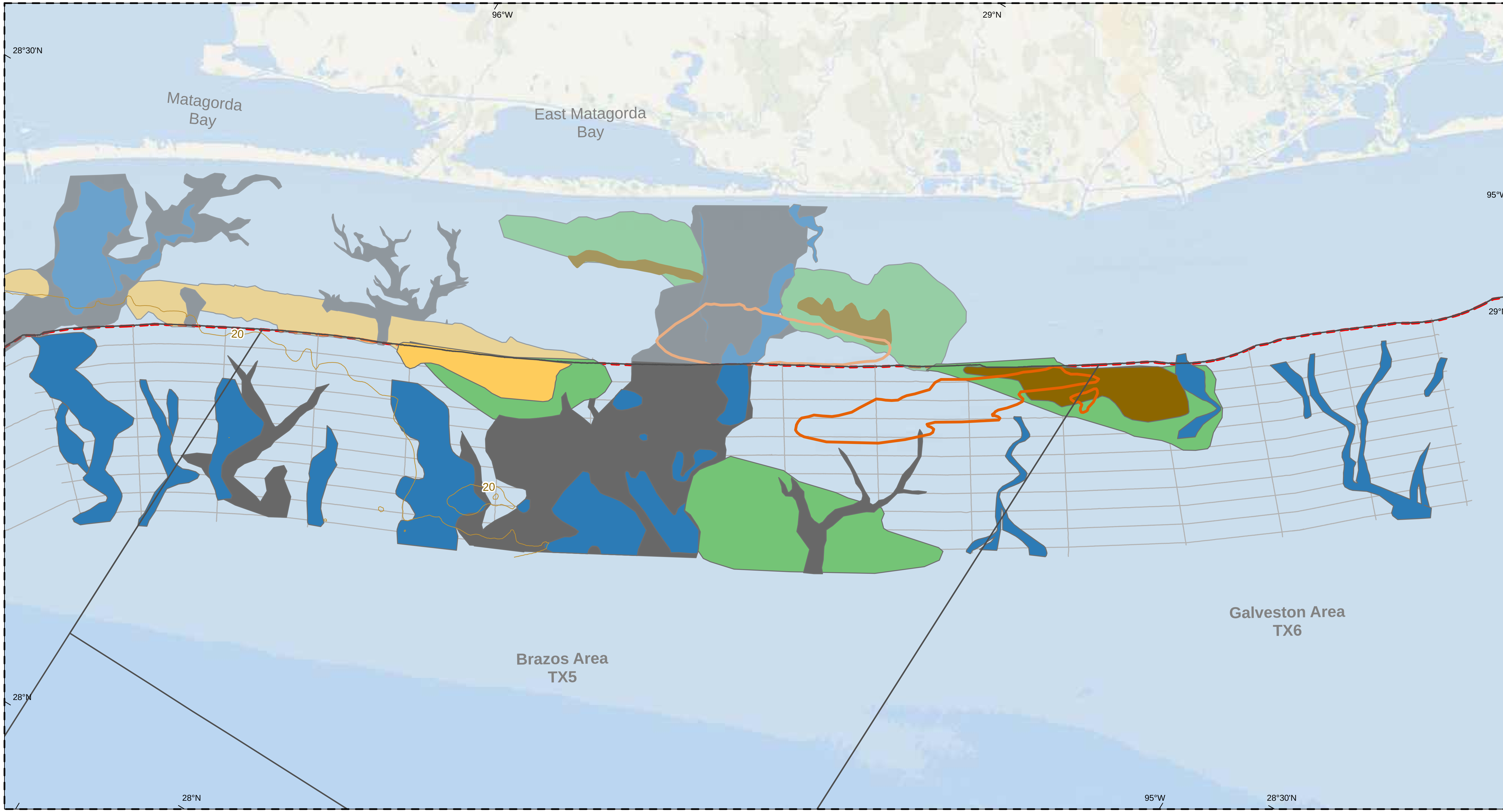
Date: 04/10/2024	Drawn By: AV	Commission No.:631021647	Appendix E Figure: 2a



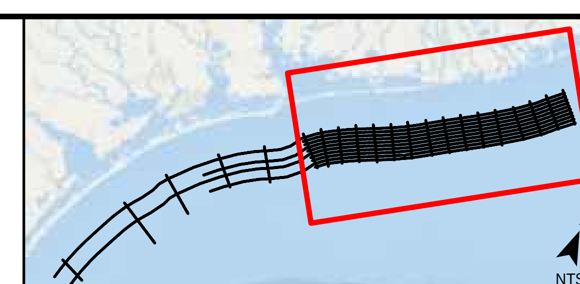
Notes:

1. Background is ERSI's World Ocean basemap.
2. Data collected by APTIM between September 23 and October 11, 2022.
3. Central OCS geologic subsurface features displayed to show continuity.

Legend:

- As-Run Tracklines
- Alluvial-Deltaic Feature
- Undifferentiated Sandy Feature
- Incisional Drainage/Valley
- Alluvial-Deltaic Feature Sandy Subunit
- Channel Belt
- Surfacial Shoal
- Texas Mud Blanket Contour
- Federal/State Boundary
- BOEM OCS Protraction Areas

0 1 2 4
Miles



Title:
Texas General Land Office Central Outer Continental Shelf Sand Source Survey
Geologic Framework Depositional Environments

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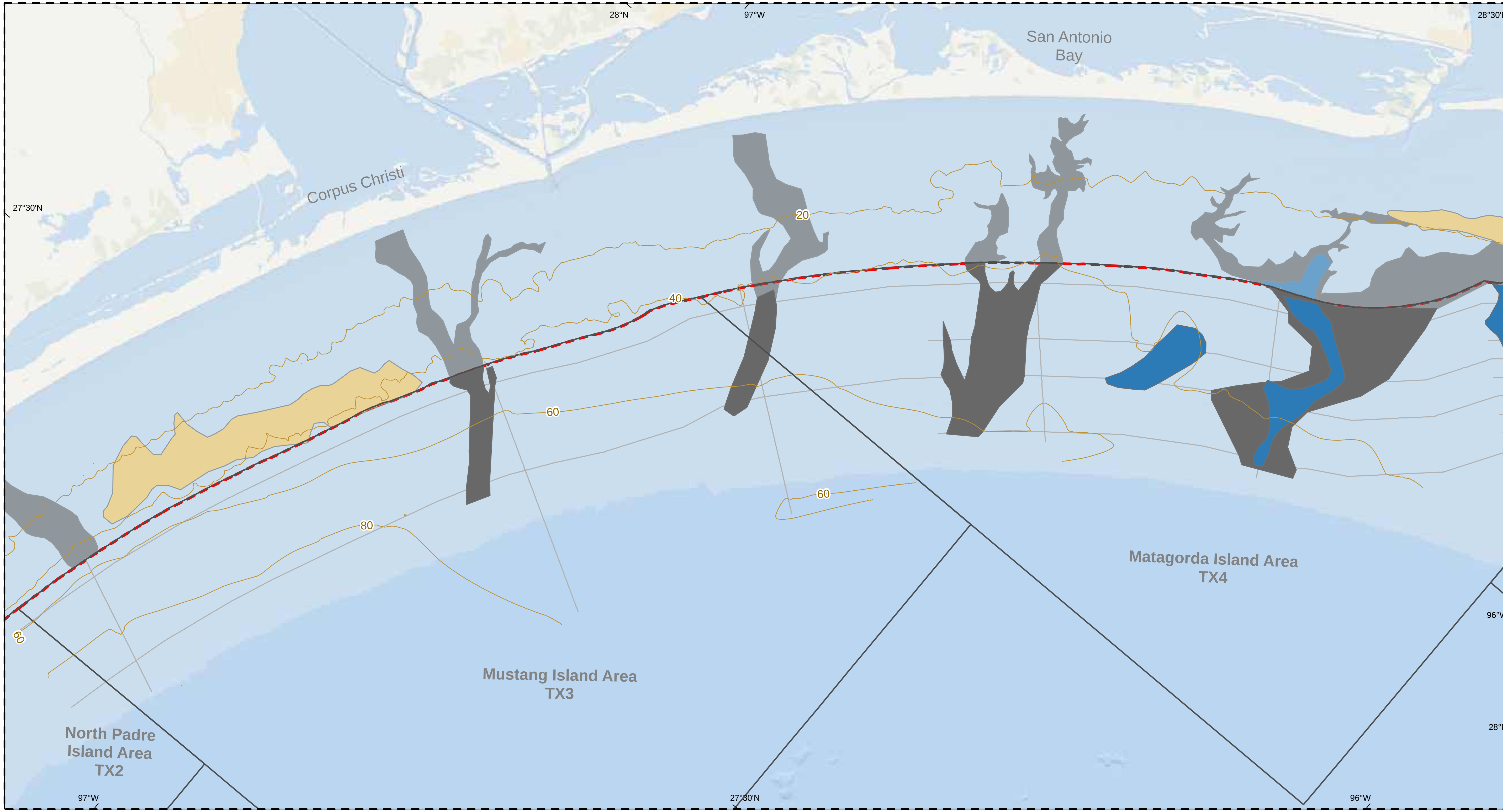
Date: 04/25/2024	Drawn By: AV	Commission No.:631021647	Appendix E Figure: 1b



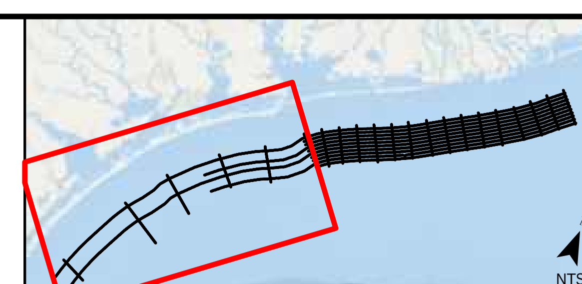
Notes:

1. Background is ERSI's World Ocean basemap.
2. Data collected by APTIM between September 23 and October 11, 2022.
3. Central OCS geologic subsurface features displayed to show continuity.

Legend:

- As-Run Tracklines
- Alluvial-Deltaic Feature
- Undifferentiated Sandy Feature
- Incisional Drainage/Valley
- Alluvial-Deltaic Feature Sandy Subunit
- Channel Belt
- Surfacial Shoal
- Texas Mud Blanket Contour
- Federal/State Boundary
- BOEM OCS Protraction Areas

0 1 2 4
Miles



Title:
Texas General Land Office Central Outer Continental Shelf Sand Source Survey
Geologic Framework Depositional Environments

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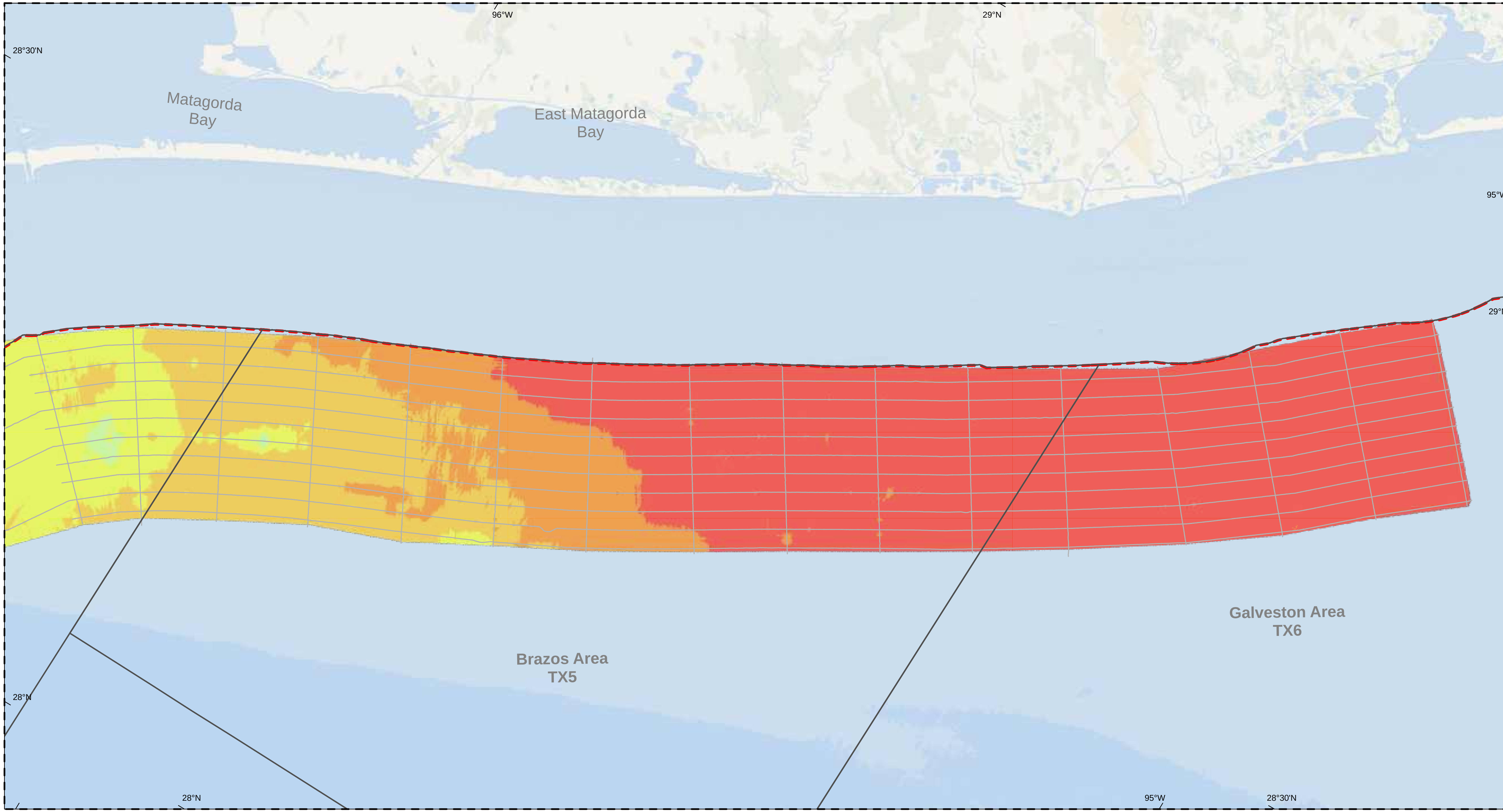


Notes:

1. Background is ERSI's World Ocean basemap.
2. Data collected by APTIM between September 23 and October 11, 2022.

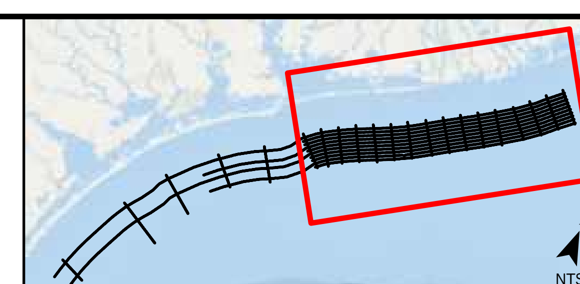
Legend:

- As-Run Tracklines
- Federal/State Boundary
- BOEM OCS Protraction Areas

Ravinement Thickness (ft)

- 0 - 5
- 6 - 16
- 17 - 27
- 28 - 37
- 38 - 48
- 49 - 59
- 60 - 70
- 71 - 81
- 82 - 92
- 93 - 102

0 1 2 4 Miles



Title: Texas General Land Office Central Outer Continental Shelf Sand Source Survey

Seismic Ravinement Surface

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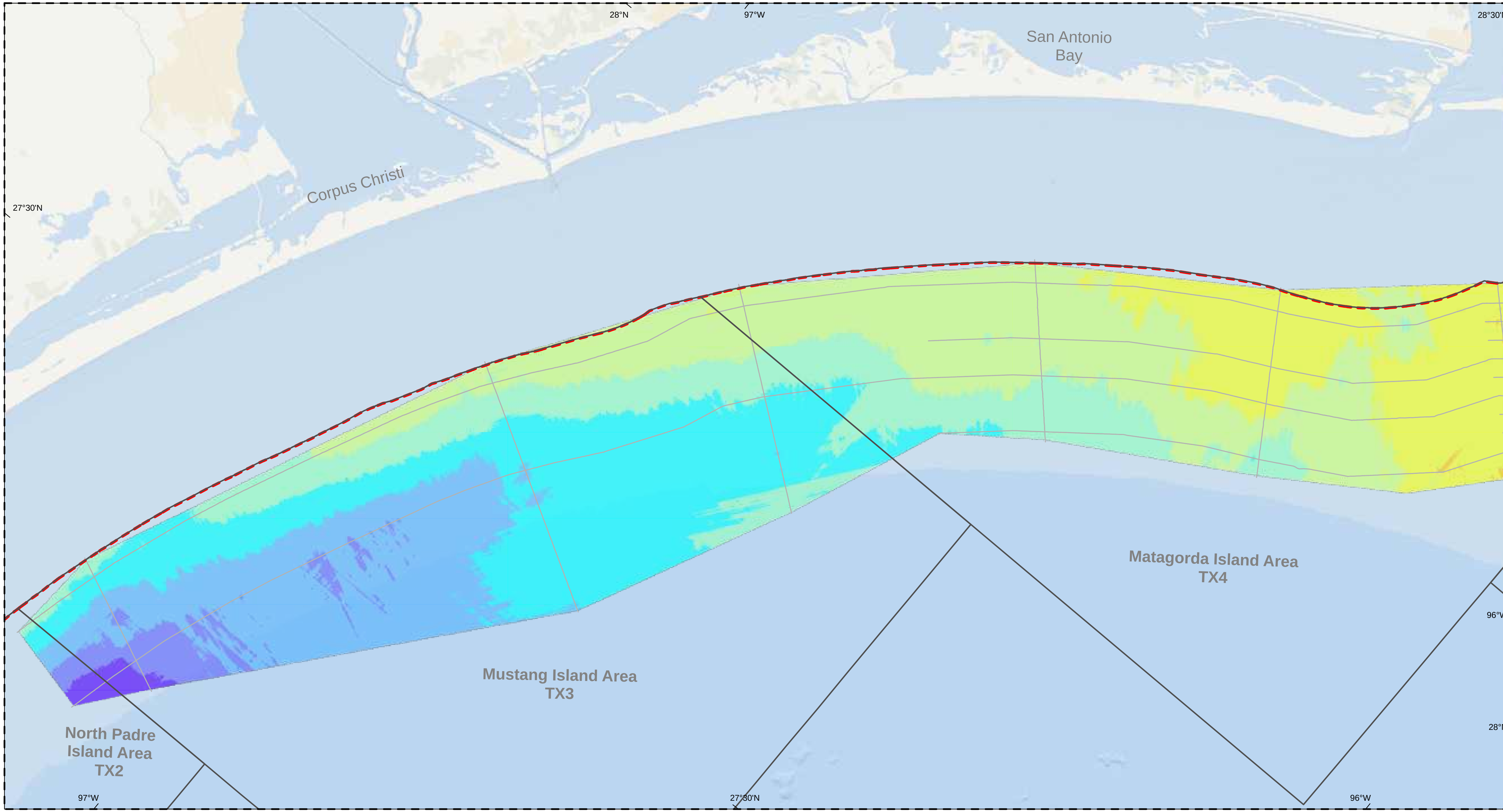
Date: 04/10/2024	Drawn By: AV	Commission No.:631021647	Appendix E Figure: 1c



Notes:

1. Background is ERSI's World Ocean basemap.
2. Data collected by APTIM between September 23 and October 11, 2022.

Legend:

- As-Run Tracklines
- Federal/State Boundary
- BOEM OCS Protraction Areas

Ravinement Thickness (ft)

- 0 - 5
- 6 - 16
- 17 - 27
- 28 - 37
- 38 - 48
- 49 - 59
- 60 - 70
- 71 - 81
- 82 - 92
- 93 - 102

0 1 2 4
Miles

NTS

Title:

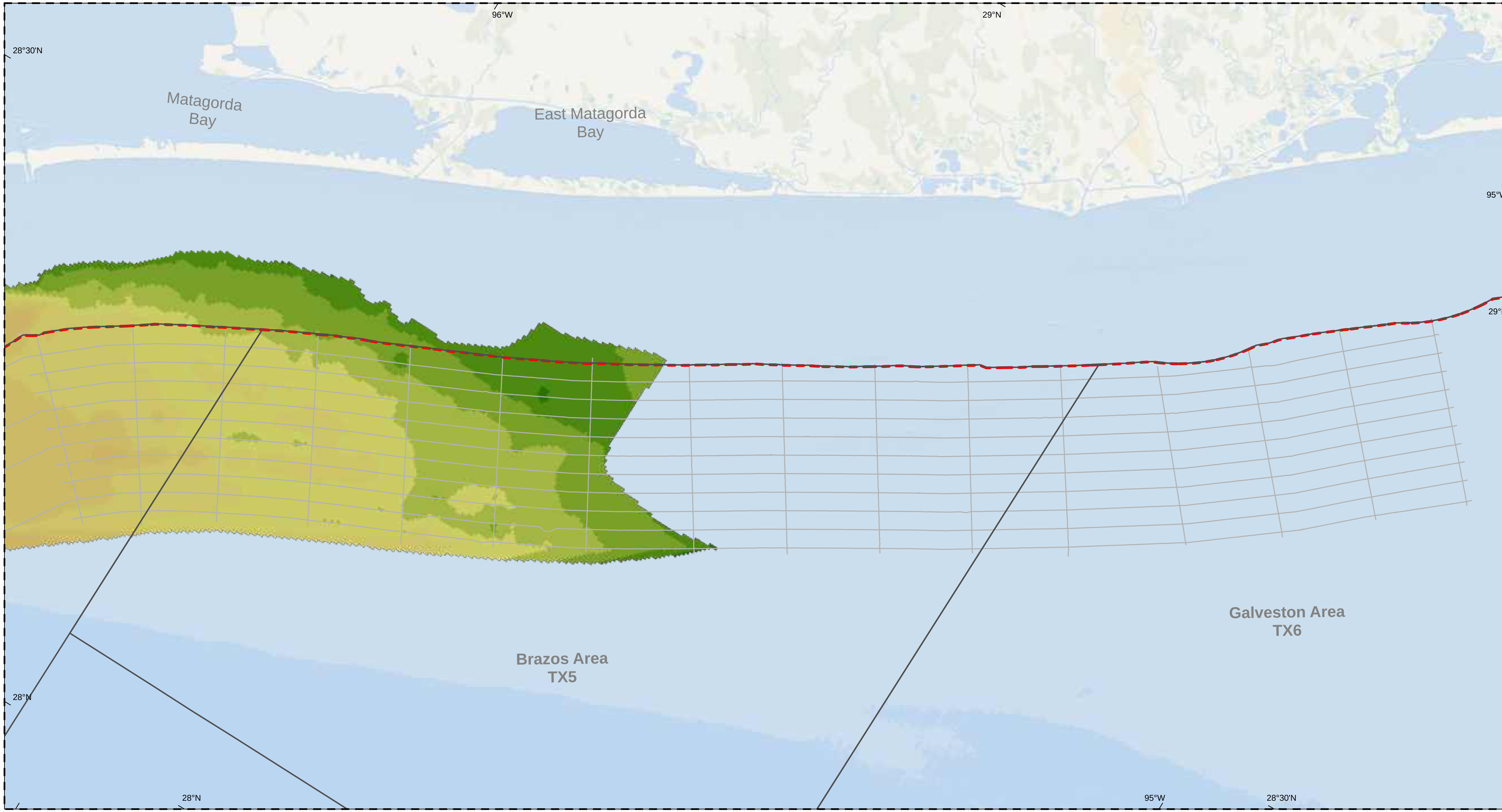
Texas General Land Office Central Outer Continental Shelf Sand Source Survey

Seismic Ravinement Surface

APTIM

725 US Highway 301 S
Tampa, FL 33619
APTIM.com

Date: 04/10/2024	Drawn By: AV	Commission No.:631021647	Appendix E Figure: 2c



Notes:

1. Background is ERSI's World Ocean basemap.
2. Data collected by APTIM between September 23 and October 11, 2022.

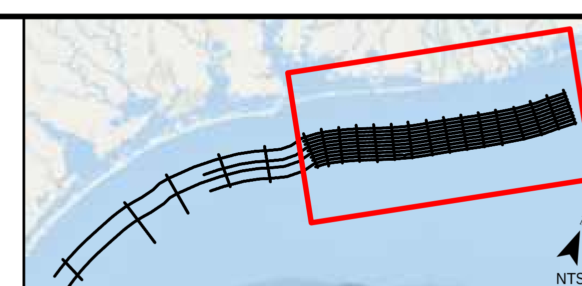
Legend:

As-Run Tracklines
Federal/State Boundary
BOEM OCS Protraction Areas

Texas Mud Blanket Thickness (ft)

3 - 5	31 - 35	61 - 65	91 - 95
6 - 10	36 - 40	66 - 70	96 - 100
11 - 15	41 - 45	71 - 75	101 - 105
16 - 20	46 - 50	76 - 80	
21 - 25	51 - 55	81 - 85	
26 - 30	56 - 60	86 - 90	

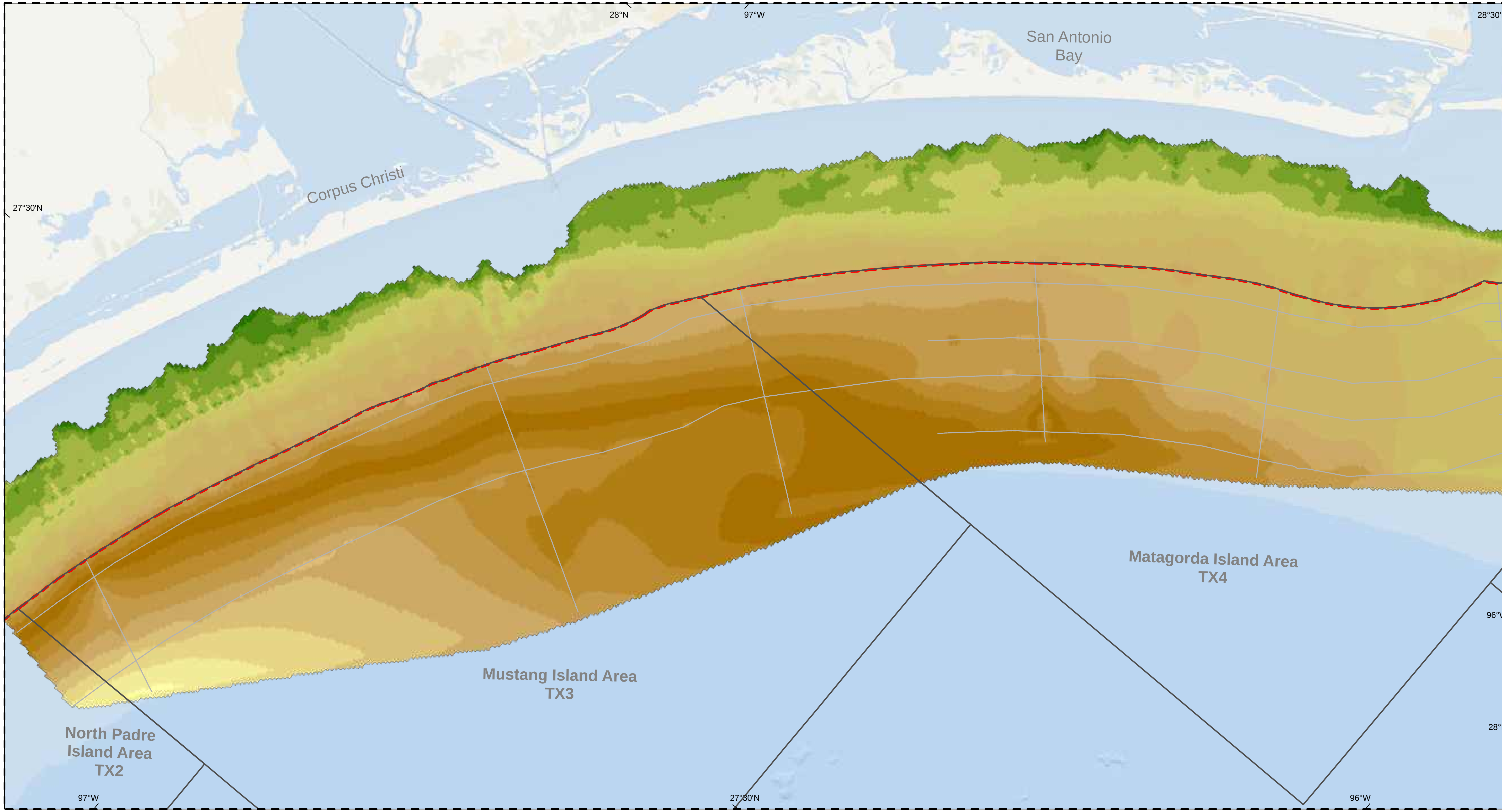
0 1 2 4
Miles



Title:
Texas General Land Office Central Outer Continental Shelf Sand Source Survey
Texas Mud Blanket Surface

APTIM
725 US Highway 301 S
Tampa, FL 33619
APTIM.com

Date: 04/10/2024	Drawn By: AV	Commission No.:631021647	Appendix E Figure: 1d



Notes:

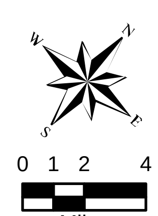
1. Background is ERSI's World Ocean basemap.
2. Data collected by APTIM between September 23 and October 11, 2022.

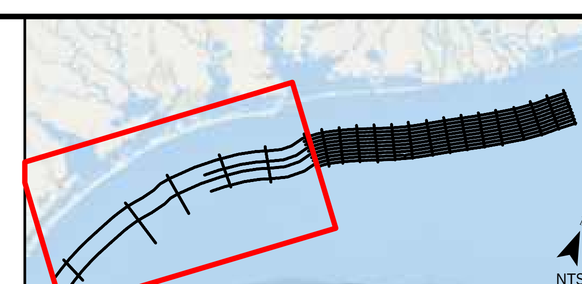
Legend:

- As-Run Tracklines
- Federal/State Boundary
- BOEM OCS Protraction Areas

Texas Mud Blanket Thickness (ft)

3 - 5	31 - 35	61 - 65	91 - 95
6 - 10	36 - 40	66 - 70	96 - 100
11 - 15	41 - 45	71 - 75	101 - 105
16 - 20	46 - 50	76 - 80	
21 - 25	51 - 55	81 - 85	
26 - 30	56 - 60	86 - 90	

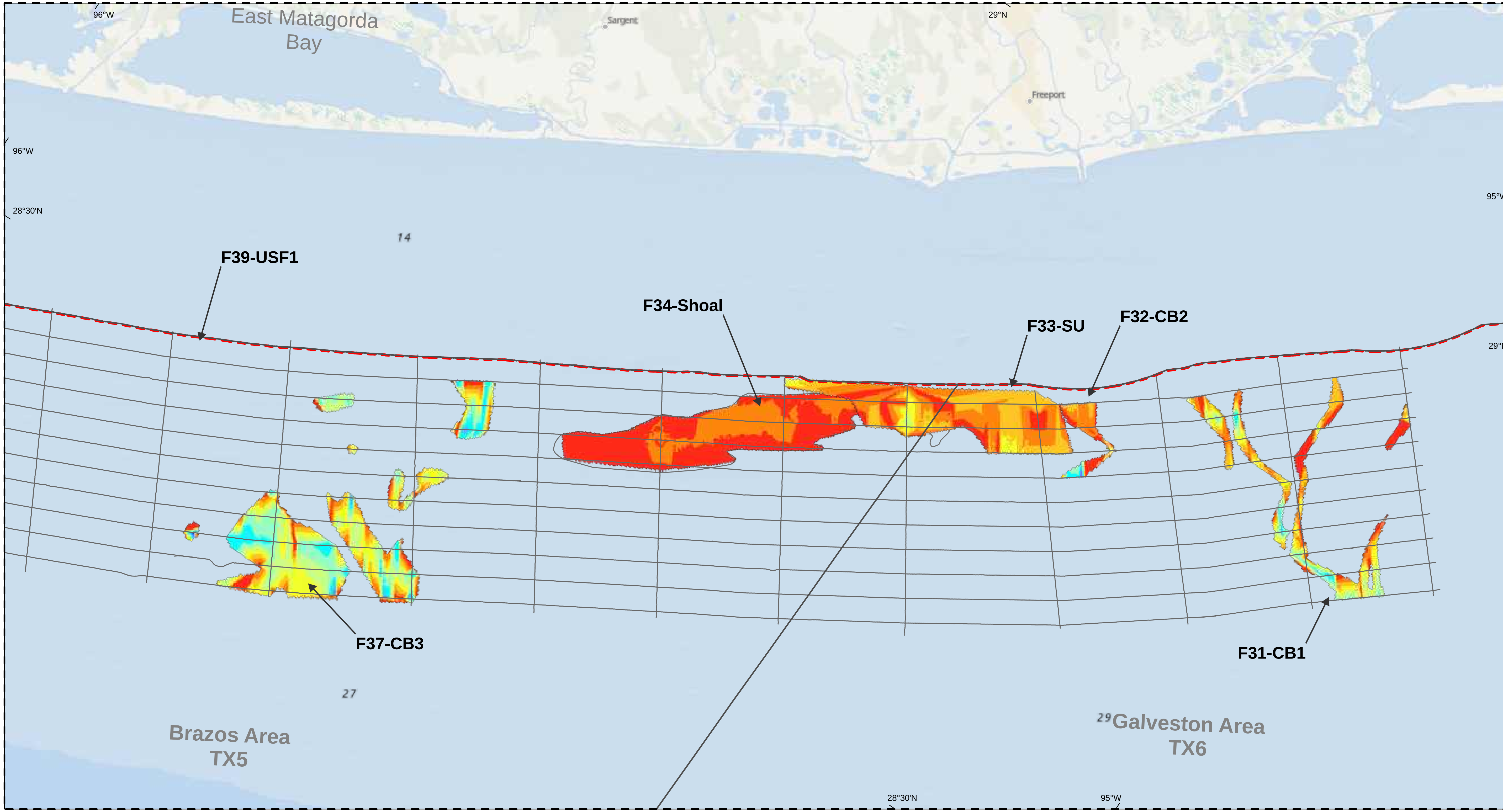




Title:
Texas General Land Office Central Outer Continental Shelf Sand Source Survey
Texas Mud Blanket Surface

APTIM
725 US Highway 301 S
Tampa, FL 33619
APTIM.com

Date: 04/10/2024	Drawn By: AV	Commission No.:631021647	Appendix E Figure: 2d



Notes:

1. Background is ERSI's World Ocean basemap.
2. Data collected by APTIM between September 23 and October 11, 2022.

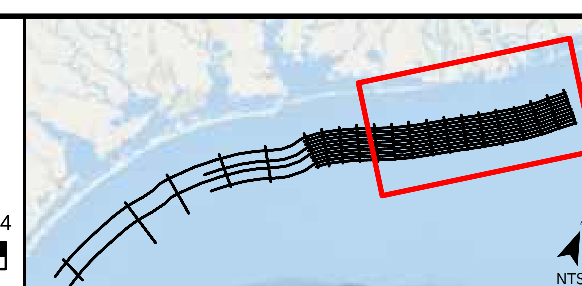
Legend:

- As-Run Tracklines
- Federal/State Boundary
- BOEM OCS Protraction Areas

Feature Thickness (ft)

1 - 5	26 - 30
6 - 10	31 - 35
11 - 15	36 - 40
16 - 20	41 - 45
21 - 25	46 - 50

0 1 2 4
Miles



Title:
Texas General Land Office Central Outer Continental Shelf Sand Source Survey
Seismic Feature Thickness

APTIM
725 US Highway 301 S
Tampa, FL 33619
APTIM.com

Date: 04/30/2024	Drawn By: AV	Commission No.:631021647	Appendix E Figure: 1e

Appendix F: UTIG Processing of Chirp Data in Central Coast OCS Regions 2 + 3

BOEM Cooperative Agreement Number M21AC00020

GLO Contract No. 22-187-000-D575

University of Texas Institute for Geophysics

Processing of Chirp Data in Central Coast Outer Continental Shelf: Addendum to APTIM/TWIG GLO Contract No. 22-004-003

Performance Period: March 1, 2023 - November 30, 2023

Lead Agency:
University of Texas Institute for Geophysics

Recipient Point of Contact Info:

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November 30, 2023

Overview

Objectives and Methods

The University of Texas Institute for Geophysics (UTIG) was separately contracted to provide high-level processing for the Central Coast Outer Continetal Shelf (OCS) chirp data collected by APTIM and TWIG under their contract. A robust workflow for processing chirp data to maximize image quality and interpretability has been developed at the University of Texas Institute for Geophysics (Saustrup et al., 2019). Processing steps include: extracting full-waveform and envelope records from the JSF files and converting to SEG-Y, towfish depth correction, heave filtering, trace equalization, water column muting, secondary deconvolution (to sharpen image), and layback correction. In this case, however, a layback correction was applied by APTIM in the topside computer during the survey, and so was not a consideration in our processing. In addition, because the navigation are in State Plane Feet coordinates, which will be difficult for many to use, we have converted those values to WGS84 latitude and longitude, and placed those values in a separate location in the SEG-Y header (bytes 81-83 for longitude, and 84-87 for latitude).

All processing steps, except secondary deconvolution, are applied to both full-waveform and envelope chirp records. Secondary deconvolution cannot be applied to envelope records because they are positive value only. Envelope records also differ from full waveform in that the former are a filtered version of the latter. We generally find that full waveform records are superior for visualizing fine details of the imaged stratigraphy, whereas envelope records are superior for visualizing the bigger picture.

Results

Figure 1 displays an example of pre- and post-processed full-waveform data from Line 210, crossing a buried channel-form feature that likely includes both estuarine and tidal facies filling what we presume to be a paleo-river channel that incised the surrounding Pleistocene strata during the Last Glacial Maximum. In the pre-processed data (Figure 1A), the record is strongly affected by boat heave, which has two significant effects: (1) the reflectors artificially rise up and down sinusoidally with the changing altitude above the seafloor, and (2) the amplitudes of the records are modulated by the changing pitch on the pole-mounted instrument, which alters the angle of the outgoing acoustic beam with respect to horizontal. The processed image (Figure 1B) smooths out the heave artifact by filtering the seafloor arrival time, evens out amplitude variations using a trace equalization, and sharpens the individual reflections throughout. The latter effect is particularly important in delineating the numerous dipping reflections within the estuarine fill units of the fluvial channel as well as the complex strata within the tidal channel.

Pre- and post-processed envelope data from the same section are shown in Figure 2. Careful comparison of the full-waveform and envelope records demonstrates that the former delineate a higher density of individual reflections than the latter. This improved resolution is an important consideration in particular for core/seismic integration.

Our processing efforts encountered two significant challenges. The first was that the GPS time was not recorded in the JSF headers, as it normally would be on an Edgetech topside computer. The reason for this is unknown; it is the first time we have encountered this issue and it took us many weeks to diagnose it. The time stamp on each ping is a small but important component of the initial stages of the processing work, and without it the remainder of the workflow fails in ways that do not obviously point to the root cause. There are, in fact, two time stamps usually recorded in the JSF header: the GPS and the computer clock. The GPS clock is the more accurate time record, and so is preferred when it is available to use in the SEG-Y header; it is our default whenever we run the processing workflow. Otherwise, the computer clock can also be used and can be sufficient for processing purposes. Fortunately, once the issue was diagnosed, the cure turned out to be a simple switch of a flag in our workflow to use the computer clock.

The second significant challenge, and a fairly common one for chirp surveys, is that the signal-to-noise ratio (SNR) for the seafloor reflection is reduced in places to the point where our bottom-tracking algorithm fails. Precisely locating the seafloor reflection is a critical step in the workflow, providing the reference against which we can filter heave-created fluctuations, as well as for aligning pings for estimating a pseudo-source for secondary deconvolution based on the average seafloor reflection waveform. Seafloor SNR can be reduced for two primary reasons: (1) the seafloor sediments are very soft, forming a low impedance contrast at the water/sediment interface, or (2) the sea surface conditions are rough, causing the chirp towfish to both heave and pitch, with the latter motion resulting in the acoustic beam being oriented away from vertical, thus reducing the acoustic energy directed downward. Our bottom picking algorithm, described in Saustrup et al. (2019), is an iterative process applied to the full-waveform records designed to prevent bottom picks that stray too far from surrounding picks, and includes several tunable parameters to help find the best amplitude and depth thresholds to minimize picking errors. Despite our best efforts, however, there are inevitably a few locations where the bottom tracking is lost for some set of pings before bottom tracking is reestablished. An example of these artifacts is shown in Figure 3.

Conclusions

With the exception of a limited number of unavoidable artifacts, the processed chirp data provide exceptional images of the complex shallow stratigraphy in the Central Coast OCS. In particular we note the presence of a buried paleo-valley and a number of potential features, for instance tidal channels, illuminated on the full waveform data that are worthy of further investigation for sand resources.

Cooperative Agreement Outputs and Deliverables

The principal deliverable for this project is a set of SEG-Y files containing the processed full-waveform and envelop chirp lines from the Central Coast OCS survey, conducted by APTIM and TWIG. These data files are accompanied by a metadata file. In addition, UTIG will archive these data to the publicly accessible Academic Seismic Portal, a part of the Marine Geophysical Data Center funded by the National Science Foundation.

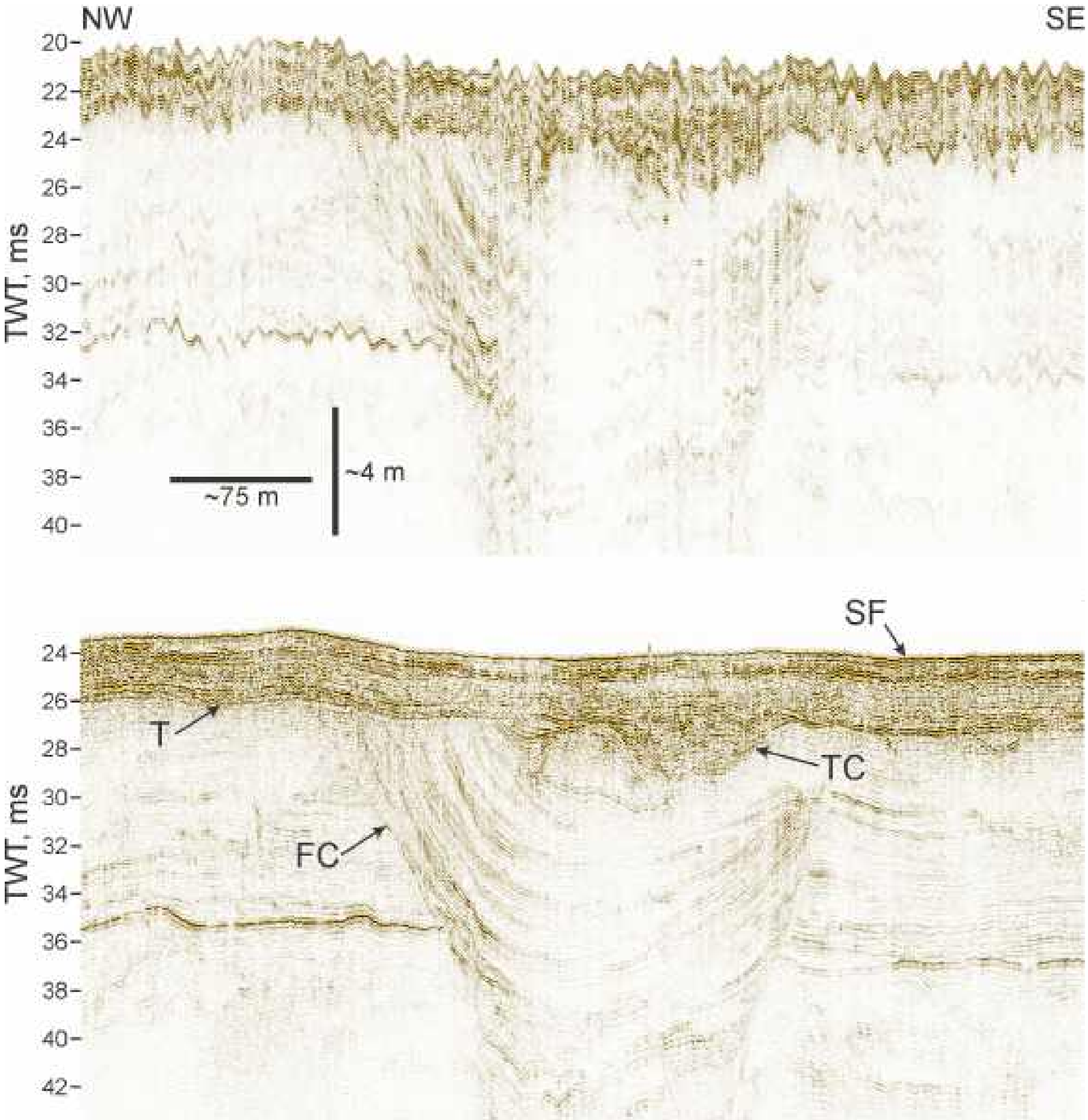

Figure1. Before- and after-processing example of full-waveform chirp records
Image of unprocessed data (top) is degraded by heave artifacts and variations in amplitude. Processed data (below) removes heave artifact, evens-out amplitudes, and sharpens reflectors. Stratigraphic features include a buried fluvial channel (FC) filled by estuarine sediments, topped by a likely tidal channel (TC) with tidal fill sediments, and capped by the erosional transgressive ravinement (T). Sediments between T and the seafloor were deposited in an open marine setting. Data are from Line 210.

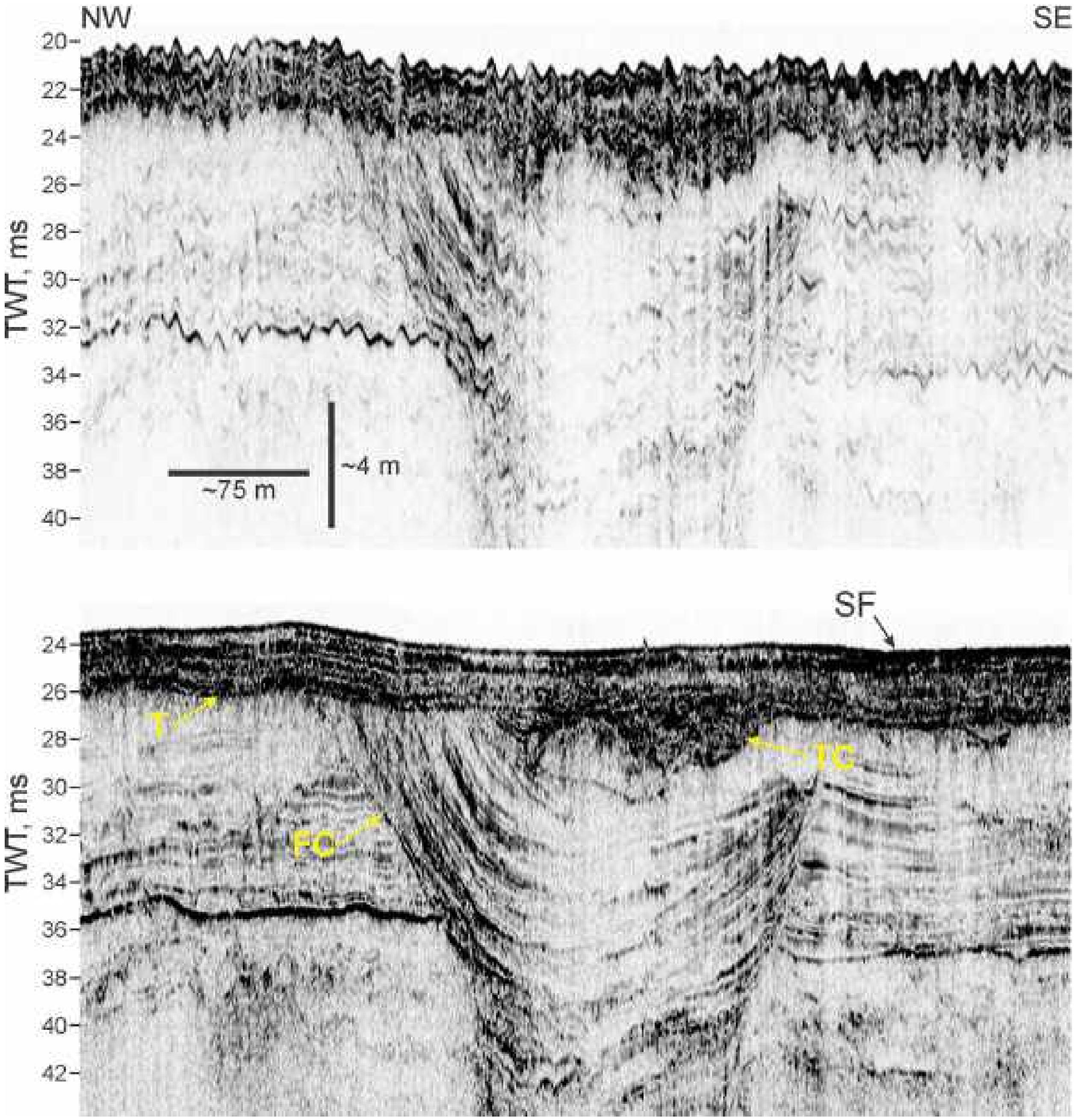

Figure 2. Before- and after-processing example of envelope chirp records
Data displayed are from the same data section as in Figure 1. The same processing steps are applied with the exception of secondary deconvolution. Processed full waveform records display improved resolution of reflectors, which is particularly noticeable on the steeply-dipping reflectors of the estuarine fill within the fluvial channel (FC), as well as in the fill strata within the tidal channel (TC).

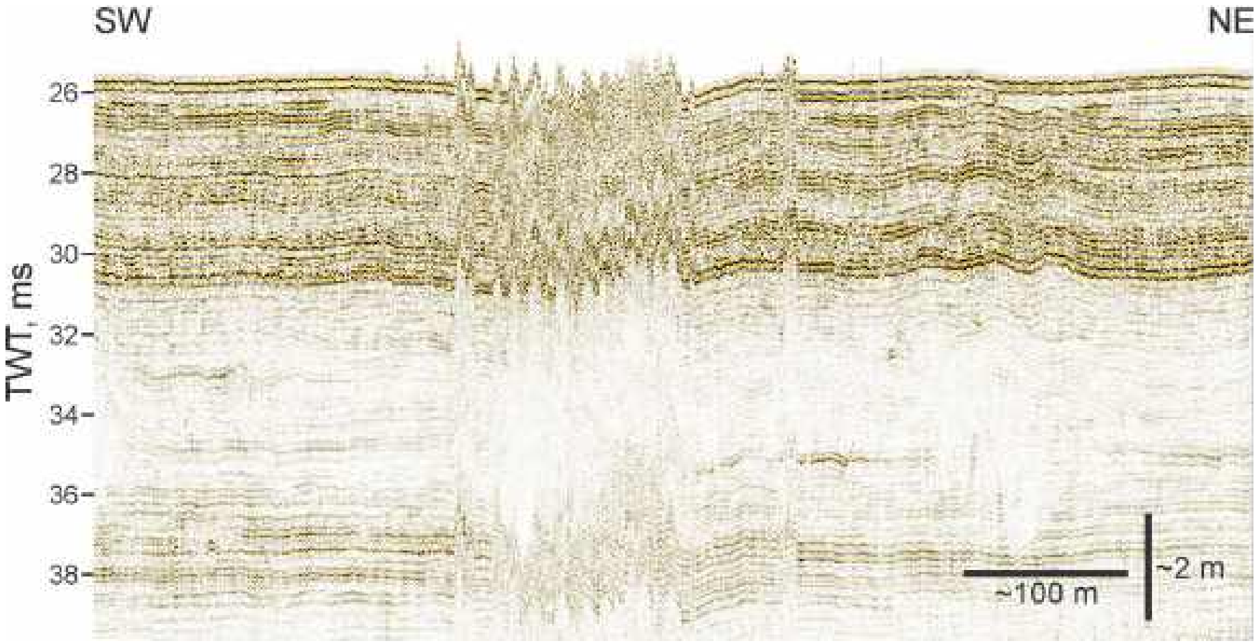

Figure 3. Example of artifacts in processed full-waveform record.
Image displays artifacts caused by failure to detect the seafloor arrival. Data are from Line 106A.

Appendix G: MMIS Database (Digital only)