Deepwater Port License Application for the
Texas Gulf Terminals Project

Volume II – Environmental Evaluation (Public)

Section 10:
Geological Resources

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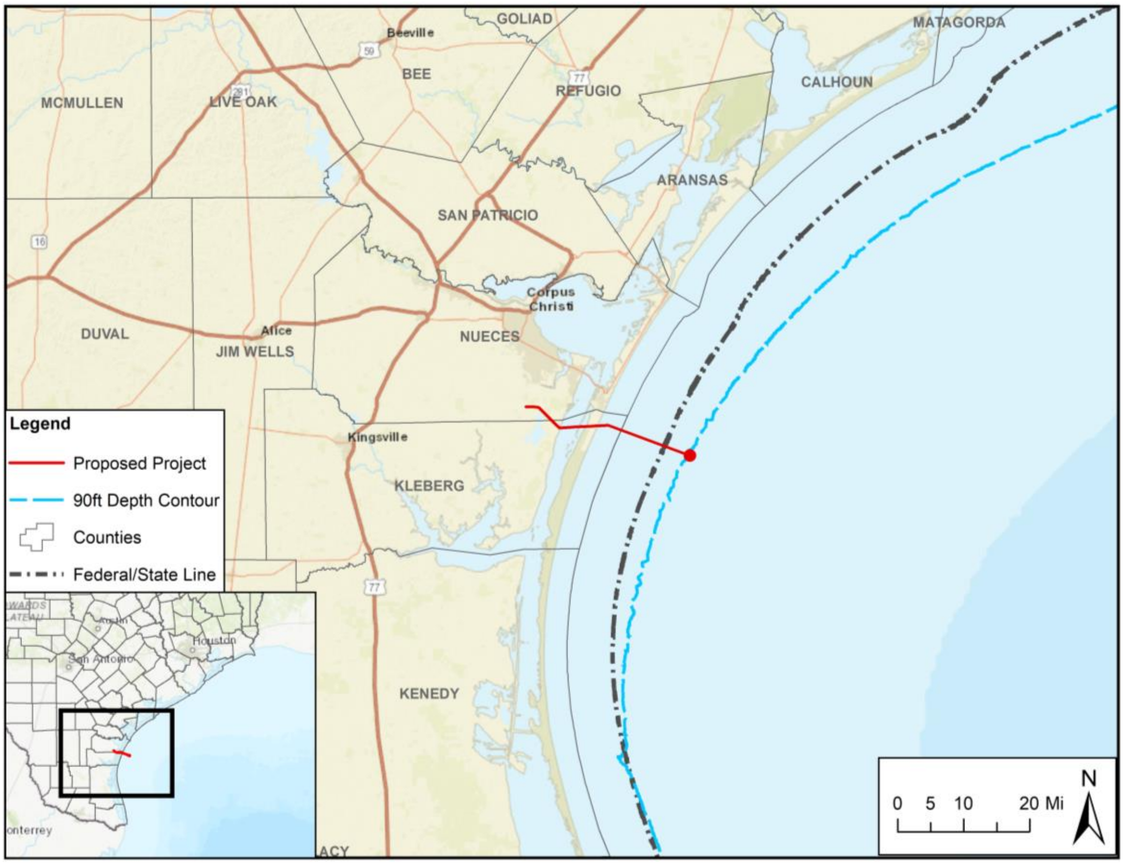
ACRONYMS AND ABBREVIATIONS

°	degrees
ac	acre
Applicant	Texas Gulf Terminals Inc.
bml	below mud line
BMP	best management practices
BOEM	Bureau of Ocean Energy Management
bph	barrels per hour
BSEE	Bureau of Safety and Environmental Enforcement
CALM	Catenary Anchor Leg Mooring
CFR	Code of Federal Regulations
DWP	deepwater port
DWPA	Deepwater Port Act of 1974, as amended
DWPL	Deepwater Port License
e.g.	exempli gratia [Latin for '*for example*']
EO	Executive Order
et al.	et alia [Latin for *'and others'*]
FEMA	Federal Emergency Management Agency
ft.	feet
GLO	General Land Office
GMTI	Geo-Marine Technology, Inc.
GOM	Gulf of Mexico
ha	hectare
HDD	Horizontal Directional Drilling
km	kilometer
m	meter
MARAD	Maritime Administration
MHT	mean high tide
mi	miles
mya	million years ago
NEPA	National Environmental Policy Act
nm	nautical miles
NTL	Notices to Lessees
OCS	Outer Continental Shelf
OCSLA	Outer Continental Shelf Land Act
OSTF	onshore storage terminal facility
PLEM	pipeline end manifold
Project	Texas Gulf Terminals Project
ROW	right of way
SPM	single point mooring
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
U.S.	United States [of America]
USCG	United States Coast Guard
USDA	United States Department of Agriculture
V-Zone	high-velocity zone

PROJECT OVERVIEW

Texas Gulf Terminals Inc. (TGTI; also referred to as Applicant) is proposing to construct and operate a deepwater port (DWP), associated pipeline infrastructure, booster station, and an onshore storage terminal facility (OSTF), collectively known as the Texas Gulf Terminals Project (Project), for the safe, efficient and cost-effective export of crude oil to support economic growth in the United States of America (U.S.). The Applicant is filing this Deepwater Port License (DWPL) application to obtain a license to construct, own, and operate the Project pursuant to the Deepwater Port Act of 1974, as amended (DWPA), and in accordance with the U.S. Coast Guard (USCG) and the Maritime Administration's (MARAD) implementing regulations.

The Applicant is proposing to construct and operate the Project to allow direct and full loading of very large crude carriers (VLCC) at the DWP, via a single point mooring (SPM) buoy system. The proposed Project consists of the construction of a DWP, onshore and inshore pipeline infrastructure, offshore pipelines, and an OSTF. The proposed DWP would be positioned outside territorial seas of the Outer Continental Shelf (OCS) Mustang Island Area TX3 (Gulf of Mexico [GOM]), within the Bureau of Ocean Energy Management (BOEM) block number 823. The proposed DWP is positioned at Latitude N27° 28' 42.60" and Longitude W97° 00' 48.43", approximately 12.7 nautical miles (nm) (14.62 statute miles [mi]) off the coast of North Padre Island in Kleberg County, Texas. Refer to the Vicinity Map depicting the location of the proposed Project.



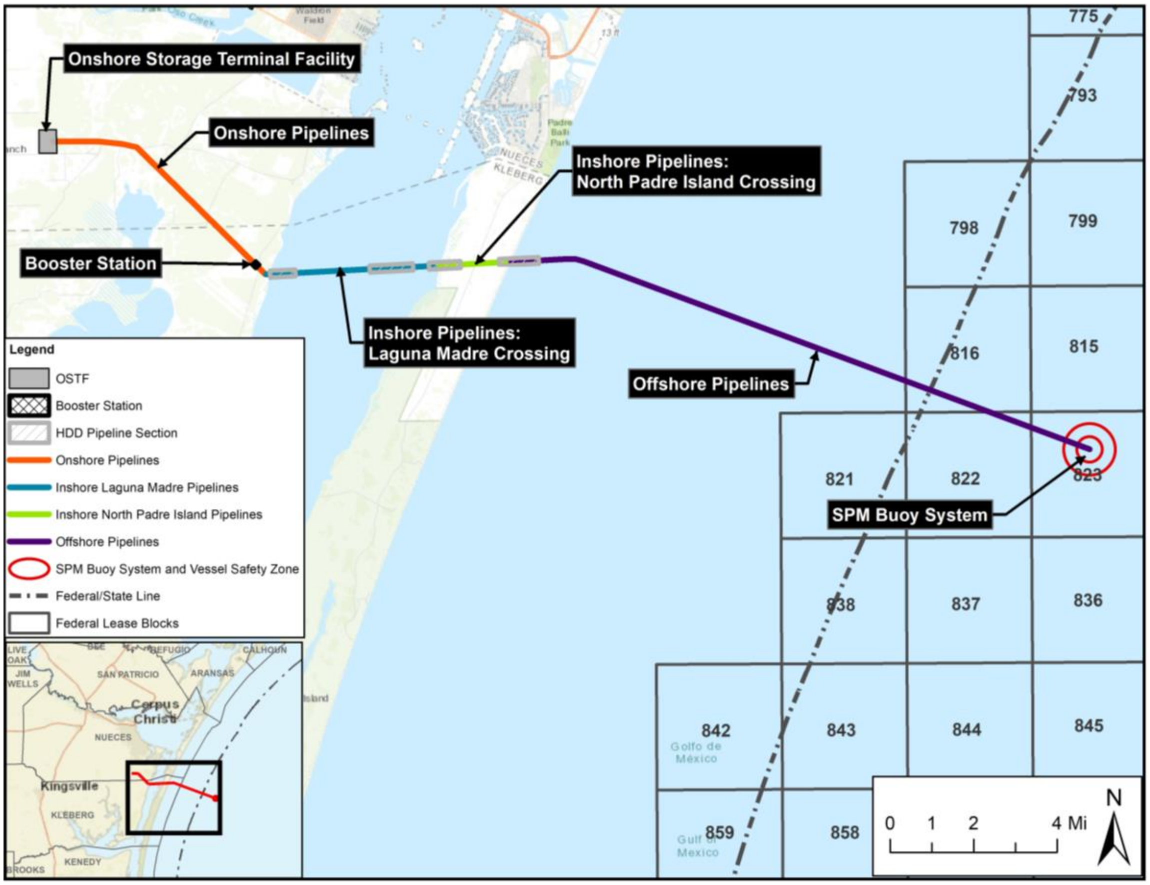
Vicinity Map

The proposed Project involves the design, engineering, and construction of a DWP, 26.81 miles of pipeline infrastructure, booster station, and an OSTF. For the purposes of this DWPL application, the proposed Project is described in three distinguishable segments by locality including "offshore", "inshore", and "onshore".

Onshore Project components includes an approximate 150-acre (ac) (60.7 hectares [ha]) OSTF, an 8.25 ac (3.3 ha) booster station, and approximately 6.36 mi of two (2) new 30-inch-diameter crude oil pipelines extending from the OSTF located in Nueces County, to the booster station located in Kleberg County, and continue to the landward side of the mean high tide (MHT) line of the Laguna Madre. The proposed OSTF will serve as the primary collection and storage terminal of crude oil to be directly pumped through the proposed pipeline infrastructure to the DWP. Outbound flow rates from the OSTF to the DWP are anticipated to be approximately 60,000 barrels per hour (bph).

Inshore components associated with the proposed Project are defined as those components located between the western Laguna Madre MHT line and the MHT line located at the interface of North Padre Island and the GOM; this includes approximately 5.74 mi of two (2) new 30-inch-diameter crude oil pipelines and an onshore block valve station located on North Padre Island. The onshore valve station will serve as the primary conjunction between the proposed onshore and offshore pipeline infrastructure.

Offshore components associated with the proposed Project include the DWP and offshore pipelines. Principle structures associated with the proposed DWP includes one SPM buoy system consisting of the SPM buoy, pipeline end manifold (PLEM), sub-marine hoses, mooring hawsers, and floating hoses to allow for the loading of crude oil to vessels moored at the proposed DWP. The proposed SPM buoy system will be of the Catenary Anchor Leg Mooring (CALM) type permanently moored with a symmetrically arranged six-leg anchor chain system extending to pile anchors fixed on the seafloor. Offshore pipeline infrastructure associated with the proposed Project consist of approximately 14.71 mi of two (2) new 30-inch-diameter pipelines extending from MHT line on North Padre Island to the SPM buoy system located at the proposed DWP. Refer to the Project Components Map below for a depiction of the location of the Project components discussed above.



Project Component Map

10.0 GEOLOGICAL RESOURCES

Geological resources are discussed in terms of inshore and offshore habitat. Inshore habitat refers to aquatic environments located landward from the mean high tide (MHT) line of North Padre Island. Offshore habitat refers to the aquatic environment located seaward into the Gulf of Mexico (GOM) from the MHT line of North Padre Island. This section describes the various geological resources and the potential Project impacts on this resource. The framework for the evaluation of environmental consequences and cumulative impacts in the Introduction of Volume II of the Deepwater Port License (DWPL) application. Section 10.0 is organized as follows:

- Section 10.1 Applicable Laws and Regulations: Background on relevant regulatory laws for consideration;
- Section 10.2 Existing Conditions: Information on the existing inshore and offshore aquatic environment in the Project vicinity;
- Section 10.3 Environmental Consequences: An analysis of environmental consequences;
- Section 10.4 Cumulative Impacts: An analysis of cumulative impacts;
- Section 10.5 Mitigation Measures: Proposed mitigation measures;
- Section 10.6 Summary of Potential Impacts: A summary of potential impacts; and
- Section 10.7 References.

10.1 Applicable Laws and Regulations

The Applicant has reviewed the following laws and statues that relate to geological resources required to comply with the Deepwater Port (DWP) Act during construction and operation of the proposed Project; Submerged Lands Act, Outer Continental Shelf Lands Act Administered by the Bureau of Energy Management's (BOEM) Notice to Lessees and Operators, and Flood Plain Management and Protection, E.O. 11988, 42 FR 26951.

10.1.1 Federal

10.1.1.1 Submerged Lands Act

The Submerged Lands Act (SLA) of 1953 identifies the jurisdictional boundary between state and federal lands submerged beneath the GOM. The SLA promulgates policy that designates ownership of navigable waters and submerged lands and granting rights and title to the natural resources of submerged lands to the Gulf Coast states, extending 3 nm from the coastline into the GOM (or to three marine leagues (9 nm) offshore of Texas and the Gulf Coast of Florida) (43 U.S.C. §1301-1315). The SLA defines natural resources to include: oil, gas, all other minerals, fish, shrimp, oysters, clams, crabs, lobsters, sponges, kelp, and other marine animal and plant life. The SLA also preserves federal claim to the Outer Continental Shelf (OCS), which consists of submerged lands seaward of states' jurisdiction out to the limit of the Exclusive Economic Zone (EEZ). The EEZ consists of those areas adjoining the territorial sea of the U.S. and extends up to 200 nm from the coastline depending on the proximity of neighboring coastal nations. Texas General Land Office (GLO) Coastal Management Program (CMP) has review authority for projects and activities that occur within the Texas Coastal Zone. Activities that would occur in state waters over state submerged lands will be permitted under the CZM CMP with the Texas GLO.

Construction and operation of the proposed Project would occur within the waters of Laguna Madre (within the jurisdiction of the State of Texas), on North Padre Island, offshore waters of the State of Texas (within 9 nm of the mean low water mark), and within waters outside the State of Texas jurisdiction and on a portion of the seabed under the territorial jurisdiction of the federal government (discussed below).

10.1.1.2 Outer Continental Shelf Lands Act

The Outer Continental Shelf Lands Act of 1953 (OCSLA) defines the OCS as all submerged lands lying seaward of state submerged lands and waters (as defined in the SLA) which are under U.S. jurisdiction. Under the OCSLA, the Secretary of the Interior is responsible for the administration of mineral exploration and the development of the OCS, and has authority to grant leases to the highest qualified responsible bidder. The Act, as amended, provides guidelines for implementing an OCS oil and gas exploration and development program. In 1982 after Congress passed the Federal Oil & Gas Royalty Management Act, the Secretary delegated this leasing function to BOEM. Pursuant to section 4(e) of the OCSLA, permits issued by the USACE are required for construction of any artificial islands, installations, and other devices permanently or temporarily attached to the seabed located on the OCS. Section 4(f) of the OCSLA extends the authority of the USACE under Section 10 to regulate installations on the seabed to the seaward limit of the OCS.

The BOEM and its sister agency, Bureau of Safety and Environmental Enforcement (BSEE), both agencies within the Department of the Interior, are tasked under the OCSLA and the Energy Policy Act of 2005 with managing the development of the seabed resources off the coast of the U.S. BOEM regulates the leasing and operation of sulfur, oil and gas, and other mineral mining operations on the OCS. The proposed Project extends into the OCS Region Blocks comprising the Western Planning Area, as designated by the BOEM.

In addition, BSEE regulations (including Notices to Lessees [NTL]) that govern evaluation and protection of geological features, such as the Shallow Hazards Program (NTL No. 2008-G05), are covered in this section.

10.1.1.3 Flood Plain Management and Protection

The Federal Emergency Management Agency (FEMA) classifies foredunes as falling within “high-velocity zones” (V-Zones). Foredunes are included in V-Zones because they absorb the brunt of storms, protecting the interior. FEMA imposes more rigorous construction standards in these areas and prohibits any “alteration of sand dunes…within zones V1-30, VE, and V within the community’s FIRM which would increase potential flood damage.” (44 Code of Federal Regulations [CFR] 60.3[e][7]).

10.1.2 State

A portion of the proposed Project will be constructed on lands within the jurisdiction of the State of Texas, and within the seabed of waters owned by the State of Texas. Within all parts of the State of Texas, the Texas Department of Licensing and Regulation regulates the use and exploitation of Texas aquifers. The Texas General Land Office (GLO) regulates the leasing of the state lands for mining operations, including offshore oil and gas exploration, and the Texas Railroad Commission regulates the drilling and production of oil and gas wells, as well as the mining of coal. However, there are no state regulatory standards relating to geology and soils for the construction of an offshore facility.

The Dune Protection Act (Sections 63.001-63.181 of the Texas Natural Resources Code) requires that a dune protection line be established on the Gulf shoreline by the Commissioners Court of any county with public beaches bordering the GOM. This also applies to the Gulf shoreline of islands. The dune protection line can be established up to 1,000 feet landward of the mean high tide line. A permit is required from the City or County Commissioners Court for most activities seaward of the established dune protection line.

Pursuant to Chapter 86, Subtitle F, of the Texas Parks and Wildlife Code, The Texas Parks and Wildlife Commission shall manage, control, and protect marl and sand of commercial value and all gravel, shell, and mudshell located within tidewater limits of the state, and on islands within those limits, and within the freshwater areas of the state not embraced by a survey of private land, and on islands within those areas. A Marl, Sand, Gravel, Shell or Mudshell Permit from the Texas Parks and Wildlife Department (TPWD) must be obtained for removal of any of these sediments.

Sections 61.211 through 61.227 of the Texas Natural Resources Code regulate the removal of all sediments, such as marl, sand, gravel, and shell from islands, peninsulas, and all land within 1,500 feet of mainland public beaches outside corporate limits. A permit must be obtained from the relevant County Commissioners Court for the excavation of any of these materials unless it is to be moved by a landowner or with a landowner’s consent, from one location to another on the same property.

10.2 Existing Environment

10.2.1 Geologic Setting

The Project area, defined as areas of Nueces and Kleberg Counties and offshore continental shelf traversed by project components, lies on the northwest edge of the GOM, within the Coastal Bend region of the Texas Gulf Coast. It is generally accepted that the GOM formed around the transition between the Triassic and Jurassic periods, ca. 200 million years ago (mya), as a result of the breakup of the supercontinent Pangea. By the end of the Mesozoic era (ca. 65 mya), the Gulf Coast region underwent dramatic change as the subsidence of the natural basin, along with an increase in sedimentation rates, caused large quantities of clastic sediments to form and overwhelm the cretaceous reefs in what is now Texas and Louisiana, filling the northern gulf. The Texas coastal plain then prograded steadily basin ward throughout most of the Cenozoic era (c. 65-2 mya) (Garrison and Martin 1973).

10.2.1.1 Onshore/Inshore

The Quaternary-age portion of the coastal plain consists of a series of terraces deposited during interglacial periods, formed by alluvial and deltaic processes, in an approximate 150 kilometer (km) belt along the coast, with the youngest of these terraces being the Beaumont formation along the eastern margin of the state (Aten 1983) (Figure 10-1). At its surface, this area is composed of late Pleistocene-aged clay and mud of the Beaumont formation, underlain by the Pliocene- and Miocene-aged Fleming formation (USGS 2015, Hosman 1996). In south Texas, the Fleming formation is composed predominantly of clay with sand content increasing eastwardly until it is mostly sand along the coast. Here, calcareous strata contain thin layers of chalky limestone and cross bedded sands. Only 200 feet thick in the outcrop, the Fleming Formation actually extends thousands of feet below the surface (Hosman 1996).

From the end of the Pleistocene epoch, sea level along the Gulf coast has varied drastically in accordance with contemporary degrees of glaciation. However, sea level variance generally stabilized by ca. 1,500 BCE, when postglacial shoreline transgression had reached its furthest position inland. At this point, deposition processes became the major contributing factor in forming the modern Texas coast (Aten 1983). It has been interpreted that around this time, the barrier islands that dot the Texas Gulf coast began to form on the present continental shelf as sea level moved slowly landward (Davis 1994).

Many inland and coastal areas in South Texas are overlain by aeolian sand sheets while the littoral margin is often comprised of newly-formed barrier island deposits, such as South Padre and North Padre Island, the longest continuous barrier island in the world. These deposits predominantly consist of well-sorted sand, with abundant shells and shell fragments, and interfingers with silt and clay in the landward direction (USGS 2002). The eastern margin of North Padre Island is comprised of foredunes which effectively shield the fragile ecosystem of the interior grasslands from storm tide inundation and westward dune advancement. These dunes will be avoided during construction, as well as the adjacent beach, via Horizontal Directional Drilling (HDD).

Between the Texas coast and North Padre Island lies the Laguna Madre, a series of lagoons extending southward from Corpus Christi to Port Isabel, Texas. These lagoons are categorized as hypersaline environments, with salinity levels exceeding 80% at times. These lagoons formed as a consequence of the formation of the many barrier islands dotting the coast approximately 5,000 years ago (Hedgepeth 1967).

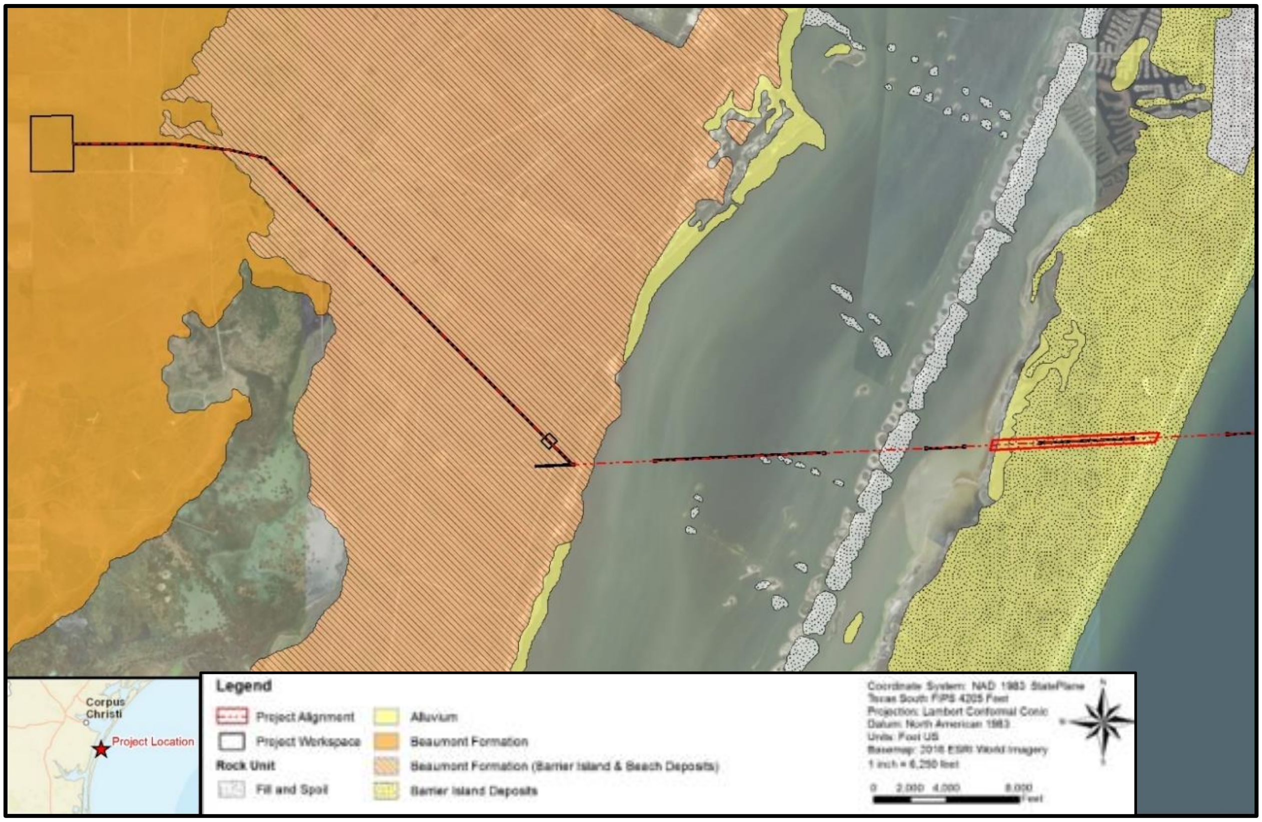


Figure 10-1: Terrestrial geology of the Project area

10.2.1.2 Offshore

Extending into the GOM from the coast of Texas, the continental shelf ranges in width from approximately 100 km at the southern tip of the state to 200 km in the north. The Texas shelf is marked by subtle relict features, such as stream channels and shorelines, formed when sea levels were lower due to glaciation. Structurally, this Northwestern Gulf Shelf has also been influenced by the presence of vast amounts of salt in the sedimentary sequence, which causes a high degree of tectonic mobility in an area that is otherwise relatively stable. Formations of the Neogene period have been arched by deep-seated salt pillows while sedimentary beds from the same period have been pierced by narrow columns of salt (Garrison and Martin 1973). These evaporite (salt-rich) deposits commonly form domes and other diapiric formations as the buoyant, evaporitic material upwells through the overlying sediment (Davidson and Mace 2006). It is generally accepted that these salts have their origin in the Jurassic period (ca. 200-145 mya). Although the Rio Grande Embayment, a significant inland depression extending through the majority of south Texas, is underlain by several salt domes, these features are located further inland and away from the proposed Project area. The lateral migration of evaporitic material has also displaced and replaced clastic deposits via faulting, slumping, and local thickening or thinning of beds. In the strike-fault systems that pervade the northern Gulf Coastal Plain, faulting is normal and down-to-basin with the fault-plane being 35°-70°, flattening basin ward with depth (Garrison and Martin 1973). Faults along the Texas Gulf Coastal Plain are known as growth faults-curved faults that are syndepositional and grow with depth of burial-and are commonly caused by the buoyant rise of materials such as salt or shale (Chowdhury and Turco 2006)

Sea Floor Sediments

The GOM is host to various depositional environments made up of sediments primarily transported via fluvial processes from the mainland. The terrigenous sediment supply along the coastal bend of Texas is the second largest such supply (after the Mississippi-borne sediment supply) in the GOM due to the numerous rivers crossing the region’s coastal plain. After initial deposition, sediments migrate via wave, tidal, current, and gravitational forces, with some eventually arriving in the deep abyssal environment.

Presently, Holocene sediments-especially those deposited since the recent stabilization of sea level-dominate coastal environments, with small amounts of locally-produced biogenic skeletal material contributing to a limited extent (Davis 2017). Due to the often-dense human populations in these environments, these sediments are typically polluted to some degree. Sediments arrive at the continental shelf via three significant modern drainage systems: the Mississippi River, the Rio Grande delta complex, and the Colorado-Brazos delta complex. These drainages deposit sediments in a rather thin blanket across the inner portions of the shelf, covering the fluvial-deltaic deposits laid down during the sea level low stands of the Quaternary period (Davis 2017). Outer portions of the shelf are primarily composed of these low stand deposits, with little to no overlying Holocene sediment. Beyond the shelf, sediments of the continental slope arrive in pulses caused by sediment gravity phenomena, which also occurred during low stand periods. In these periods, the rivers of the mainland extended near the edge of the continental shelf before forming deltas and delivering terrigenous sediments directly to the continental slope, with some of these sediments migrating, ultimately, to the abyssal plain (Davis 2017).

Sea Floor Features

Common seafloor features in the region of the current alignment include the faults and salt domes found across the continental shelf. However, the current alignment does not extend directly over or within proximity to these features.

Faults can be found extending out onto the continental shelf, paralleling the coastline and becoming increasingly younger as they progress basin ward. The current alignment begins on the western margin of North Padre Island and extends eastward, into the GOM, approaching the Lunker fault system, the oldest (Upper Oligocene to Lower Miocene) of these offshore normal faults, although, the DWP at the alignment's terminus lies some distance west of this feature (BOEM 2017).

Salt domes have been identified on the OCS, however, they are located approximately 30 mi east of the DWP (Garrison and Martin 1973).

Several banks occur on the OCS, however, these banks lie some 30 mi east of the DWP around the 71-foot bathymetric contour and, therefore, should not be encountered during construction (BOEM 2018).

10.2.2 Project Area Geology

It is generally accepted that North Padre Island began to form around 5,000 years ago as the sea was rising to its current level from the lows of the Pleistocene epoch. A brief period of rapid sea level rise created a chain of offshore barrier islands. The eventual integration of these individual formations into one virtually continuous barrier island enclosed and deepened the Laguna Madre. The lagoon was then partially infilled by hurricane washover events and strong landward winds until reaching its modern depth (Fisk 1959).

The island is now dominated along its eastern margin by foredunes that serve to protect the fragile grassland ecosystem that stretches across Padre's interior from inundation by tropical storms and to hinder sand from blowing into the sea. As mentioned, these dunes and the eastern beach of North Padre Island will be avoided during construction via HDD techniques.

Inland the soils are generally made up of sandy loam over dense clay. These soils tend to be very flat and less permeable than their shoreline counterparts. This leads to the retention of water and by affect finer soil particles during times of flooding. This process compounds the clay content in the area and creates the local prairies and marshes. The perfect setting for several species of wildlife to thrive and cultivation of rich farmland.

10.2.3 Geologic Hazards

10.2.3.1 Faults and Soil Liquefaction

A belt of seaward-facing normal faults pervades the coastal areas around the northern GOM. The portion of this belt in eastern and southern Texas consists of faults facing southeast, normal to the coast. In the early to middle Mesozoic age, the opening of the GOM formed a rifted, passive margin along southern

North America which was then buried beneath the Louann salt in the Middle Jurassic period, as well as an overlying carbonate and clastic, marine sequence, still being deposited today. The post-rift sequence thickens seaward, with thickness exceeding 12 km under coastal Texas (Wheeler and Heinrich 1998). The thickness of these post-rift sediments caused them to collapse and spread toward the Gulf while buoyant evaporite materials pierced the overlying sediments extending on listric, normal, growth faults that flatten downward into detachments in the salt. (Wheeler and Heinrich 1998). Faults along the Gulf Coastal Plain have exhibited strikingly low historical seismicity, with slip rates estimated at less than 0.2 mm/yr. (Wheeler and Heinrich 1998).

Faults can also be found extending out onto the continental shelf, paralleling the coastline and becoming increasingly younger as they progress basin ward. The current proposed pipeline alignment begins on the western margin of North Padre Island and extends eastward, into the GOM, approaching the Lunker fault system, the oldest (Upper Oligocene to Lower Miocene) of these offshore normal faults, although, the DWP at the alignment's terminus lies some distance west of this feature (BOEM 2017).

Soil liquefaction can occur in sandy, unconsolidated soils as a result of high wave loads, which are normally induced by seismic activity or powerful storms, as solid sediment sequences essentially behave as a fluid (de Groot, et al. 2006). This can cause great damage to standing structures as their rigidity fails to accommodate the shifting sediments below, resulting in fallen buildings or floating pipelines. Although seismic activity has been relatively low in the northwestern Gulf and coastal Texas for the last century (with the exception of two seismic events recorded between 1973 and 2016, occurring approximately 30 mi west of the Project area), the frequency of powerful tropical storms and hurricanes, as well as the unconsolidated, sandy character of seafloor sediment on the inner continental shelf, could be important considerations for hazard analysis (USGS 2018a, 2011). Pipelines, themselves, can contribute to localized liquefaction and deformation as their position redirects the loading of the sand around them (de Groot, et al. 2006). Geotechnical consultation may provide Project specific methods of mitigation.

10.2.3.2 Gas Hydrates

While gas hydrates occur naturally throughout the OCS of the GOM, the portion of the continental shelf crossed by the proposed pipeline is considered too shallow to support the natural formation of gas hydrates (Frye 2008). Although seafloor features such as faults and salt domes have been known to correlate with significantly shallower instances of gas hydrate formation, the current alignment does not cross any of these features.

10.2.3.3 Subsidence

Seabed subsidence can occur in the Gulf Coast region due commonly to the erosion of salt diapirs or the collapse of karst structures. Although concentrations of salt domes and diapiric formations do persist throughout the coastal plain of Texas in areas further south within the Rio Grande Embayment, further north within the Houston Embayment, and further seaward into the GOM, approximately 30 mi beyond the projected location of the DWP, the current alignment crosses no known mineral deposits of this kind (Garrison and Martin 1973).

10.2.4 Mineral Resources

10.2.4.1 Oil and Gas

The proposed DWP lies at the eastern terminus of the current alignment and is located approximately 4 mi into the OCS oil and gas resource play known as the Shelf Unit. The inner continental shelf is primarily composed of clastic sediments deposited throughout the mid-to-late Cenozoic Age, the loading of which caused the deformation of the underlying Louann salt and produced many structures favorable for the entrapment of hydrocarbons (BOEM 2017). The current alignment approaches the Lunker fault system (Upper Oligocene to Lower Miocene) which has been thoroughly explored for decades, although little exploration is currently taking place due to the maturity of the overall trend (BOEM 2017). OCS lease blocks intersected by the current alignment (816, 822, and 823) contain only one established oil or gas well, with adjacent blocks containing seven more, all of which having been permanently abandoned, providing a general impression of the local resource potential and exploration history (BOEM 2018).

Data obtained from the Texas GLO via the Land and Lease Mapping Viewer was utilized to determine lease blocks intersected by the current alignment and the current and historical mineral explorations within the 10 mi of state-governed waters extending east from North Padre Island and waters within the Laguna Madre. Intersected lease blocks offshore include 816, 817, 818, 822, 927, 928, 929, and 933. Of these, only part N/2 of lease blocks 818 (0.7 mi) and 926 (0.5 mi) are currently under active lease and within a mile of the current alignment (TXGLO 2018). An active gas well is also crossed by the current alignment in the northwestern corner of lease block 818. Also within 1 mile of the alignment, five active gas wells, five abandoned gas wells, and four dry holes are located in state waters. Intersected lease blocks within the Laguna Madre include 146A, 146, 170, 178, and 179. A total of 12 abandoned oil or gas wells and eight dry holes are located within 1 mile of this segment of the alignment. No active wells occur within this area (TXGLO 2018).

10.2.4.2 Offshore Sediment Sources

As mentioned in 10.2.1.2.1, the Texas-Louisiana shelf is marked by subtle relict features, such as stream channels and shorelines, formed when sea levels were lower due to glaciation (Garrison and Martin 1973). Sediments deposited here as late as the early Holocene, arrived via fluvial transport. The relict sediment cover on most of the GOM inner continental shelf is limited to shore-parallel sand sediment bodies which are likely to be relict barrier islands, covered during rapid sea-level change during the Pleistocene epoch. Most of these relict barrier features date to the late Pleistocene or early Holocene (Davis 2017). A thin, modern sediment blanket can be found overlying the older, fluvio-deltaic sediments deposited during Quaternary minimum sea levels. These sediments are imported from three modern drainage systems: the Mississippi River, the south Texas intra-deltaic ramp, and the Rio Grande delta complex. Moving further east to the OCS, a thick blanket of mud (tens of meters in depth) represents the second largest are of maximum deposition on the continental shelf after the Mississippi Delta. This blanket, mostly deposited in the late Holocene (last 3,000years) is believed to have originated from the production of mud by the Brazos, Colorado, and Mississippi Rivers (Davis 2017).

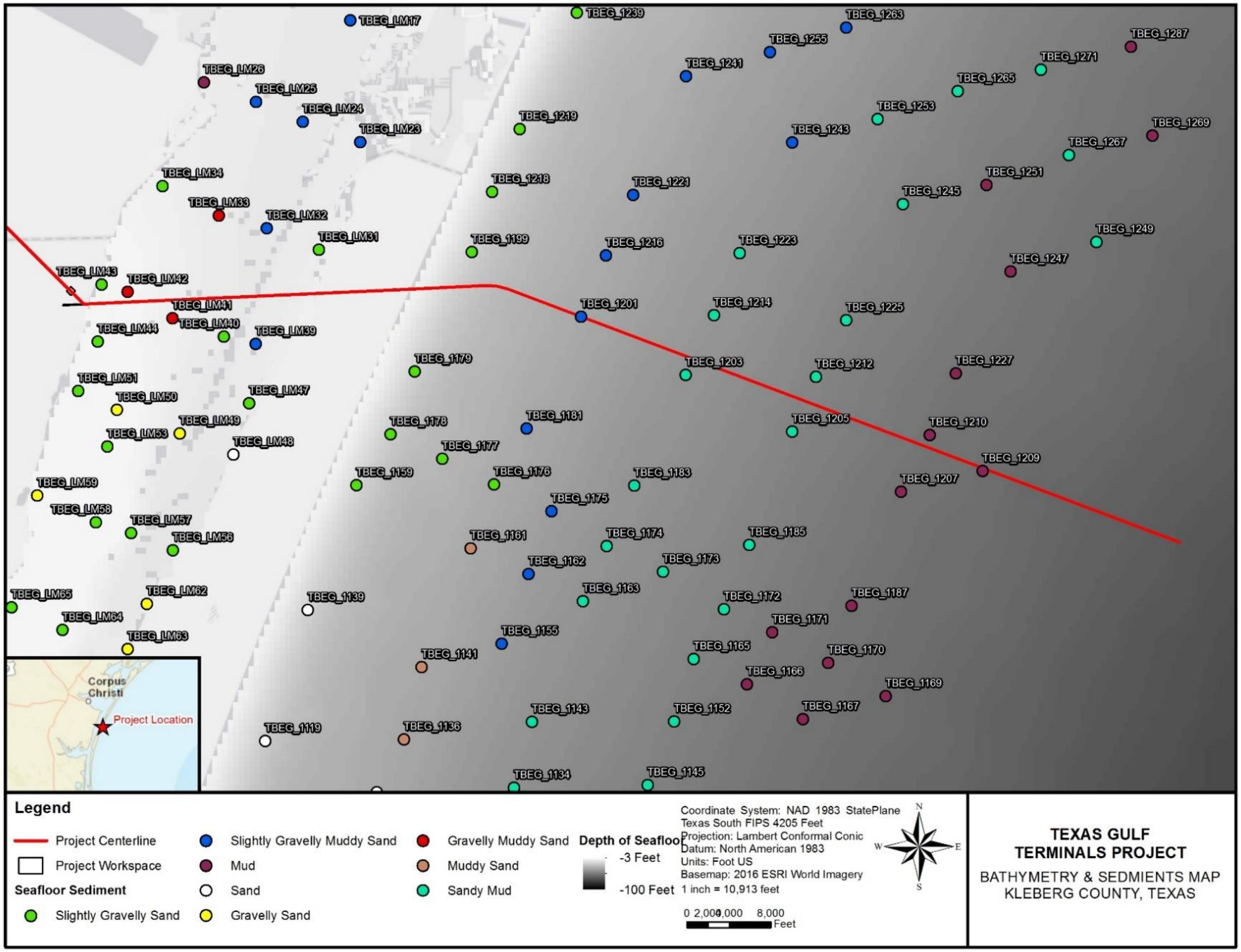
10.2.5 Sediments

Offshore sediment samplings obtained from the us SEABED database have been compiled to provide a representative picture of offshore sediments occurring near the Project area (Table 10-1; Figure 10-2).

Table 10-1: Offshore Sediments near Project Area (USGS 2006)

Site Name	Distance Offshore	Distanced from Proposed Project Area	Folk Code	Shepard Code
TBEG_1199	0.74 mi	0.5 mi	Slightly Gravelly Sand	Sand
TBEG_1201	2.95 mi	0.5 mi	Slightly Gravelly Muddy Sand	Sand
TBEG_1203	5.12 mi	0.6 mi	Sandy Mud	Silty Sand
TBEG_1205	7.25 mi	0.6 mi	Sandy Mud	Sandy Silt
TBEG_1207	9.46 mi	0.4 mi	Mud	Silt
STOCS018_AHRY	21.98 mi	13.6 mi	Mud	Silty Clay
STOCS018_AHJV	28.34 mi	17.56	Mud	Silty Clay

Figure 10-2: Bathymetric map of Project area including seafloor sediment sample data



10.2.5.1 Soil Series

Soils within the Project area formed in sand-dominated sediments deposited by the aeolian and alluvial processes at work since the stabilization of sea level during the late Holocene. Data from the Natural Resource Conservation Service (NRCS) was utilized to create a table and figure illustrating all soil units crossed by the Project area (Table 10-2; Figure 10-3). Soils in the coastal prairie surrounding Corpus Christi are primarily composed of vertisols with a higher presence of the mineral smectite in the clay fraction (NRCS 2018a). Typical soil series in the area consist of Edroy and Banquet clay further inland, Rockport fine sands along the Laguna Madre, and Greenhill, Padre, and Mustang fine sands on North Padre Island (NRCS 2018b).

Table 10-2: Soils within the Project area.

Soil Map Units	Primary soil components	Texture	Location	Description	Minor soil components
Tatton fine sand, 0-1 % slope, very frequently flooded	Tatton (95%)	Fine sand	Barren wind-tidal flats	Very deep, very poorly drained, very slowly permeable soils formed in sandy aeolian and storm washover sediments of Holocene age. These nearly level soils are on wind-tidal flats on the bay or lagoon side of barrier islands. These soils are subject to very frequent flooding by wind tides and tropical storms	None
Madre-Malaquite Complex, 0-1% slope, occasionally flooded, frequently ponded (MaA)	Madre (45%)	Fine sand	Barrier flats	Very deep, poorly drained, very slowly permeable soils that formed in sandy aeolian and storm washover sediments on barrier islands. These soils are subject to occasional flooding by high storm surge from strong tropical storms, and are ponded after periods of heavy rainfall.	None
	Malaquite (38%)	Fine sand	Barrier flats	Very deep, poorly drained, very slowly permeable soils that formed in sandy aeolian and storm washover sediments on barrier islands. These soils are subject to occasional flooding by high storm surge form strong tropical storms, and are ponded after periods of heavy rainfall.	None
Mustang-Padre Complex, 0-2% slope, occasionally flooded, frequently ponded (MtB)	Mustang (49%)	Fine sand	Barrier flats	Very deep, poorly drained, very slowly permeable soils that formed in aeolian and storm washover sediments. These soils are subject to occasional flooding by high storm surge from tropical storms, and are ponded after periods of heavy rainfall.	None
	Padre (42%)	Fine sand	Dunes on barrier flats	Very deep, somewhat poorly drained, very slowly permeable soils that formed in sandy aeolian and storm washover sediments on barrier islands. These soils are subject to occasional flooding by high storm surge from strong tropical storms.	None
Mustang fine sand, 0-1% slope, occasionally flooded, frequently ponded (MsA)	Mustang (85%)	Fine sand	Barrier island	Very deep, poorly drained, very slowly permeable soils that formed in sandy aeolian and storm washover sediments. These soils are subject to occasional flooding by high storm surge from strong tropical storms, and are ponded after periods of heavy rainfall.	None
Greenhill-Mustang Complex, 0-12% slope, occasionally flooded, occasionally ponded (GmE)	Greenhill (50%)	Fine sand	Foredunes and back-island dune fields	Very deep, excessively drained, rapidly permeable soils that formed in deep, sandy, aeolian sediments on barrier islands. These soils are on strongly rolling foredunes and stabilized back-island dune fields and subject to rare flooding by high storm surge from strong tropical storms.	None

Soil Map Units	Primary soil components	Texture	Location	Description	Minor soil components
	Mustang (48%)	Fine sand	Barrier flats	Very deep, poorly drained, very slowly permeable soils that formed in sandy aeolian and storm washover sediments. These soils are subject to occasional flooding by high storm surge from strong tropical storms, and are ponded after periods of heavy rainfall.	None
Novillo peat, 0-1% slope, rarely flooded, frequently ponded (NeA)	Novillo (88%)	Peat	Fresh water swales on barrier flats	Very deep, very poorly drained soils that formed sandy aeolian sediments on barrier islands. These soils are ponded for very long periods in normal years and are rarely flooded by high storm surge from strong tropical storms.	None
Greenhill fine sand, 2-12% slope, rarely flooded (GhE)	Greenhill (85%)	Fine sand	Foredunes and back-island dune fields	Very deep, excessively drained, rapidly permeable soils that formed in deep, sandy, aeolian sediments on barrier islands. These soils are on undulating rolling foredunes and stabilized back-island dune fields and are subject to rare flooding by high storm surge from strong tropical storms.	None
Satatton fine sand, 0-1% slope, frequently flooded (StA)	Satatton (50%)	Fine Sand	Wind-tidal flats on the bay or lagoon side of barrier islands	Very deep, poorly drained, very slowly permeable soils that formed in sandy aeolian and storm washover sediments of Holocene age. These nearly level soils are subject to frequent flooding by wind tides and tropical storms.	Coastal Dunes 6%
	Tatton (44%)	Fine Sand	Wind-tidal flats on the bay or lagoon side of barrier islands	Very deep, very poorly drained, very slowly permeable soils that formed in sandy aeolian and storm washover sediments of Holocene age. These nearly level soils are subject to very frequent flooding by wind tides and tropical storms.	
Portalto fine sand, 0-2% slopes, rarely flooded (PoB)	Portalto (90%)	Fine sand	Mounds and ridges on the strand plain	Very deep, moderately permeable, moderately well drained soils that have formed in sandy and loamy sediments of Quaternary age	None
Rockport fine sand, 0-2% slopes, rarely flooded (RoB)	Rockport (90%)	Fine sand	Strand plain	Very deep, somewhat excessively drained, moderately rapid permeable soils that formed in aeolian sands on the Pleistocene age Ingleside Strandplain.	None
Dietrich loamy fine sand, 0-2% slopes, very rarely flooded (DsB)	Dietrich (90%)	Fine sand	Strand plain	Very deep, poorly drained, very slowly permeable soils that formed in loamy sediments of late Pleistocene age.	None
Twinpalms occasionally flooded-Yarborough frequently flooded complex, 0-3% slopes (TwA)	Twinpalms (55%)	Fine sand	Bays	Very deep, somewhat poorly drained, moderately permeable soils that formed in sandy and loamy sediments dredged from submerged areas.	None
	Yarborough (40%)	Fine sandy loam	Bays	Very deep, poorly drained soils that formed in sandy and loamy sediments dredged from submerged areas.	None
Baffin soils, submerged (Ba)	Baffin (95%)	Sandy clay loam	Lagoon bottom	Very deep, very poorly drained (permanently submersed) soils that formed in slightly fluid sandy and loamy estuarine sediments.	None
Galveston and Mustang fine sands, occasionally flooded, 0-12% slope	Galveston (50%)	Fine sand	Coastal terraces, dunes and offshore barrier islands	Very deep, somewhat excessively drained, very rapidly permeable soils that formed in sandy eolian deposits derived from igneous, metamorphic and sedimentary rock. These nearly level to strongly sloping soils are occasionally flooded with salt water during severe storms.	None

Soil Map Units	Primary soil components	Texture	Location	Description	Minor soil components
	Mustang (30%)	Fine sand	Planar to concave barrier island flats	Very deep, poorly drained, very slowly permeable soils that formed in sandy eolian and storm washover sediments. These are nearly level soils are subject to occasional flooding by high storm surge from strong tropical storms, and are ponded after periods of heavy rainfall.	None
Nueces Fine Sand, 0-5% slope (Nu)	Nueces (100%)	Fine sand	Sandsheet Prairie	Very deep, moderately well drained, moderately slow permeable soils that formed in sandy eolian deposits over loamy Quaternary age alluvium. These are nearly level to gently sloping soils.	None
Orelia Fine sandy loam, 0-1% slope (Of)	Orelia (90%)	Fine sandy loam	Flats on coastal plains	Very deep, well drained, slowly permeable soils that formed in loamy fluviomarine deposits of Pleistocene age. These are nearly level soils.	None
Edroy Clay, 0-1% slope (Bn)	Edroy (85%)	Clay	Enclosed depressions	Very deep, poorly drained, very slowly permeable soils that formed in clayey over loamy fluviomarine deposits of Pleistocene age. These are nearly level soils	None
Banquet Clay, 0-% slope (Ba)	Banquet (85%)	Clay	Open-ended shallow depressions and swales plains	Very deep, moderately well drained, very slowly permeable soils that formed in clayey fluviomarine sediments derived from the Beaumont Formation of Late Pleistocene age. These are nearly level soils	None
Raymondville complex, 0-5% slopes (CcA)	Raymondville (90%)	Fine sandy loam	Gently sloping uplands	Deep, moderately well drained, slowly permeable soils that formed in calcareous moderately fine and fine textured sediments. These soils are on nearly level to gently sloping uplands.	None

Source: NRCS 2018a

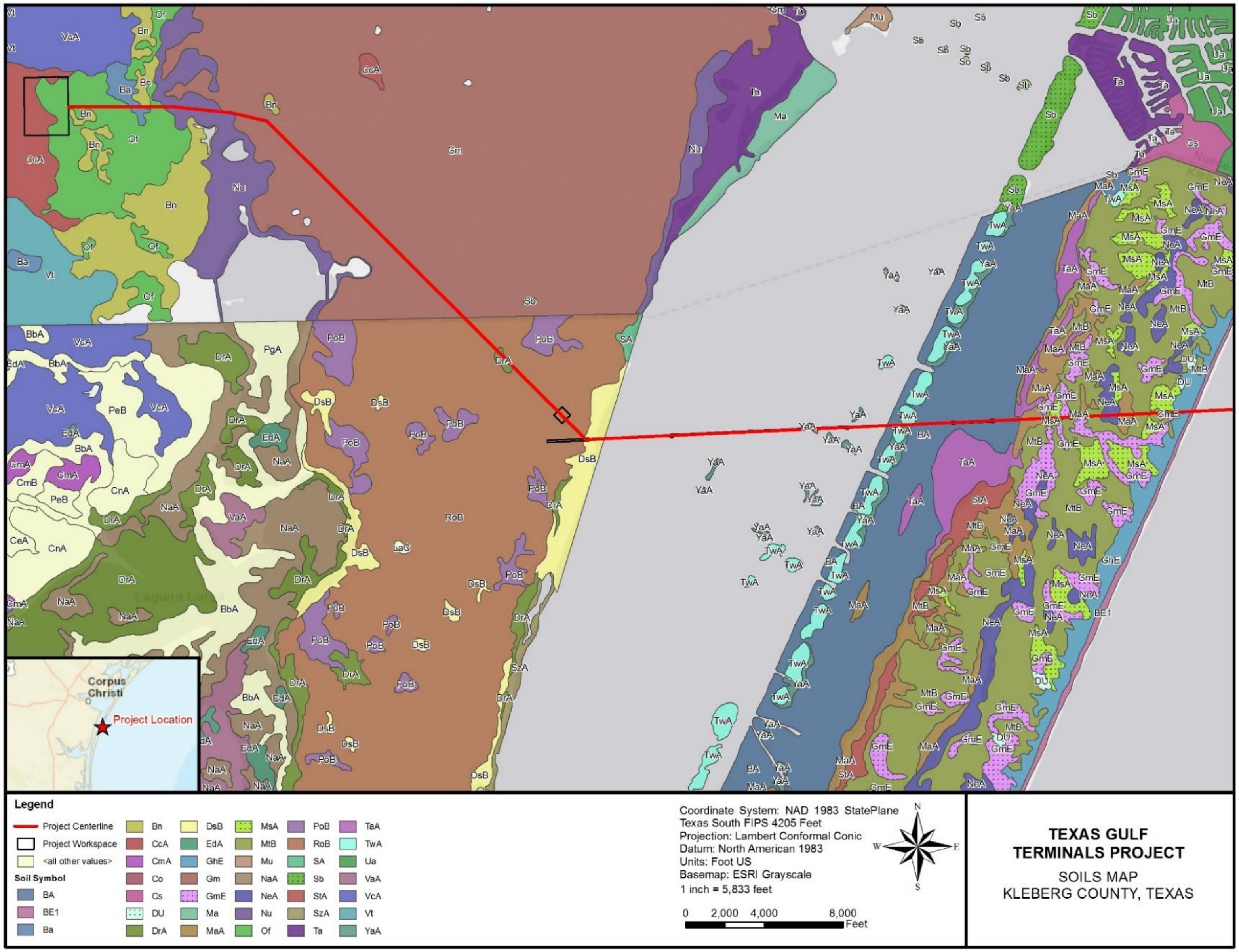


Figure 10-3: Soils intersected by the Project area.

10.2.5.2 Geotechnical Surveys

A geophysical survey conducted and submitted by Geo-Marine Technology, Inc (GMTI)., prepared for Naismith Marine Services (NMS), provides detailed information concerning soil consistency, structure, and bathymetric features intersected by the proposed alignment in the offshore section (GMTI 2018). Moving eastward from Padre Island, the proposed Project alignment will extend over a series of three offshore bars, with reliefs upwards of five feet and flanks exceeding 5°. The bathymetry eastward of these bars consists of a gentle concave surface steadily descending to the 96-foot isobath at the alignment's eastern terminus. Slopes are generally less than 1°. Subtle mounds and depressions occur between the 30-foot and 45-foot isobaths on this part of the Texas Shelf. From here to approximately 50 feet, a series of low-angle, shore-parallel hummocks and swales mark the seafloor. Beyond 50 feet in depth, topography becomes very smooth. Data obtained via Side Scan Sonar (SSS) and magnetometer survey revealed light and dark banding correlating with the subtle ridges and swales previously mentioned. It is uncertain as to whether these bands correlate with any variations in grain size or degree of consolidation of seabed sediments since no seabed samples were taken. It was suggested by GMTI that these bands likely indicate seabed changes due to bottom current activity (GMTI 2018).

At the western end of the alignment, the shallow subsurface is likely composed of sand, as indicated by the presence of offshore bars, and comprises the "Shoreface Sand" deposit. This deposit is underlain by Holocene paleochannels which seem to outcrop east of the Shoreface Sand deposit. These paleochannels are likely remnant distributaries from periods of lower sea level, when the Nueces River delta extend further seaward. Further east, a mass of acoustically chaotic reflections suggests bioturbated or reworked deltaic sediment near the mouths of these remnant distributaries. Even farther east, the horizontal orientation of Holocene deposits suggests deposition in a marine setting. These Holocene deposits are underlain by the Wisconsinan unconformity and ranges from just 10 feet in thickness in the western section of the alignment to approximately 65 feet thick at the 96-foot isobath at the alignment's eastern edge. East of the Holocene paleochannels, the Wisconsinan unconformity is underlain by older, Late-Pleistocene paleochannels.

10.2.5.3 Prime Farmlands

Given the Project's location on the Gulf coast of Texas, the sand-dominated soil profile of the area, and the likelihood of high salinity levels due to occasional flooding, the Project area does not meet the criteria for Texas Prime Farmlands as laid out by the U.S. Department of Agriculture's (USDA's) Natural Resource Conservation Service (NRCS 2007).

10.2.5.4 Offshore Sediment Quality

Toxic substances and pesticides are discharged into GOM estuaries from industrial and municipal discharges, urban and agricultural runoff, accidental spills, and atmospheric deposition. These activities can often have adverse effects on estuarine and nearshore habitats. From 1991 to 1997, the USCG received an annual average of 6,217 notifications of oil or chemical spills in GOM ports (USEPA 1999). Chemicals that enter estuaries are often bound to suspended particulate matter that eventually deposits on the sediment surface. Sediment deposition and accumulation rates in an estuary depend greatly on the rate of freshwater inflow and access to flushing from the GOM.

After deposition in the sediment, toxic chemicals may be available for uptake by benthic organisms. Bioavailability is dependent on sediment characteristics, including concentrations of total organic carbon and acid-volatile sulfide. Some chemicals are acutely toxic, resulting in death of the animal; others may have chronic toxicity effects, affecting growth or reproduction. Toxic chemicals can affect humans because they may become biomagnified as they are stored in animal tissue and transferred through the food chain. When sediment chemistry information is combined with sediment toxicity data and benthic health indicators, a better assessment of overall sediment quality can be accomplished.

Evaluation of the potential effects of contaminated sediments on estuarine organisms is difficult because few applicable state or federal regulatory criteria exist to determine "acceptable" sediment concentrations for most identified potential chemical compounds of concern. However, informal guidelines based on many field and laboratory studies have been suggested. These include benchmarks such as effects range-low and effects range-median values (Long et al. 1995), which enable environmental managers to determine whether contaminated sediments have the potential to adversely affect aquatic organisms.

A study conducted by Freese and Nichols, Inc. for the Texas General Land Office in 2016 provides data that illustrates levels of trace metals and contaminants within the Corpus Christi Bay Complex, a network of waterbodies that includes the Laguna Madre. Sources of contaminants within the Corpus Christi Bay Complex include the Nueces River, urban and industrial runoff, and the GOM. Reportedly, sediments within the complex have shown high concentrations of heavy metals such as arsenic, barium, copper, mercury, nickel, and selenium. However, while these trace metals have been identified in widespread distribution, no hot spots for contaminants were detected. (Freese and Nichols 2016).

Moving offshore from the Texas coast, contaminant levels decrease rapidly. Natural oil and gas seepage are the primary contributors to traces of petroleum detected on the continental shelf and slope. Still, few human-caused releases of petroleum in the region make their way into the underlying sediments, except for metal-contaminated drill muds and cuttings and petroleum discharges from nearby platforms. The activity of currents normally aids in the dilution of these contaminated sediments with surrounding, uncontaminated sediments. These localized contaminated sediment deposits have been interpreted as having limited impact. In summary, concentrations of contaminants and trace metals are considerably lower in the offshore region, where pesticides and polychlorinated biphenyls are generally absent, than in coastal regions (Kennicutt 2017).

10.3 Environmental Consequences

The methodology for evaluating impacts to geological resources has identified consequence-producing factors within three distinct phases of the Project, including Construction, Operation, and Decommissioning. Consequences are assessed to determine the magnitude of impact. Refer to Appendix A: Construction, Operation and Decommissioning Procedures, for a detailed description of techniques, procedures, and phases of the Project that were used to evaluated environmental consequences in the following sections.

Adverse impacts on geological resources may occur when an activity is likely to damage or disturb a unique geological feature, induce soil erosion, modify seafloor stability, affect sediments, or affect mineral resources. It is anticipated that subsea blasting activities would not be required for the proposed Project. Except for the dunes located on the eastern portion of the inshore Project area and localized normal faults, there are no unique geological features present in the study areas for the Project. In addition, the Project is likely to affect soils and sediments within the Project area. Seafloor stability will be protected using careful Project siting. Apart from affecting the sediment itself, sediment disturbance would likely result in minor impacts on water quality and marine resources (see Volume II, Section 3 – Water Quality).

10.3.1 Seafloor Sedimentary Processes

During construction of the Offshore and Inshore pipeline segments, minor to negligible disturbance to seafloor sedimentary processes is expected due to sediment displacement, increased turbidity, and increased scour from the presence of equipment and materials at or near the seafloor. Upon the completion of the Project, pipeline trenches are expected to backfill naturally, returning the seafloor to the pre-excavation contours, and consequently, to the pre-floor seafloor sedimentary regime.

Seafloor sedimentary processes may be affected by operation of the DWP, as the SPM buoy will be anchored to the seafloor with 6–7 prefabricated anchor pilings, and the PLEM will likely be set on a piled foundation to enhance stability. Connections from the anchor pilings to the SPM buoy will be constructed with chains, limiting hydrodynamic effects. In addition, the sub-seafloor pipeline will be connected to the PLEM, which will be connected to the SPM buoy by flexible hoses. However, scour, or the removal of granular bed material by hydrodynamic forces, could occur when hydrodynamic stresses are greater than sediment shear stresses. Scour can cause changes in local turbidity concentrations and result in sediment disruption and movement due to changing tides and currents. Current forces in the GOM near the site and the local sediment types would determine the level of the scour effect. The relatively slow tidal/current speeds and soft-bottom sediments in the vicinity suggest that scour would be minor, short-term, and local.

Demolition of the DWP should not affect seafloor sedimentary processes. Geologic impacts on the seafloor during decommissioning would be similar to installation, as all materials will be removed. This would involve the re-excavation of sediments deposited within the trench, and disturbance of sediments around the SPM buoy. Since the terminal would be in an area of sediment reworking, any scars are expected to be temporary and reversible, thereby resulting in negligible geologic impacts on the seafloor.

10.3.2 Mineral Resources

Based on review of available geologic data, no currently exploitable mineral resources are present within the Project area. While the DWP would be located in the eastern end of the Shelf Unit play, there are no proven or unproven reserves near the Project alignment (BOEM 2018). Should this play be developed, it would require horizontal directional drilling, thus access to these potential, unproven reserves could easily avoid the Project area. Therefore, there would be no impacts on mineral resources from the proposed Project.

10.3.3 Geologic Hazards

Geologic hazards within the Project area include faulting, soil liquefaction, gas hydrates, and subsidence. Faulting in the vicinity is low and has exhibited a low degree of seismicity. Conditions in the vicinity are susceptible to soil liquefaction, especially during storms, and have potential to damage or destroy portions of the Project. Gas hydrates and subsidence are affected by the presence of faults and salt diapirs, neither of which are present within the Project area, limiting the risk of such hazards. The proposed Project would not affect the occurrence of faulting, gas hydrate formation, or subsidence. Soil liquefaction may be affected by the presence of the pipeline and DWP anchor and foundation pilings, but the effect would be minor to negligible.

10.3.4 Soil and Sediment Displacement

10.3.4.1 Construction

During construction, minor, adverse impacts on soils and sediments within the pipeline construction corridor can be expected. Disturbance of soils within the terrestrial portion of the Project area would result in the increased potential for erosion, compaction, and mixing of topsoil. Disturbance of sediments and increases in turbidity within the submerged portions of the Project area can be expected by pipeline installation, anchor piling installation, and through the direct contact of anchors or supports from jack up work boats. These impacts would be temporary, minor, and reversible. On land, trench topsoil and subsoil would be segregated to prevent mixing, and would be returned to trenches in proper order, with the ground surface returned to pre-excavation contours. During construction, BMPs including but not limited to silt fencing, matting, and hay bales would be utilized to present erosion. The construction area would be allowed to re-vegetate naturally. The sensitive depositional environment of the seaside dunes would be avoided through an HDD beginning west of the dune protection line, 1000 feet west of the mean high tide line. Erosion on tidal flats and beaches lacking vegetation would also be mitigated by use of HDD through these areas.

Offshore portions of the proposed would be installed within a 36-foot-wide construction corridor using jet-sled techniques. Pipelines would be installed at a minimum of 5 feet below mud line (BML) and would be allowed to backfill naturally as well as backfilled by the amphibious trencher. At the DWP location, the SPM buoy would be anchored to the seafloor with 6–7 prefabricated anchor pilings. Depth of impacts would be determined by the local refusal conditions. Piling installation may be expected to result in minor sedimentary mixing and increased local turbidity by forcing more deeply buried deep sediments to the surface. Local, minor, temporary effects could be expected to sediments and turbidity within the Project area.

10.3.4.2 Operation

Terrestrial impacts to soils and sediments would be negligible during pipeline operation. As vegetation clearing would not be required along the pipeline corridor, maintenance related impacts would be negligible.

Due to the lack of anchorage at the DWP, no seafloor disturbing impacts would be expected from the operation of the DWP. However, scour, or the removal of granular bed material by hydrodynamic forces, could occur when hydrodynamic stresses are greater than sediment shear stresses. Scour can cause changes in local turbidity concentrations and result in sediment disruption and movement due to changing tides and currents. Current forces in the GOM near the site and local sediment types would determine the level of the scour effect. The relatively slow tidal/current speeds and soft-bottom sediments in the vicinity suggest that scour would be minor, short-term, and local.

10.3.4.3 Decommissioning

Geologic impacts on the soils and the seafloor during decommissioning would be similar to installation, as all materials will be removed. This would involve the re-excavation of sediments deposited within the trench, and disturbance of sediments around the SPM buoy. Since the terminal would be in an area of sediment reworking, any scars are expected to be temporary and reversible, thereby resulting in negligible geologic impacts on the seafloor.

10.4 Cumulative Impacts

Cumulative effects generally refer to impacts that are additive or synergistic in nature and result from the construction of multiple actions in the same vicinity and time frame. Cumulative impacts can result from individually minor, but collectively significant actions, taking place over a period of time. In general, small-scale projects with minimal impacts of short duration do not significantly contribute to cumulative impacts (see Volume II Introduction, Evaluation Framework, and Summary of Impacts).

While activities necessary in offshore oil and gas exploration and production, including the decommissioning of existing infrastructure, carry the potential for impacting local geological resources, activities present in the Western Planning Area have not demonstrated any adverse cumulative impact on geologic resources, with the potential exception of regular resource reserve reduction.

The proposed Project will disturb 130 sq. ft of shallow sediment in the immediate vicinity associated with installation of the SPM buoy and associated piles, as well as additional area due to the anchoring of construction vessels. Minor temporary displacement of sediment will occur during laying and jetting of the pipelines and during HDD activities. The resulting temporary displacement of sediment from these activities would be similar to that resulting from installation of pipeline, platforms, and other similar structures associated with oil and gas activity in the Western Planning Area. As discussed in section 10.2.2, BOEM projects that as many as 1,788 production structures and 6,930 mi (11,153 kilometers) of pipeline may be installed in the Western Planning Area over the next five years. Furthermore, between 740 and 1,892 structures may be removed.

Onshore ground disturbance will be in an area that poses a limited potential for erosion and landslide hazards but will have direct impacts on near-surface geology and soils during construction (within the 75 ft wide workspace). Installation of the pipelines by the HDD method will avoid any beach erosion areas. Most of the nearby projects sufficiently far enough away from the Project such that they will not contribute to cumulative impacts on geological resources in the Project area. Erosion control and restoration techniques and requirements will be determined prior to construction based on requirements within the USACE permit and other applicable agency recommendations.

Overall the proposed Project will not adversely affect geological resources; therefore, it will not contribute to any potentially adverse cumulative impacts on the geologic resources in the Western Planning Area.

10.5 Mitigation Measures

Effects on soils, sediments, and sedimentary processes from the pipeline and terminal installation and decommissioning would be the only activities with respect to geological resources that could warrant mitigation. Proper siting and HDD procedures will avoid geologic hazards and mineral resources within and near the Project area. Although the proposed activities would impact soils, sediments, and sedimentary processes, the geologic impacts would be negligible since the ground surface would be returned to the original contours, the terrestrial pipeline scar would be revegetated, and alterations to the seafloor would recover naturally.

The following BMPs will be employed to reduce the potential impacts to soils:

- Temporary erosion/sediment controls including but not limited to silt fencing, matting, and hay bales will be utilized when necessary as required by issued permits. These controls are designed to keep sediment from flowing off the Project site and into places where it may harm the environment. These temporary erosion controls will be properly placed and maintained throughout construction and will be reinstalled as necessary until they are replaced by permanent erosion/sediment controls or until construction activities have ceased and permanent vegetation has become established.
- During construction, a Stormwater Pollution Prevention Plan (SWPPP) will be implemented to minimize soil erosion and impacts on surface waters. All work will be conducted in accordance with a Texas Pollutant Discharge Elimination System (TPDES) General Permit No. TXR150000 for stormwater and TPDES General Permit No. TXR050000 for industrial waste water meeting all provisions within the respective permit.
- As part of Project restoration, all portions of the pipeline right of way (ROW) impacted, including wetlands and floodplains, will be returned to preconstruction conditions and contours.

10.6 Summary of Potential Impacts

Table 10-3: Summary of Potential Impacts to Cultural Resources

Project Phase	Impact	Duration	Significance	Mitigation
Installation/ Commissioning - Inshore	Soil disturbance (terrestrial); Seafloor and sediment disturbance (inshore and offshore waters);	During Construction	Direct, adverse, minor, short term, local	All construction will be done with the least invasive techniques possible to minimize soil disturbance; pipeline trenches will be backfilled to natural contours and revegetated naturally. Seafloor trenches will be allowed to backfill naturally. HDD procedure will be implemented to avoid tidal flats, dunes, and beaches
Routine pipeline operations	Operational scour	Throughout the active operation of the pipelines within the action area	Minor, short-term, local	Concrete mats and sand/cement bags shall be used, if necessary, to minimize scouring
Decommissioning	Soil disturbance (terrestrial), Seafloor and sediment disturbance (inshore and offshore waters) Increased sedimentation	During decommissioning period	Negligible	Decommissioning will be done with the least invasive techniques possible to minimize potential increased sedimentation. pipeline trenches will be backfilled to natural contours and revegetated naturally. Seafloor trenches will be allowed to backfill naturally
Cumulative	Erosion, resource depletion,	Life of Project	Negligible	None

10.7 References

Aten, Lawrence E. 1983. Indians of the Upper Texas Coast, In New World Archaeological Record, edited by James Bennett Griffin, Academic Press, New York.

Bureau of Ocean Energy Management (BOEM). 2017. Assessment of Technically and Economically Recoverable Hydrocarbon Resources of the Gulf of Mexico Outer Continental Shelf as of January 1, 2014. U.S. Department of the Interior, BOEM, Gulf of Mexico OCS Region, Office of Resource Evaluation, New Orleans.

———. 2018 Marine Cadastre National Viewer. Available at: https://marinecadastre.gov/nationalviewer. Accessed February 2018.

Chowdhury, Ali H. and Mike J. Turco. 2006. Geology of the Gulf Coast Aquifer, Texas, in Aquifers of the Gulf Coast of Texas, edited by R. E. Mace et al, pp. 23-50. Texas Water and Development Board, Austin.

Davidson, Sarah C. and Robert E. Mace. 2006. Aquifers of the Gulf Coast of Texas: An Overview, In Aquifers of the Gulf Coast of Texas, edited by R. E. Mace et al, pp. 1- 22. Texas Water and Development Board, Austin.

Davis, Richard A. (editor). 1994. Barrier Island Systems. In Geology of Holocene Barrier Island Systems, edited by R. Davis, pp. 1-46. Springer, New York.

Davis, Richard A. 2017 Sediments of the Gulf of Mexico. In Habitats and Biota of the Gulf of Mexico: Before the Deepwater Horizon Oil Spill, edited by C. Ward, pp. 165-215. Springer, New York.

Fisk, H. N. 1959. Padre Island and the Laguna Madre Flats, Coastal South Texas. Second Coastal Geography Conference. Coastal Studies Institute, Louisiana State University, Baton Rouge. pp. 103-152.

Freese and Nichols, Inc. 2016. Texas Coastal Sediment Sources General Evaluation Study. Report prepared for the Texas General Land Office. Available at http://www.glo.texas.gov/coastal -grants/_documents/grant-project/13-333-sediment-study.pdf. Accessed March 2018.

Frye, Matthew. 2008. Preliminary Evaluation of In-Place Gas Hydrate Resources: Gulf of Mexico Outer Continental Shelf. U.S. Department of the Interior, Minerals Management Service, Resource Evaluation Division.

Garrison, Louis E. and Ray G. Martin, Jr. 1973. Geologic Structures in the Gulf of Mexico Basin USGS Professional Paper 773. U.S. Government Printing Office., Washington D.C.

Geo-Marine Technology, Inc. 2018. Texas Gulf Terminals Project. Report prepared for Naismith Marine Services. June 4, 2018

Hedgepeth, Joel W. 1967. Ecological Apects of the Laguna Madre, A Hypersaline Estuary. In Estuaries: Ecology and Population. University of the Pacific Press. Stockton, California.

Hosman, R.L. 1996. Regional Stratigraphy and Subsurface Geology of Cenozoic Deposits, Gulf Coastal Plain, South-Central United States. USGS Professional Paper 1416-G. U.S. Government Printing Office., Washington D. C.

Kennicutt II, M.C. 2017. Sediment Contaminants of the Gulf of Mexico. In Habitats and Biota of the Gulf of Mexico Before the Deepwater Horizon Oil Spill, Springer, New York, NY.

Long, E.R., D.D. MacDonald, S.L. Smith, and F.D. Calder. 1995. Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. Environmental Management 19(1): 81-97.

Natural Resources Conservation Service (NRCS). 2007. Prime Farmland-Texas Criteria. Available at https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid...ext=pdf. Accessed March 2018.

———. 2018a Natural Resources Conservation Service. The Soil Orders of Texas. Available at: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/tx/home/?cid=nrcs144p2_003094. Accessed January 2018.

———. 2018b Natural Resources Conservation Service Official Soil Series Descriptions. Available at: http://soils.usda.gov/technical/classification/osd/index.html. Accessed January 2018.

Texas General Land Office. 2018. Land and Lease Mapping Viewer. Available at gisweb.glo.texas.gov/glomaps/index.html. Accessed February 2018.

United States Environmental Protection Agency (EPA). 1999. The Ecological Condition of Estuaries in the Gulf of Mexico. USEPA 620-R-98- 004, July 1999, USEPA, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Gulf Ecology Division, Gulf Breeze, Florida. Available at: http://nepis.epa.gov/Exe/ZyPDF.cgi/300042FE.PDF?Dockey=300042FE.PDF.

U.S. Geological Survey (USGS). 2002. USGS Texas Geology Web Map Viewer. Available at: https://txpub.usgs.gov/DSS/texasgeology/. Accessed January 2018.

———. 2006. usSEABED: Gulf of Mexico and Caribbean (Puerto Rico and U. S. Virgin Islands) Offshore Surficial Sediment Data Release. Accessed via Marine Cadastre National Viewer at https://marinecadastre.gov/nationalviewer/, January 2018.

———. 2011. Seismicity of the Earth 1900-2010 Mexico and vicinity. Available at http://pubs.usgs.gov/of/2010/1083/f. Accessed March 2018.

———. 2015. Texas Geologic Map Data. Available at: http://mrdata.usgs.gov/geology/state/state.php?state=TX. Accessed January 2018.

———. 2018a. USGS Earthquake Catalog. Available at https://earthquake.usgs.gov/earthquakes/search/. Accessed February 2018.

———. 2018b. USGS Simplified 2014 Hazard Map (PGA, 2% in 50 years). Available at https://earthquake.usgs.gov/hazards/hazmaps/conterminous/2014/images/HazardMap2014_lg.jpg. Accessed February 2018.

Wheeler, R. L. and P.V. Heinrich. 1998. Gulf-Margin Normal Faults, Louisiana and Arkansas, in Quaternary Fault and Fold Database of the United States: U.S. Geological Survey Website, Available at: https://earthquakes.usgs.gov/hazards/qfaults. Accessed February 2018.