LOWERMOST MISSISSIPPI RIVER MANAGEMENT PROGRAM

Regional Sediment Management Below Venice

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PREFACE

Historically, USACE's management of the Lowermost Mississippi River (LMR) has focused on objectives that are each addressed independently of one another. These objectives include maintaining a navigable waterway, reducing flood risk to communities, and restoring and protecting ecosystems. However, these objectives all rely on the effective management of river water and sediment. The use of a holistic approach for water and sediment management with mutual benefit across objectives, state and federal agencies, and funding authorizations has the potential to be more cost-effective, resilient, and sustainable for the Mississippi River and the communities, commerce, and ecosystems that rely on it. The Lowermost Mississippi River Management Program aims to identify mutually beneficial holistic strategies for river management and assess what the outcomes of those potential approaches would be for the interests of CPRA and other stakeholders. This study outlines the sediment availability and cost considerations such a strategy would need to consider in order to change the present operations regime of the LMR.

The report and all related items of information were prepared by the authors through a sub-contract with CPRA, who was funded under Award No. GNTCP18LA0035 from the Gulf Coast Ecosystem Restoration Council (RESTORE Council). The data, statements, findings, conclusions, and recommendations are those of the authors and do not necessarily reflect any determinations, views, or policies of the RESTORE Council.

EXECUTIVE SUMMARY

The Mississippi River has traditionally been managed separately in a partitioned manner, for navigation, flood risk reduction, and ecosystem restoration, but all three objectives require management of the same water and sediment. Large volumes of restoration-quality sand are dredged from the Mississippi River Ship Channel below Venice annually that could derive far greater benefits if placed along the barrier system instead of the existing disposal areas that are presently used. This high-level analysis intends to evaluate a specific opportunity that involves using the sand that is frequently removed from the Hopper Dredge Disposal Area (HDDA) to programmatically nourish the barrier islands and headlands along the Barataria Bight extending from Belle Pass in the west to Sandy Point in the east. While there are other opportunities to harvest restoration-quality sand from the Lowermost Mississippi River (LMR), the sand produced for HDDA cleanouts is a unique opportunity that offers cost savings because, among other things, the dredge is already working there, it is cleared environmentally, and location in the LMR provides for sheltering from waves that in the open Gulf may limit production by up to 50%. The results of this analysis suggest that an approach that involves a federal-state partnership to programmatically direct sand dredged from HDDA cleanouts to manage the barrier shoreline of the Barataria Bight has potential cost savings of existing practices, provides a higher-quality sand resource that enhances benefits of barrier island restoration, and provides for a somewhat reliable, renewable sand resource in a regime where sand for barrier restoration is extremely scarce.

This report provides initial insights into the limiting questions surrounding utilizing sand produced from the HDDA during maintenance dredging to programmatically nourish the Barataria barrier shoreline over the long term:

1. What is the supply of sand available from HDDA cleanout activities?
2. What is the demand for suitable sand for barrier island restoration along the Barataria Bight (from Belle Pass to Sand Point) based on historic restoration practice?
3. Is the supply sufficient to satisfy the demand?
4. If there is sufficient supply to meet the sand demand, what would a realistic range of sand delivery alternatives and costs be to deliver the sand from the river to the barrier shoreline in question?

In total, the 50-year sand demand for the Barataria Bight barrier shoreline was estimated to be 114.8 million cubic yards, or approximately 2.3 million cubic yards /yr., versus the estimated annual availability from HDDA cleanouts of 3.3 million cubic yds/yr. Thus, the supply was found to be sufficient to satisfy the historic demand for this section of barrier shoreline. A series of cost estimates were generated, which found that delivering sand from the HDDA to the Barataria Bight shoreline for a period of 50 years could range from 96% to 291% of historic costs to restore the barrier islands while using a superior quality of sand that provides benefits over longer periods than the nearshore sand sources.

The findings of this report support the assertion that collaborative regional sediment management in the Mississippi River below Venice can be accomplished in a way that enhances benefits to both navigation and coastal protection and restoration, under existing authorities.

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LIST OF ACRONYMS

Acronym	Term
AHP	Above Head of Passes
BHP	Below Head of Passes
BISM	Barrier Island System Management
BUDMAT	Beneficial Use of Dredged Material
CM	Construction Management
CMP	Coastal Master Plan
CPRA	Coastal Protection and Restoration Authority
CSD	Cutter-suction dredge
CY	Cubic yards
EA	Environmental Assessment
EIS	Environmental Impact Statement
E&D	Engineering and Design
FY	Fiscal Year
HDDA	Hopper Dredge Disposal Area
LA	Louisiana
LASAAP	Louisiana Sediment Availability and Allocation Program
LASARD	Louisiana Sand Resources Database
LASMP	Louisiana Sediment Management Plan
LMR	Lowermost Mississippi River
LMRMP	Lowermost Mississippi River Management Program
MCY	Million Cubic Yards
MRSC	Mississippi River Ship Channel
NEPA	National Environmental Protection Act
NS	Near Shore
NWR	National Wildlife Refuge
OCS	Outer Continental Shelf

Acronym	Term
ODMDS	Ocean Dredged Material Disposal Site
O&M	Operations and Maintenance
RM	River Mile
RSM	Regional Sediment Management
SWP	Southwest Pass
USACE	U.S. Army Corps of Engineers
VABP	Venice Area Borrow Pit
WMA	Wildlife Management Area

1.0 INTRODUCTION

Regional Sediment Management (RSM) is generally defined as a holistic, systems-based approach for stewardship of sediment resources to provide broad benefit and advance objectives across stakeholders (Brutsche & Lillycrop, 2018; Georgiou, Kime, et al., 2019; Khalil et al., 2018). A core principle of coastal restoration management in Louisiana, espoused by the Louisiana Coastal Protection and Restoration Authority (CPRA) in *Louisiana's Master Plan for a Sustainable Coast* (CMP; CPRA, 2023a) is that sediment is a commodity to be managed regionally and holistically for efficient, cost-effective, and sustainable ecosystem restoration. CPRA's RSM is implemented through the Louisiana Sediment Management Plan (LASMP), which identifies and quantifies sediment resources for restoration to provide a framework and developing best practices for cost-effective, systematic management of this valuable resource (Khalil et al., 2018).

Likewise, the U.S. Army Corps of Engineers (USACE) has embraced RSM as essential to the success of their mission to maintain national security, energize the economy, and reduce disaster risk; setting a goal that at least 70% of sediment dredged for navigation purposes will be used beneficially for ecosystem restoration and/or flood risk reduction by 2030 (USACE, 2023c). In their most recent reporting for 2019, USACE New Orleans District staff noted that of the 76.5 million cubic yards (MCY) dredged across the district's maintained waterways, 39.5 MCY (52%) was deemed suitable and available for beneficial use, of which 16.7 MCY (22% of total dredged, 42% of available for beneficial use) were placed beneficially (USACE, 2019).

The availability of restoration-quality sand resources is a primary limiting factor for implementation of barrier shoreline projects in CPRA's CMP (CPRA, 2017a). However, the Mississippi River still delivers restoration-quality sand to the Louisiana coastal area that must be dredged annually to maintain the federally authorized navigable depths in the Mississippi River Ship Channel (MRSC). This activity under the Lowermost Mississippi River Management Program (LMRMP) is intended as a starting point to assess feasibility of programmatically using the restoration-quality sand dredged during MRSC maintenance (and specifically sand dredged from the Hopper Dredge Disposal Area; HDDA)—a "renewable" sand resource that is delivered naturally to the coast—for barrier island restoration projects.

One of the primary goals of the LMRMP is to identify and evaluate strategies for managing water and sediment within the Lowermost Mississippi River (LMR). Historically, USACE's management of the LMR has focused on objectives that are each addressed independently of one another. These objectives include maintaining a navigable waterway, reducing flood risk to communities, and restoring and protecting ecosystems. However, these objectives all rely on the effective management of river water and sediment. The use of a holistic approach for water and sediment management with mutual benefit across objectives, state and federal agencies, and funding authorizations has the potential to be more cost-effective, resilient, and sustainable for the Mississippi River and the communities, commerce, and ecosystems that rely on it. LMRMP aims to identify mutually beneficial holistic strategies for river management and assess what the outcomes of those potential approaches would be for the interests of CPRA and other stakeholders.

Sediment management on the LMR below Venice—including the Venice and Pilottown anchorages, the HDDA, Southwest Pass (SWP) navigation channel, and coastal sand needs along the Barataria Bight shoreline (Figure 1)—have linked, and sometimes conflicting, stakeholder objectives. This document provides a high-level analysis that considers a holistic, systems-based sediment management approach that maximizes benefits across stakeholders and management objectives (navigation, ecosystem restoration, and storm and flood risk reduction) and provides recommendations on a path forward and next steps. Similar high-level thought exercises occurred for over two decades (e.g. Khalil et al., 2010; Kulp et al., 2001; Penland et al., 1990) before sand resources from Ship Shoal were utilized for successful barrier headland and island restoration projects (e.g., Coastal Engineering Consultants Inc., 2012). This document provides an initial foundation toward a similar paradigm shift in enhancing sustainability and resilience of both Louisiana's barrier islands and the economically vital MRSC.

Figure 1. Barrier islands and headlands of the Barataria Bight.

1.1. SAND RESOURCES FOR BARRIER ISLAND SYSTEM MANAGEMENT

Louisiana's barrier islands are rapidly migrating landward and disintegrating due to high rates of relative sea-level rise, expanding back barrier tidal prism, and an increasing sand deficit (Miner et al., 2009), and an increasing sand deficit (Miner et al., 2009). CPRA has implemented extensive barrier island restoration efforts to mitigate these effects by introducing large volumes of sand, sourced from offshore and riverine borrow areas, into the system to supplement the sand deficit. The Barrier Island System Management (BISM) program is currently being implemented to programmatically manage the barriers as a system by applying adaptive management and RSM principles and building on the success of the past two decades, to ensure barrier integrity is maintained into the future (Dalyander et al., 2021). BISM relies on LASMP for identification of optimal sand resources with sufficient volumes to support CPRA's 50-year Coastal Master Plan (Dalyander et al., 2021). A component of BISM relies on LASMP for identification of optimal sand resources with sufficient volumes to support CPRA's 50-year Coastal Master Plan.

Because of prior findings on the relationship between sand quality (sand grain-size coarseness) and longevity (i.e., the expected length of time the sand placed for restoration will remain in subaerial barrier islands; Caffey et al., 2020; Georgiou, Kime, et al., 2019), this analysis considers it a priority that barrier island and headland restoration utilize the coarsest grain-size available for Louisiana barriers to maximize benefits over longer time periods. Previous studies, such as the Louisiana Barrier Island Comprehensive Monitoring Program, have extensively sampled barrier islands and environments found within (i.e., berm, dune, backbarrier, etc.), to evaluate grain size spatially and temporally (Georgiou, Yocum, et al., 2019). Median grain size results from the Barataria Bight (Late Lafourche and Modern Delta sample regions) for dune and berm environments, range from ~177-198 microns [µm] and ~190-213 µm; Georgiou, Yocum, et al., 2019), respectively, indicating similar grain sizes found within Ship Shoal and the HDDA. Smaller sand grain sizes and higher fines content can make barrier shorelines more susceptible to erosion during energetic events such as tropical cyclones, whereas coarser-grained sands are less mobile, leading to extended project life (Caffey et al., 2020, 2022; Georgiou, Kime, et al., 2019; Twichell et al., 2013). To date, barrier island restoration within the Barataria Bight (for this analysis, the coastline from Scofield Island in the east to Belle Pass in the west) has typically used offshore sediment resources (~110–220 microns [µm] D_{50}; Coastal Engineering Consultants Inc., 2012, 2013, 2019; Coastal Planning & Engineering, Inc., 2013) with some projects that have pumped coarser sand (~167–220 µm D_{50}; (GeoEngineers, 2019; SJB Group LLC & Coastal Engineering Consultants Inc., 2010) from the Mississippi River in the vicinity of Pelican and Scofield islands. In general, offshore sand sources proximal to the Barataria barrier islands contain significantly finer-grained sands than those found comprising bars in the Mississippi River. For example, the mean grain size for the recently constructed West Grand Terre restoration was ~150 µm (Ocean Surveys, Inc., 2019) whereas the mean grain size in HDDA per communication with industry representatives, is 170–210 µm (personal communication with Weeks Marine, 2023; personal communication with Ancil Taylor, 2023). Ongoing work under LASMP that has identified new, restoration-quality sand resources offshore Sandy Point is at a reconnaissance scale so subsequent, more detailed, design level surveys are required to more accurately quantify, delineate, and clear/permit before these resources be utilized (Rob Hollis, personal communication). Despite these recent developments, it is certain that restoration-quality offshore sand reserves are limited to what is in-place versus the renewable sand dredged annually for nearby MRSC maintenance. While out-of-system offshore sandy-sediment volumes suitable for barrier restoration are non-renewable and becoming scarce, the nearby LMR provides a renewable and somewhat predictable sand resource.

1.2. EXISTING SEDIMENT MANAGEMENT PRACTICES IN THE LOWERMOST MISSISSIPPI RIVER

For the context of this report related to LMR RSM, a summary of USACE maintenance dredging practices for the MRSC is provided below. For a more detailed treatment of MRSC dredging practices, please refer to Esposito et al. (2021) and USACE (2018). For the purposes of this summary of MRSC dredging practices, the LMR can be divided into three distinct river segments based on hydraulic conditions and sediment transport efficiency leading to different dredging strategies for each river segment (2021) and USACE (2018). For the purposes of this summary of MRSC dredging practices, the LMR can be divided into three distinct river segments based on hydraulic conditions and sediment transport efficiency leading to different dredging strategies for each river segment (Figure 2):

1. Deep Draft Crossings (Baton Rouge to New Orleans vicinity)
2. Transfer Reach (New Orleans vicinity to Venice)
3. SWP (Venice to the Gulf)

The Deep Draft Crossings are composed of 12 river crossings (shallow portion of channel between two successive river meanders where the thalweg shifts from one side of the channel to the other because of the tendency to for the deepest portion of the natural channel to abut the outer bank of each meander) that are located between Baton Rouge and New Orleans that require annual maintenance dredging. This river reach is characterized by relatively high sinuosity and undergoes significant changes in river stage seasonally (up to ~25 ft annually at Baton Rouge). Most deposition throughout this reach occurs during high discharge (spring flood) but dredging operations do not typically begin until river stages start to fall (spring flood recedes). The elevated river stage during high flow events provides enough draft clearance in the channel, even though the channel is experiencing shoaling. Once the river stage begins to fall, dredging is required to maintain authorized depths. However, dredging in the Deep Draft Crossings is historically only involved discharge into the adjacent thalweg, so no sediment is actually removed from the river.

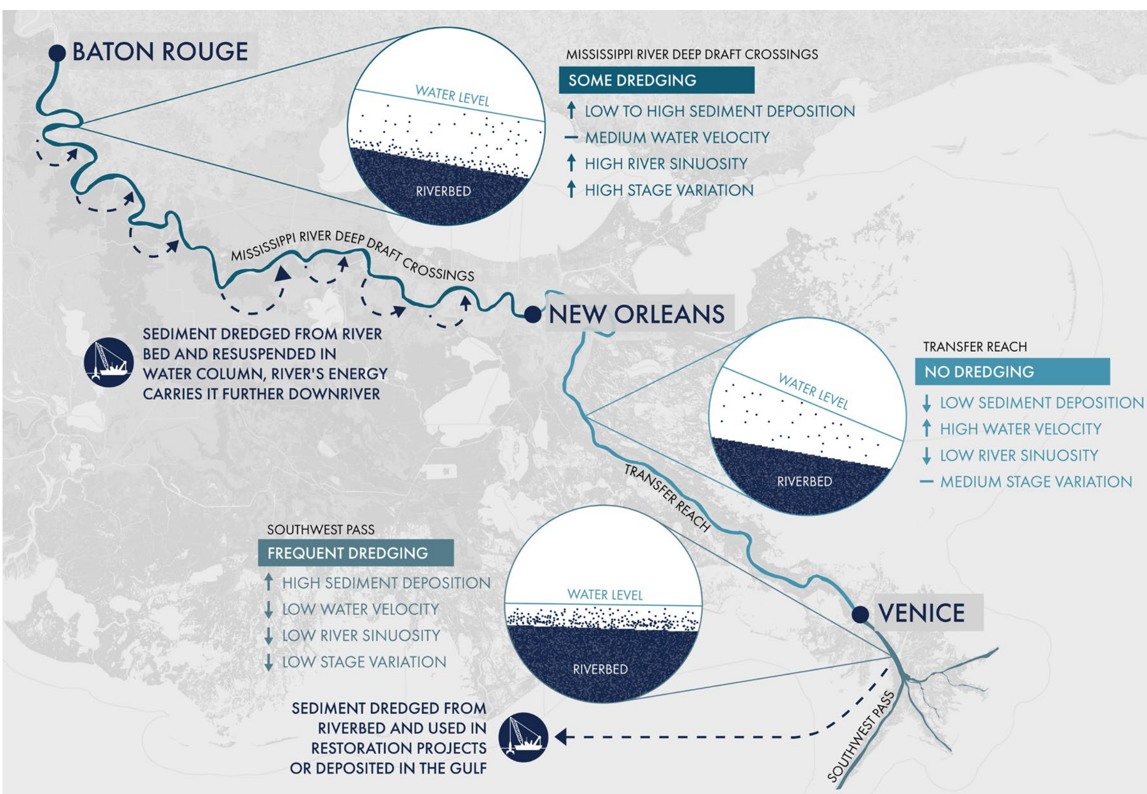

Figure 2. Sediment management reaches of the Lowermost Mississippi River.

Dredge type and disposal practices in this reach consist of operating dustpan and hopper dredges that employ open water disposal. This tactic leverages natural flow velocities in the river to transport sediment downstream or places sediment in portions of the channel that do not directly impede navigation (e.g., in deep scour holes or on bars adjacent to the navigation channel). It is known that dredging operations throughout the Crossings have the potential to rehandle sediment multiple times (Brown, 2018), but this method is still more economical than employing direct removal of sediment from the channel in the Crossings (Esposito et al., 2021). Previous tasks under the LMRMP program have discovered that the annual mass dredged in the Crossings is comparable to the annual mass of suspended sand at Baton Rouge (Esposito et al., 2021), demonstrating the effectiveness and magnitude of dredging operations in this river segment. The average cost per cubic yard (CY) to dredge sediment within the Crossings reach was ~$1.77/CY (in 2022 dollars, $1.89 in 2023 dollars) for the time period between 1996–2019 (USACE, n.d.).

The Transfer Reach, located between New Orleans and Venice, is a segment of the MRSC that does not require maintenance dredging. This reach is characterized by a steeper gradient with lower sinuosity than the Crossings and is a zone of hydraulic transition between the high stage variation experienced in the Crossings and minimal stage variation experienced downstream approaching the Gulf. During high flow conditions, this river segment experiences steeper water surface slopes than upstream, causing an increase in stream power and the river's ability to flush sediment through this reach.

The SWP reach, located approximately from Venice to the Gulf, requires almost constant dredging except during low flow conditions. Unlike the Deep Draft Crossings and Transfer Reach, the SWP segment experiences minimal stage fluctuations and water surface gradients due to its proximity to Gulf base level. Additionally, there are numerous outlets that contribute to flow loss in this reach, effectively reducing stream power and sediment transport (Andrus & Bentley, 2023; Georgiou et al., 2023). The combination of small stage variations, minor water surface gradient, and flow loss promotes deposition in the channel that must be addressed immediately due to its impact on navigation. Because this lowermost reach marks the point at which the river cannot naturally flush sand any further downstream, it is the first point along the LMR where sand must be removed from the channel to maintain navigable depths (i.e., instead of in the Crossings where downstream sediment transport is mechanically assisted by dredging, but without removing any sediment from the river). Sediment dredged in the SWP reach (Figure 2, Figure 3) is removed from the channel and placed within the HDDA, the SWP Offshore Dredge Material Disposal Site (ODMDS), or used to maintain bank integrity and build wetlands (USACE, 2018). A combination of cutterhead suction dredges (CSDs) and hopper dredges are used to perform maintenance dredging activity in the SWP reach. Southwest Pass can experience rapid shoaling throughout the channel, which requires immediate attention and frequent changes to dredging assignments. Cutterhead suction dredges, by design (spudding systems, swing anchors, discharge lines, etc.), have limited mobility and are restricted in certain portions of SWP for navigational safety. Hopper dredges provide increased mobility and are best suited to respond to multiple shoaling locations and can be utilized throughout the entirety of SWP without posing a safety hazard. Cutterhead suction dredges typically work between River Mile (RM) 13.4 above Head of Passes (AHP)-RM 1 AHP and RM 1 below Head of Passes (BHP)- RM 19 BHP and discharge material on either side of the navigation channel for bankline stabilization or wetland creation (Figure 3). Additionally, CSDs are used to clean out the HDDA. Hopper dredges working in the vicinity of Head of Passes (RM 13.4 AHP- RM 11 BHP) will dispose of sediment within the HDDA, or if operating below RM 11 BHP, will dispose of sediment in the ODMDS. Occasionally, hopper dredges working near the terminus of SWP (jetty and bar channel) may employ agitation dredging.

Due to the river's geomorphic evolution in response to relative sea-level rise and anthropogenic manipulation over the past century, the volume of sand that must be removed to maintain navigable drafts in SWP has increased over the past two decades (Esposito et al., 2021; USACE, n.d.).

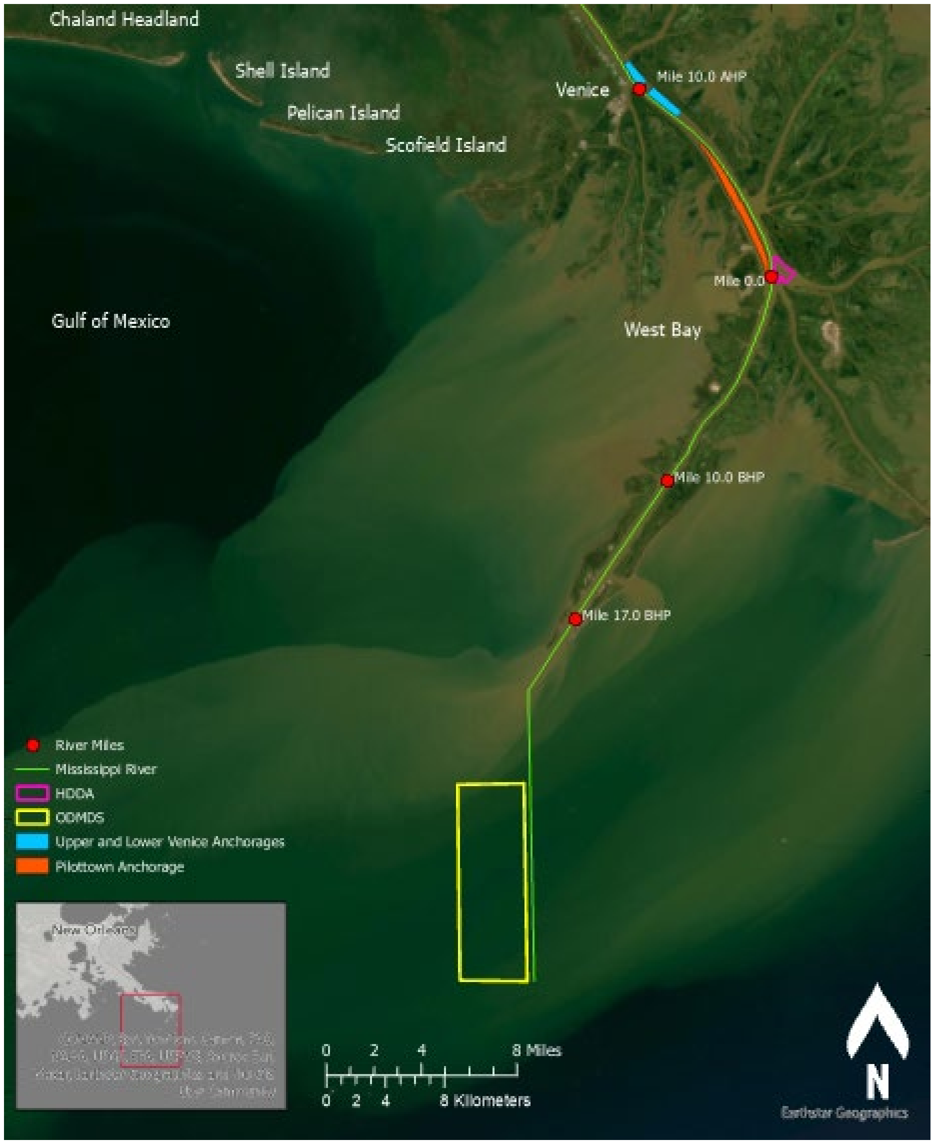

Figure 3. Lowermost Mississippi River Maintenance Dredging Regime: Material removed between RM 10.0 Above Head of Passes (AHP) and RM 11.0 BHP is placed into the HDDA for future removal or placed over bank; material removed below RM 11.0 BHP is placed over bank or into the ODMDS. Adopted from (USACE, 2018).Adopted from (USACE, 2018).

All three options are cleared for disposal under programmatic National Environmental Policy Act (NEPA) analyses and attendant consultations (Figure 4). Prior to and during operations the use of each disposal option requires close coordination between the USACE, U.S. Coast Guard, river pilots, and other mariners to minimize impacts to navigation within the MRSC.

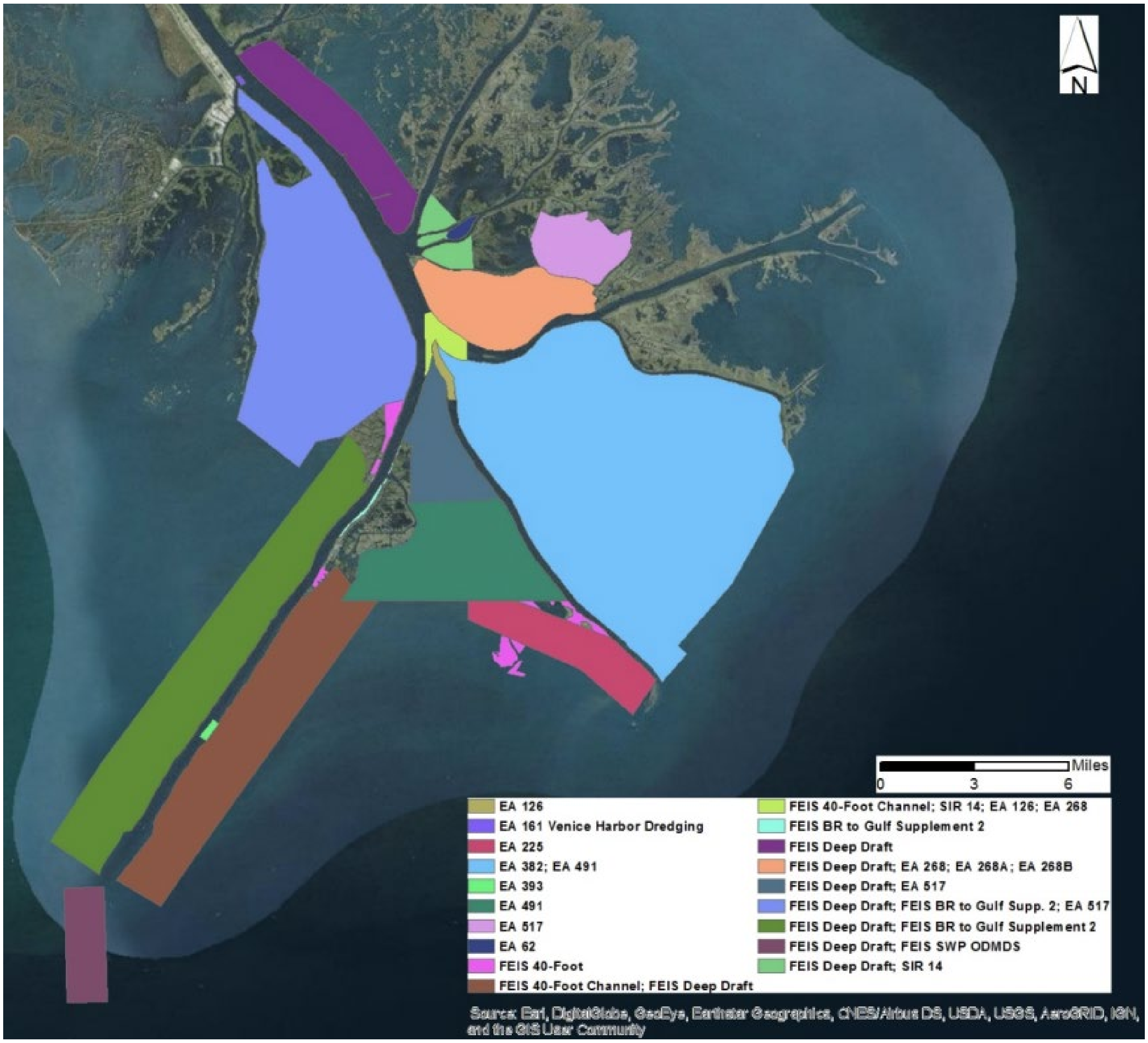

Figure 4. Historic NEPA clearance areas from Environmental Assessments (EAs) and Environmental Impact Statements (EISs). Adopted from USACE (2018). Adopted from USACE (2018).

For the timeframe of fiscal years (FY) 1996–2019, when costs are available from the USACE, the average cost per CY to dredge sediment within SWP was $3.60/CY in 2022 dollars, $3.85 in 2023 dollars (USACE, n.d.). Dredging contracts to remove sediment from the HDDA to be used for beneficial use are issued every 1–2 years (USACE, 2018). These HDDA cleanout contracts are performed by CSDs with placement sites proximal to Head of Passes (Figure 5), amounting to an average cost per CY of $5.04/CY and an annualized cost of $15.0M/yr. for FY 1998–2022 with values increasing in recent years (in 2023 dollars, Table 1 and Figure 6; USACE, n.d.). These HDDA cleanout events are the focus of this analysis as an opportunity as a renewable sand resource for barrier shoreline restoration along the Barataria Bight.

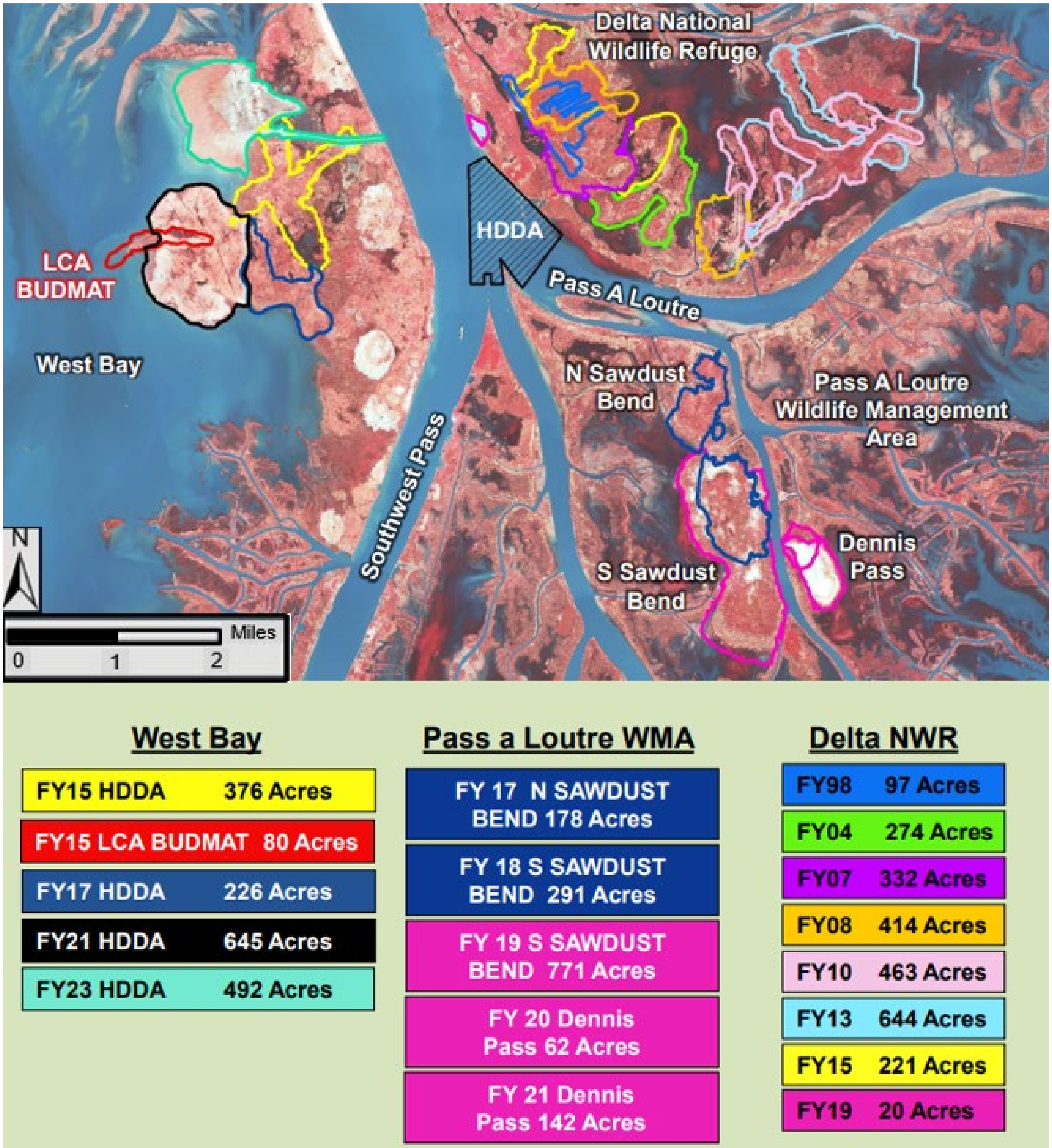

Figure 5. Beneficial Use of Dredged Material (BUDMAT) placement areas for dredge material sourced from HDDA spanning FY 1998–2023. Different color polygons reference specific FYs. Image sourced from USACE (2023a).

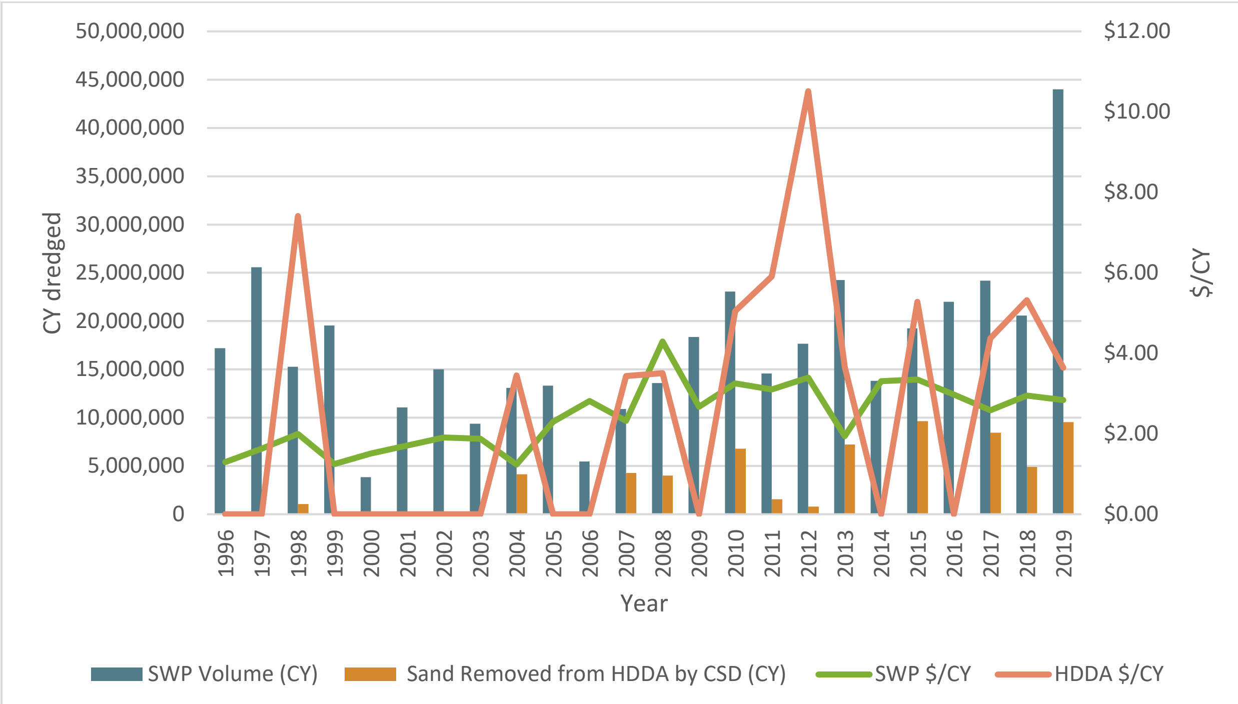

Figure 6: Comparison of total Southwest Pass dredged volumes and dredging unit costs to HDDA volumes and dredging unit costs for 1996-2019.

Long-term (1996–2023) average annual quantities of sediment removal for the entire SWP reach (including HDDA) was ~20 MCY, while for the same timeframe removal from HDDA was ~3.4 MCY (USACE, n.d.). Recent annual averages (2019–2023) of sediment removed from HDDA were ~6.3 MCY (USACE, n.d., 2023b). Essentially, there is a renewable sand resource at HDDA that has to have been cleaned out more frequently over the past decade, resulting in increased annual costs to manage this dredged sediment and ensure there is capacity in existing cleared placement sites.

Beginning in FY 2020, the USACE began deepening the Mississippi River to 50 ft. Construction of the deepening was done in response to the Panama Canal expansion project and to enable the Mississippi River to accommodate Post Panamax deep draft ships (USACE, 2018). The deepening of SWP began in FY 2020. Southwest Pass dredging records (ending in FY 2021) associated with the deepening, indicate that the majority of the sediment was beneficially used for bankline stabilization and/or wetland development, and not disposed in the HDDA (USACE, n.d.). Since most disposal related to the deepening did not occur in the HDDA, projections of sand availability from the HDDA in this analysis have not been skewed. Federal Standard regulations and limitations of existing disposal areas (NEPA, property rights, etc.), impose a geographic limit in which cutterheads dredging sediment from the HDDA can place dredged sediment (Figure 7).

Table 1. Historic HDDA cleanout contract volumes, unit costs, and total contract costs converted to 2023 dollars. Note, data only available through 2021 from USACE. Highlighted values are discussed further in Section 4.0 and 5.0.

Fiscal year	Sand placed into HDDA by hopper dredges (CY)	Sand removed from HDDA by CSD (CY)	$/CY (2023 dollars) for HDDA cleanout contract	HDDA cleanout contract value (2023 dollars)
1996	4,523,643	-	$ -	$ -
1997	6,834,574	-	$ -	$ -
1998	5,379,303	1,051,661	$ 7.41	$ 7,795,427
1999	3,374,550	-	$ -	$ -
2000	1,762,413	-	$ -	$ -
2001	1,835,445	-	$ -	$ -
2002	6,731,179	-	$ -	$ -
2003	2,371,043	-	$ -	$ -
2004	3,124,549	4,124,598	$ 3.45	$ 14,241,687
2005	6,273,615	-	$ -	$ -
2006	2,825,820	-	$ -	$ -
2007	6,011,974	4,266,078	$ 3.43	$ 14,637,130
2008	6,965,801	4,013,912	$ 3.51	$ 14,086,447
2009	9,605,685	-	$ -	$ -
2010	11,954,802	6,793,848	$ 5.05	$ 34,313,230
2011	6,798,443	1,538,859	$ 5.91	$ 9,094,663
2012	5,604,011	787,274	$ 10.51	$ 8,277,149
2013	6,735,331	7,235,381	$ 3.67	$ 26,523,573
2014	3,755,816	-	$ -	$ -
2015	5,227,431	9,646,404	$ 5.28	$ 50,943,166
2016	7,009,809	-	$ -	$ -
2017	6,463,950	8,432,365	$ 4.37	$ 36,888,173
2018	6,738,808	4,891,195	$ 5.32	$ 26,021,724
2019	18,455,392	9,525,553	$ 3.64	$ 34,674,616
2020	9,771,334	4,008,790	$ 3.64	$ 14,588,338
2021	6,613,332	13,480,852	$ 5.16	$ 68,258,198
Average per event	6,259,541	5,699,769	$ 5.03	$ 25,738,823
Annualized value	6,509,922	3,324,865	N/A	$ 15,014,313
50-year annualized projection	325,496,106	166,243,271	N/A	$ 750,715,670

The existing MRSC sediment management strategy from Baton Rouge downstream to the Gulf, as summarized above, provides for a unique opportunity in which restoration-quality sand is continuously delivered to the coastal area where it must be mechanically removed from the channel on an annual basis. The method USACE employs to mechanically assist sediment transport through the Deep Draft Crossings and the efficient natural sediment flushing through the Transfer Reach can be considered together as a nature-based solution for sand delivery to the sand-starved coast. If combined with an additional step of using the sediment removed from the river at the HDDA to construct coastal restoration projects such as those identified in the Louisiana Coastal Master Plan, a large portion of MRSC maintenance dredging (including that conducted in the Deep Draft Crossings) could be considered beneficial use. This presents a mutually beneficial opportunity in which CPRA requires sand along the coast, and the USACE has an excess supply in the HDDA that can be applied to meet their goals of 70% beneficial use of dredged material by 2030.

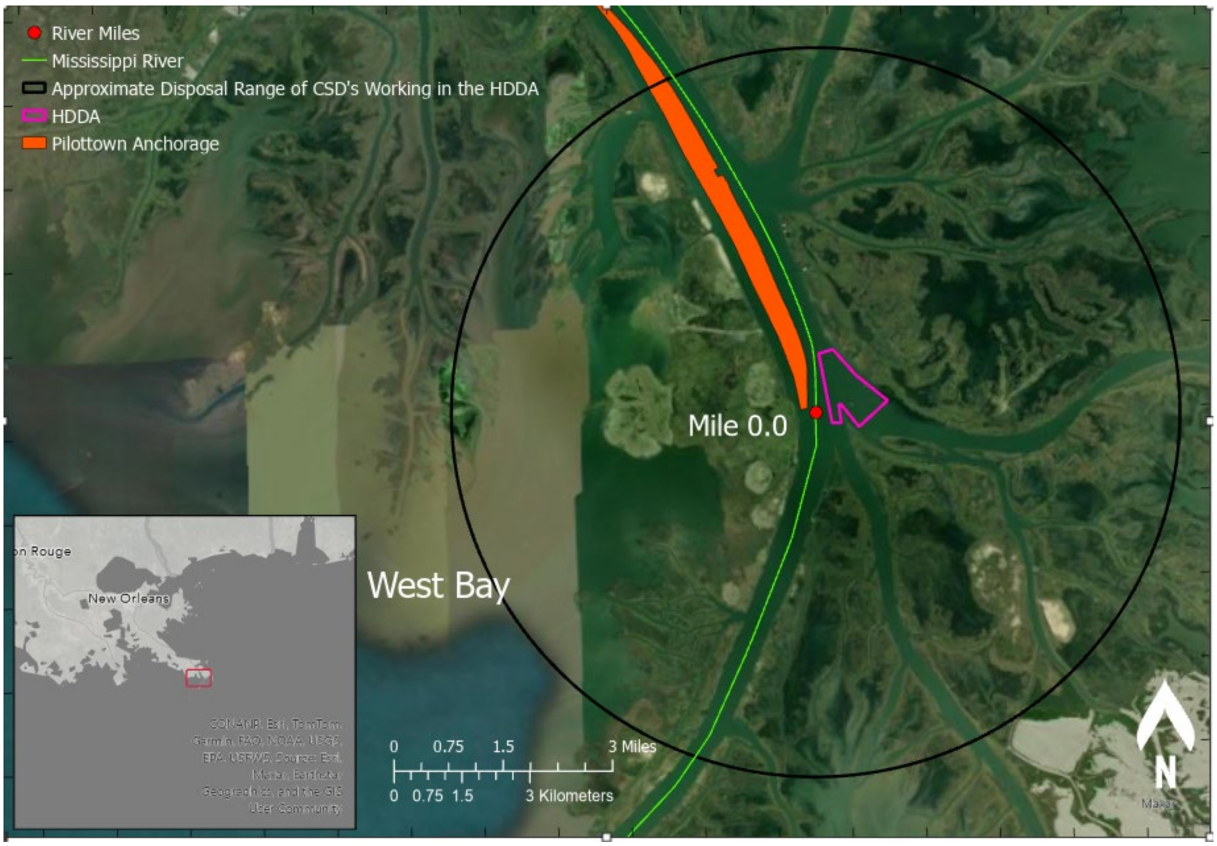

Figure 7. Depiction of the approximate disposal range (white circle) for cutterhead dredges working in the HDDA. Images sourced from USACE Lower Mississippi River Stakeholder Meeting on Aug. 29, 2023.

1.3. LOWERMOST MISSISSIPPI RIVER SEDIMENT BUDGET: DOWNSTREAM EFFECTS OF RIVER SAND MINING AT VENICE ANCHORAGE

While it is important to understand USACE's historic sand management practices within the LMR to inform an RSM strategy, it is also important to understand the influences of other restoration objectives and actions undertaken by CPRA and their implications on sand supply uncertainty in the LMR. These activities typically fall into one of two categories:

- Past and future dedicated dredging of bars upstream of HDDA in the LMR's Transfer and upper SWP reaches for marsh restoration purposes (Table 2), and

- The future potential implementation and operation of sediment diversions within the LMR, which will alter stream power and remove some fraction of the sand load depending on the hydrograph and operational regime of the structure.

While the full impacts of potential future sediment diversion operations to downstream sediment supply remain somewhat uncertain, Georgiou et al. (2023) analyzed the downstream effects of mining the Venice Anchorage, which was recently utilized as the borrow source to provide nearly 11 MCY of high sand-content sediment for the BA-0203 Spanish Pass Marsh and Ridge restoration project (CPRA, 2023b). Numerous other such dedicated-dredging projects that mine predominantly sandy deposits of river channel bars have occurred within the transport reach in the past two decades or are planned for the near future (CPRA, 2022). A numerical modeling analysis conducted to examine potential impacts of such sand mining on the river's sediment budget estimated that mining the Venice Anchorage would reduce downstream maintenance dredging by 3–9%, depending on the annual hydrograph (Figure 8; Georgiou et al., 2023). The reduction in maintenance dredging volume corresponding to the 3–9% was 15–100 times smaller than the sediment volume captured by the excavated dredge pit at the Venice Anchorage. This suggests that the dredge pit, beyond reducing maintenance dredging, captured sediment that would otherwise deposit in the Pilottown Anchorage Bar or further downstream (model projected an ~500,000 CY decrease in sedimentation at Pilottown Anchorage with the dredge pit). In other words, if the pit was not present, there would be 3–9% more maintenance dredging as well as deposition at the anchorages and downstream passes outside of the annual navigation channel dredging template that require periodic maintenance.

Table 2. CPRA projects which have mined river sand for restoration in the transfer reach[1].

CPRA ID	Project Name	Project Status
BA-0039	Bayou Dupont Sediment Delivery System	Built
BA-0040	Riverine Sand Mining/Scofield Island Restoration	Built
BA-0042	Lake Hermitage Marsh Creation	Built
BA-0043	Mississippi River Long Distance Sediment Pipeline	Built
BA-0048	Bayou Dupont Marsh and Ridge Creation	Built
BA-0141	Lake Hermitage Marsh Creation Increment 2	Built
BA-0164	Bayou Dupont Sediment Delivery and Marsh Creation #3 and Terracing	Built
BA-0173	Bayou Grand Cheniere Marsh and Ridge Restoration	In Planning
BA-0207	Large Scale Barataria Marsh Creation	Built
BA-0240	Grand Cheniere Ridge Marsh Creation	In Construction
BA-0257	Grand Bayou Ridge and Marsh Creation Increment 2	In Planning
BS-0033	East Bank Sediment Transport Corridor	In Planning

These projects collectively represent nearly 50 MCY of sediment extraction from the Mississippi River from 2010 through 2030. Complex interactions between sediment trapping as borrow pits infill, sediment

[1] https://cims.coastal.la.gov/outreach/projects/

and water removed from the channel via diversions, and navigation channel sediment dynamics and maintenance dredging have and will continue to influence sand supply uncertainty. Further development and refinement of decision support tools such as those presented in Georgiou et al. (2023) to quantify sediment budgets and adaptively manage sediment resources are needed.

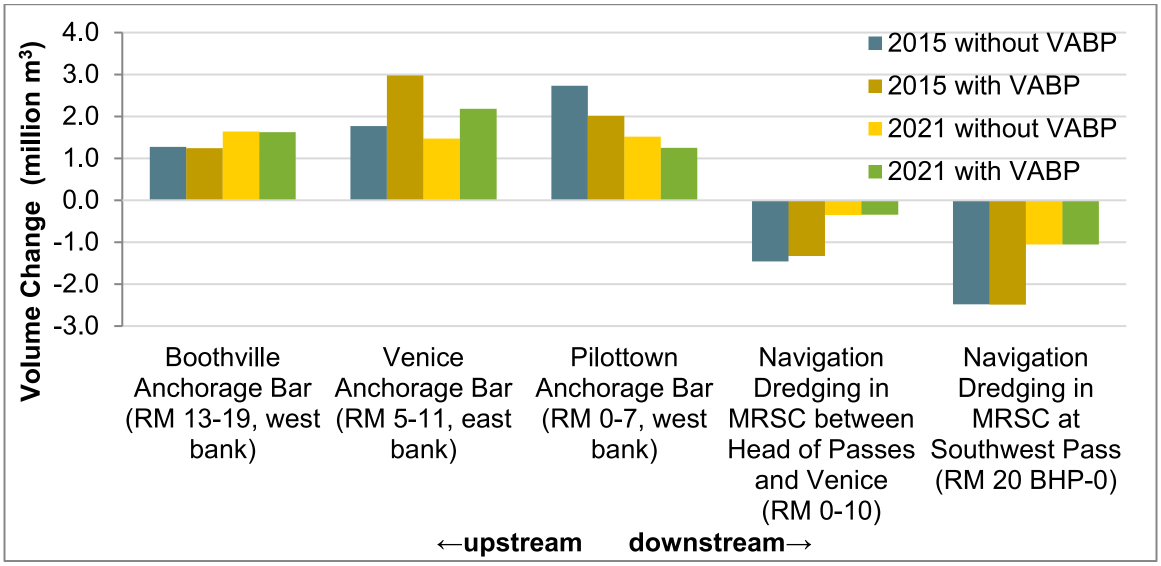

Figure 8. Volume changes at sand bars and dredged volumes from the MRSC between Venice (RM 13) and SWP (RM 20 BHP) for scenarios without and with the Venice Anchorage Borrow Pit (VABP, RM 8) for 2015 and 2021 hydrographs. From Georgiou et al. (2023).

1.4. GRAIN SIZE AND RELATIONSHIP TO BARRIER PROJECT PERFORMANCE

A key consideration for state and federal decision makers is that restoration-quality sand for barrier shoreline restoration purposes should be considered a commodity due to its cost to obtain, transport, and retain within a desired footprint over decadal time scales. A benefit of using sand from the HDDA to restore barrier shorelines within the Barataria Bight is coarser grain size of the HDDA sand versus much of what has been previously identified offshore. Due to the re-handling by multiple dredges, sand placed into the HDDA has been “washed” twice, which results in the removal of fines during operations. That is, sand that is excavated from the navigation channel moves through a hopper dredge’s hydraulic system, where many of the fines remain suspended in the slurry that overflows out of the hopper, a process to remove water from the slurry as denser (coarser-grained) solids are retained. Furthermore, once the contents of the hopper are dumped into the HDDA, the Mississippi River’s natural currents carry the lighter fine materials away, leaving coarser sand to be deposited in the HDDA. There is further loss of fines that occurs during the cutterhead dredging for HDDA cleanout as the cutterhead entrains the material that is pumped into the dredge plant. This phenomenon of sorting and coarsening during dredging operations has been documented and quantified—with up to 90% of fine material removed during dredging and rehandling—and has been proposed as a methodology to enhance sediment resource quality for beach and barrier island restoration (Smith et al., 2019). Coarser grain sizes have been demonstrated to be less mobile than finer sands under the energetic wave conditions experienced along the Louisiana coast during tropical cyclone impacts (Georgiou, Kime, et al., 2019). Barrier island projects constructed with 200 µm and approximately 5 % fines that transport sand 15–20 miles have been analyzed to be more cost-effective than those constructed with lower quality sediments obtained from proximal sources (156 µm, 20% fines transported 3–5 miles; Caffey et al., 2022). For context, historic CPRA practice, for most of the islands within the Barataria Bight except for the Caminada Headland and Scofield Island, has been to deliver sand like the 156-µm class from dedicated offshore borrow sources; however, CPRA has transported sand long distance (over 10 miles), such as for Caminada Headland, when coarser-grained Ship Shoal sand were barged to the project location and for Scofield Island, where coarser-grained Mississippi River sand were pumped via a series of boosters to the project location.

When considering sand as a commodity, the economics of the commodity should be considered beyond the historic 20-year design life employed by most barrier shoreline restoration projects. The volume of sand placed and remaining within the littoral system on multi-decade timescales on the order of 50 years or more should be considered when comparing costs of restoration activities and their benefits. This is especially true for sand that remains on subaerial portion of barrier islands, providing maximum benefits (Figure 9; Caffey et al., 2022). Although the capital cost is higher initially for the coarser grained material, it provides benefits farther into the future and is therefore more cost effective because of increased island areas over 50 years when compared to similar projects constructed with finer sand. In Figure 9, the blue line represents coarser grained sand placement, in this case from Ship Shoal in the Outer Continental Shelf (OCS) and transported 15-20 miles to the project site. OCS sand can be considered representative of HDDA sand in terms of mobility due to their similarity in grain size and percent fines material (personal communication Weeks Marine, 2023; personal communication Gordon Thomson, Baird 2022). The brown line represents the historic practice of barrier island restoration in the Barataria Bight, of placing finer-grained sand from nearshore (NS) sources. Over the 50-year timeframe of the analysis, the coarser-grained material was retained in greater volume and barrier island land area was greater than the project using nearshore, finer-grained sand.

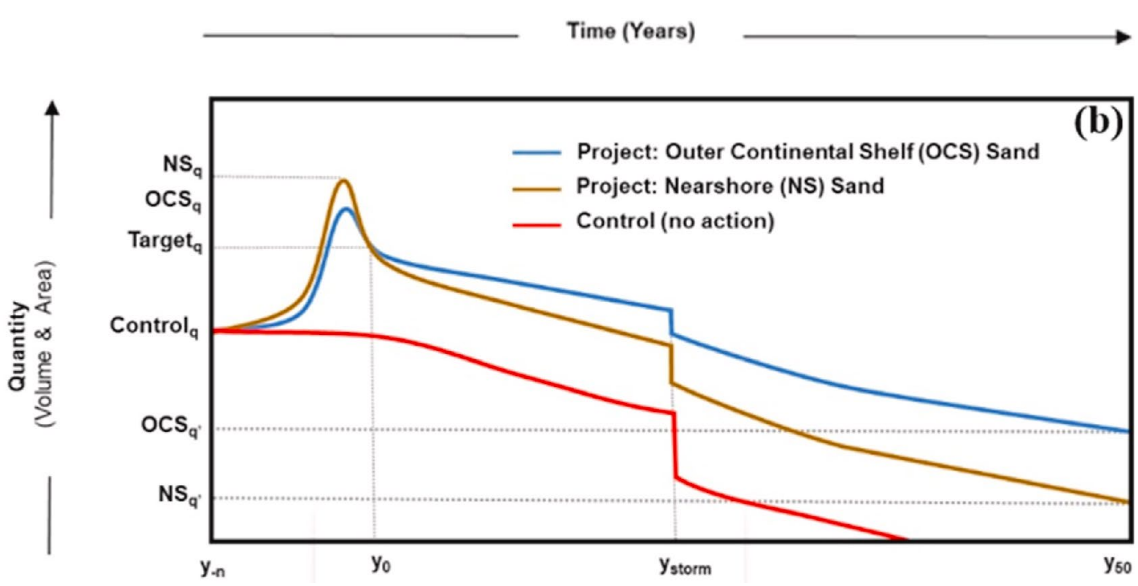

Figure 9. Relationship of sand grain size and island longevity from Caffey et al. (2022).

2.0 STAKEHOLDER ENGAGEMENT

To better define stakeholder issues related to LMR sediment management and identify opportunities for successful and mutually beneficial RSM practices, a series of meetings and discussions were held between The Water Institute, CPRA, and various federal and state stakeholders and private partners (Table 3). The Head of Passes region along the Mississippi River is a dynamic area with ongoing activities related to navigation and maritime commerce, recreation, wildlife management, and restoration. Various stakeholders converge in this vicinity, and at times, have conflicting interests. For example, wildlife managers of Delta National Wildlife Refuge (NWR) and Pass a Loutre Wildlife Management Area (WMA) prefer to have the distributaries (South Pass and Pass a Loutre) regularly dredged to maintain freshwater flow and sediment delivery into these areas for ecosystem and recreational benefits. However, navigation stakeholders prefer to have flow concentration within SWP maximized to maintain stream power and reduce shoaling in the channel. Sensitivities (both current and historical) exist between various stakeholders, and it is important context to consider when determining pathways for success regarding an RSM strategy. A structured approach of engagement such as that employed as part of Structured Decisions Making approaches is key to defining the problems, opportunities, tradeoffs, etc. among stakeholders. This enables collaboration toward a viable solution aiming to address concerns across the entire spectrum of stakeholders.

Table 3. Stakeholders engaged as part of the Regional Sediment Management task.

Associated Branch Pilots	Louisiana Maritime Association
Big River Coalition	Pontchartrain Conservancy
Coalition to Restore Coastal Louisiana	Ports Association of Louisiana
Crescent River Port Pilots' Association	National Wildlife Federation
Environmental Defense Fund	United States Army Corps of Engineers – Engineering Research and Development Center
Great Lakes Dredge and Dock Company	United States Army Corps of Engineers – Mississippi Valley Division
Louisiana Coastal Protection and Restoration Authority	United States Army Corps of Engineers – New Orleans District
Louisiana Department of Natural Resources	United States Fish and Wildlife Service
Louisiana Department of Transportation and Development	Weeks Marine

Early iterations and alternatives of the RSM strategy were brought forth to a variety of stakeholders with a vested interest in the region. The primary goal was to explore the feasibility of utilizing HDDA-sourced sand for barrier island restoration in the Barataria Bight, and what that process would look like operationally. The remainder of this section will touch on concerns, obstacles, pathways to success, and other insights derived from feedback provided by stakeholders based on the cursory engagements that were intended to serve as a high-level fact-finding and problem definition exercise.

SWP is the gateway to the Mississippi River and all the commerce that flows through it. Maintenance of the navigation channel in this area is paramount not only for Louisiana, but the nation. As outlined in this report, much of the maintenance dredging in SWP and dredged sediment from HDDA are dedicated to beneficial use (e.g., bank stabilization or wetland creation/restoration). These efforts are critical to maintaining both the banks of SWP and the surrounding marshes which help buffer against storm damage. Some stakeholders view these projects as a necessity to maintain the MRSC and the commerce it supports. For this reason, the priority placement site for sediment sourced from SWP maintenance dredging must remain dedicated to maintaining the integrity of the channel banks and wetlands that protect them around the Head of Passes region.

The navigation industry is accustomed to and highly familiar with typical dredging operations in SWP and the surrounding Head of Passes region. One of the biggest concerns and the pathway to success surrounding dredging operations and the navigation industry is to have communication with sufficient lead time for proper planning. Disruptions to the navigation channel (brief channel closure for submerged pipeline placement, dredging operations causing one-way ship traffic, etc.) can all occur, as long as the stakeholders are engaged ahead of time and the frequency of those disruptions does not exceed those that have typically occurred historically. Many beneficial use projects and emergency operations have sourced sediment from HDDA (e.g., Delta NWR wetland restoration, sand berm construction during the *Deepwater Horizon* event, etc.). These projects all required coordination with various stakeholders and have included a wide range of operations (towed scow barges, submerged dredge pipeline placement, etc.). The various alternatives explored in this report were brought to stakeholders. The overwhelming sentiment was that the navigation industry can work with dredging operations if proper planning and frequent communication is in place. This reiterated the need for a structured process.

Due to existing USACE operations at HDDA, including costs incurred to maintain capacity through cleanouts, HDDA is seen as the preferred borrow area location for this RSM strategy. However, throughout the course of stakeholder engagement, many discussions focused on using Pilottown Anchorage as a potential borrow area or even an alternative HDDA location (Figure 1). Pilottown Anchorage is seen as a critical resource among stakeholders and serves as the first available anchorage (most downstream) for vessels entering from the Gulf of Mexico, so it is a critical component to navigation safety. At present, large portions of the anchorage have shoaled, and the anchorage's full extent is not available for use by deep-draft vessels. This poses a significant safety concern for stakeholders should a navigation emergency arise. Utilizing the Pilottown Anchorage as a borrow area was identified as a "win-win" opportunity among stakeholders; recurrent dredging of the anchorage could be used as a renewable sand resource at Head of Passes while simultaneously providing sufficient draft of the anchorage for navigation use. Additionally, the anchorage lies west of the authorized navigation channel, and if pipelines were to be used to transport sand from the anchorage, it was not foreseen that any disruptions to the navigation channel would occur. This alternative of mining Pilottown Anchorage instead of (or in addition to) leveraging the existing dredging that already occurs at HDDA is not explored further here but is noted as an important consideration by the navigation sector as a potentially significant source of renewable sand for coastal restoration.

Throughout the engagement process, concerns surrounding flow loss in SWP to other distributaries, crevasses, and overbanking in the Head of Passes region and attendant shoaling that occurs in SWP were brought forth by stakeholders. Routine dredging in distributaries (South Pass, Pass a Loutre, Main Pass, etc.) are included in USACE Operations and Maintenance (O&M) and are viewed by stakeholders as having both positive and negative effects. Dredging of these channels has the potential to capture additional flow, but at the same time, maintenance of these channels plays a key role in: 1) decreasing vessel traffic congestion in SWP by providing alternative routes for shallow draft vessels and 2) enhancing delivery of freshwater, sediment, and nutrients to the wetlands that comprise Delta NWR and Pass a Loutre WMA.. Additionally, there is significant concern for bank line failures along the east side of the Mississippi River (e.g., Neptune Pass) and the resultant loss of flow outside the main navigation channel. Specifically, recent flow losses stemming from Neptune Pass have caused shoaling in the navigation channel north of Venice, requiring maintenance dredging operations to clear portions of the channel within the most downstream section of the Transfer Reach above Venice that historically have not required maintenance dredging (USACE, 2023a).

Overall, the Head of Passes region encompasses a wide range of stakeholders operating in an ever-changing landscape. This commonly results in an intricate interplay between individual stakeholder concerns and interests. Despite competing interests between stakeholders, proper engagement can uncover “win-win” opportunities among stakeholders. The likelihood of establishing a programmatic RSM strategy around Head of Passes is highly dependent on continued collaboration and communication among stakeholders. A primary goal of stakeholder engagement was to assess the feasibility of utilizing HDDA-sourced sand for barrier island restoration projects in the Barataria Bight region, which has been treated as a programmatic project in the 2017 and 2023 CMPs, and ensure that disruptions to navigation would be absent or minimal. The proposed strategy garnered support among stakeholders and all agreed it could be a mutually advantageous outcome if done properly with a structured plan for communication, coordination, and monitoring, indicating a promising path forward to the viability of the RSM strategy outlined in this report.

3.0 SEDIMENT DELIVERY ALTERNATIVES, COST CONSIDERATIONS, BENEFITS, AND TRADEOFFS

A high-level alternatives analysis was conducted to assess programmatic benefits that may be gained from a renewable LMR sand source and elimination of the need and costs for offshore sand searches, regulatory processes and costs required to mine offshore sediment, and leveraging activities and funding across state and federal agencies to align for sand delivery to the coast.

It is advantageous, and ultimately will be necessary, for state and federal entities to coordinate on sand sourcing for barrier shoreline restoration within the Barataria Bight due to offshore sand resource constraints and certain favorable aspects of Mississippi River sand from HDDA, such as its superior grain size and renewable nature. Analysis was conducted to determine the range of activities and costs associated with implementing programmatic sand delivery to the shorelines of the Barataria Bight.

3.1. HISTORIC BARRIER SHORELINE RESTORATION PRACTICE

The sandy shores of the Barataria Bight, extending from Belle Pass in the west to Scofield Island in the east, were selected for a feasibility analysis of programmatic sand mining and transport due to the robust history of restoration conducted by CPRA since 2005 (Table 4, Table 5 and Figure 10) and due to the proximity to the Mississippi River sand source. All past projects that have restored sandy barrier shoreline in this area have been dedicated dredging projects, where individual islands were restored using borrow sources that were identified, designed, and permitted specifically for that specific barrier island restoration project.

To generate estimates of future sand availability and demand, several governing assumptions were made concerning sand supply and demand:

Future HDDA cleanout volumes will be at least equal to what has been observed over the past two decades (since 2004). USACE dredging contracts from 1996–2021 were analyzed to determine the annual sand availability that may be expected from HDDA (Table 1). Prior to 2004, HDDA cleanout contracts were rare; thus, this analysis calculated the average cleanout contract volume from 2004–2021 to be approximately 3.4 MCY/yr. (Table 1). It is assumed that this volume would be available for restoration purposes. Other USACE navigation dredging activities, such as sand placement along the banks of SWP for bank maintenance or sand placement into ODMDS were not factored into the calculations. These activities are essential to maintain the integrity of the Southwest Pass channel (e.g., bank maintenance) and reduce channel closure times by disposing in the nearest disposal areas (e.g., dredge-and-haul to ODMDS), therefore associated quantities related to these operations were not included.

Table 4. Past barrier shoreline restoration projects within the Barataria Bight[2].

CPRA Project ID	Project Name	Approximate Year Dredging Completed[3]	Sand Volume Dredged from Offshore (CY)	Sand Volume Dredged from Other Sources CY)[4]	Total Sand Volume Dredged (CY)
BA-0038[5]	Pass La Mer to Chaland Pass Restoration (Chaland Headland)	2007	2,443,500	-	2,443,500
BA-0035[6]	Pass Chaland to Grand Bayou Pass Barrier Shoreline Restoration (Bay Joe Wise)	2009	2,066,472	-	2,066,472
BA-0030[7]	East Grand Terre	2010	2,735,444	-	2,735,444
N/A	Oil Spill Emergency Berms[8]	2012	-	6,650,000	6,650,000
BA-0038[9]	Pelican Island	2013	3,486,000	-	3,486,000
BA-0040[10]	Riverine Sand Mining/Scofield Island Restoration	2014	-	1,940,000	1,940,000
BA-0110	Shell Island East	2014	-	2,293,522	2,293,522
BA-0045	Caminada Headland Increment 1	2016	-	3,650,000	3,650,000
BA-0143	Caminada Headland Beach and Dune Restoration Increment 2	2017	-	5,470,000	5,470,000
BA-0076	Cheniere Ronquille	2018	1,866,214	-	1,866,214
BA-0111	Shell Island West-NRDA	2022	-	4,783,857	4,783,857
BA-0197	West Grand Terre Beach Nourishment and Stabilization	2007	5,310,000	-	5,310,000
Totals			17,907,630	24,787,379	42,695,009

[2] Values do not include small restoration activities along the Grand Isle shoreline, where data on volumes and costs were unavailable.

[3] Varying CPRA sources inconsistently attribute project completion to the end of all construction activities, such as island shaping, plantings, or sand fence installation rather than the completion of dredging activities.

[4] Other sand sources used to restore barrier shoreline within the Barataria Bight include Ship Shoal and the Mississippi River.

[5] https://cims.coastal.la.gov/RecordDetail.aspx?Root=0&sid=1301#

[6] https://cims.coastal.la.gov/RecordDetail.aspx?Root=0&sid=1302#

[7] https://cims.coastal.la.gov/RecordDetail.aspx?Root=0&sid=1210#

[8] LA-0163 https://cims.coastal.louisiana.gov/outreach/projects/ProjectView?projID=LA-0163

[9] https://cims.coastal.la.gov/RecordDetail.aspx?Root=0&sid=12036

[10] https://cims.coastal.la.gov/RecordDetail.aspx?Root=0&sid=12028

Table 5. Costs of barrier shoreline sand placement projects within the Barataria Bight shown in original and inflated to 2023 dollars (rounded to the nearest million) using USACE Civil Works Construction Cost Indexing System data for beach replenishment. These costs are representative of 20-year design lifespan of the projects.BA-0038 had two increments, however its costs have been combined.

CPRA Project ID[11]	Year Completed	Dollars at Completion[12]	2023 Cost	CY Dredged (sand)
BA-0038	2007, 2013	$53,000,000	$88,000,000	5,930,000
BA-0035	2009	$37,000,000	$57,000,000	2,066,000
BA-0030	2010	$25,000,000	$38,000,000	2,735,000
BA-0040	2013	$61,000,000	$87,000,000	1,940,000
BA-0110	2014	$48,000,000	$65,000,000	2,294,000
BA-0045	2014	$71,000,000	$96,000,000	3,650,000
BA-0143	2016	$147,000,000	$190,000,000	5,470,000
BA-0111	2017	$101,000,000	$128,000,000	1,866,000
BA-0076	2018	$39,000,000	$39,000,000	4,784,000
BA-0197	2022	$102,000,000	$110,000,000	5,310,000
Total		$676,000,000	$898,000,000	36,045,000

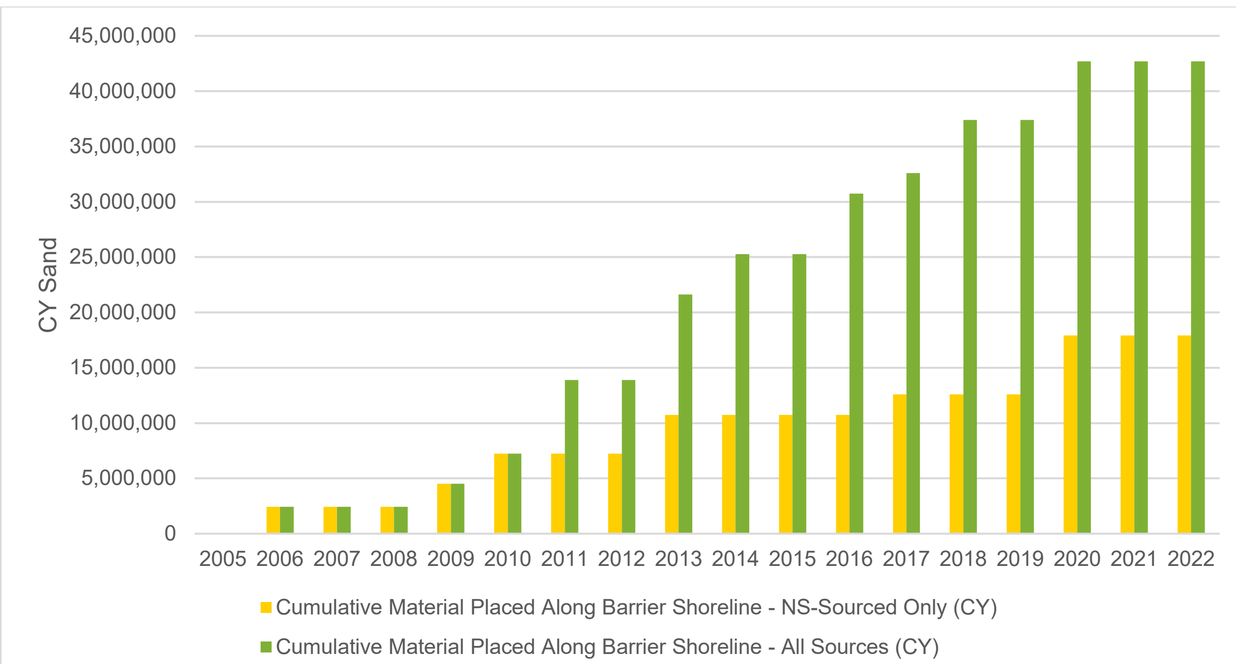

Figure 10. Amount of sand placed along the Barataria Bight shoreline from 2005 to 2022 from nearshore (NS) and all other (e.g., Ship Shoal, Mississippi River) sources.

[11] The emergency oil spill berms constructed in 2010–2011, costing approximately $251M to deliver 6,650,000 CY of sand, are not included in this list due to the highly unique nature of the project costs.

[12] Project costs at time of completion taken from https://cdn2.assets-servd.host/blue-meerkat/staging/project-assets/PDFs/Appendix_A-Project_Summaries_20230117.pdf

Future sand demand for barrier restoration was estimated by building a matrix of the years of construction completion for each of the projects listed in Table 4 and for Grand Pierre, and assuming that the same volume would be required every 20 years, to correspond to the stated design life for each project. The projects' historic designs do account for relative sea-level rise, but many projections used are outdated. As an example of the sand demand estimation system used. Pelican Island received approximately 3.5 MCY of sand in 2013 for a 20-year design life, and the authors assume here that the same amount of sand would need to be placed in 2033 and 2053. The only shoreline within the system which has not been restored to date is the island referred to as Grand Pierre. Since it has no historic renourishment data, estimates from CPRA's 2023 Master Plan were used. In total, the 50-year sand demand for the Barataria Bight barrier shoreline was estimated to be 114.8 MCY, or approximately 2.3 MCY/yr. versus the estimated annual availability of 3.3 MCY listed in Table 1. See Appendix A for further discussion on volume availabilities, retention factors, loss rates, and placed volume considerations versus the annual sand availability from the HDDA.

3.2. ALTERNATIVES LIST

Past projects requiring complex sand delivery schemes by CPRA and USACE, such as those utilizing long-distance pumping or barge transport, were evaluated to generate feasibility-level alternatives of possible sand delivery strategies. A total of 14 alternatives were generated, which include combinations of sand pumping via CSD, waterborne transport via scow barge (barge), and intermediate stockpile locations allowing for future access of sand for restoration purposes. A 14th alternative was formulated at the end of the analysis to minimize the costs calculated from the other alternatives through mixing delivery methods. The combinations of alternatives are organized under three groupings with common features (Table 6).

Table 6. Summary of three groups of programmatic alternatives for sand delivery to the Barataria Bight shoreline from the HDDA.

Means of Transport	Handoff Point	Means of Transport
Barge or CSD	Tiger Pass Stockpile	Barge or CSD
Barge or CSD	Scofield Back Barrier Stockpile	Barge or CSD
Direct Barge to Islands or Combination of CSD and Direct Barge to Islands		

1. The first group encompasses four possible combinations of barge and/or CSD transport
    a. From a CSD stationed within HDDA to a stockpile location near the Tiger Pass jetties either by barge (loaded via a spider barge) sailed through SWP or by direct pump via CSD across West Bay (Figure 11).
    b. From a CSD stationed at the Tiger Pass stockpile either by barge (loaded via a spider barge) sailed cross the Barataria Bight or by direct pump via CSD across the Barataria Bight via booster pumps (Figure 12).
2. The second group of alternatives has the same four possible combinations of transport, but the stockpile would be located approximately one mile north of Scofield Island in the protected waters of Scofield Bay. It also considered two alternative barge sail routes: through SWP as in the first group of alternatives, as well as upriver to Empire, where an unloader and series of booster pumps would then transport the sand to the stockpile in Scofield Bay.

3. The third is a single alternative which would not include a stockpile, but rather a continuous delivery of sand from a CSD stationed within HDDA (either direct pump to proximal islands, barges loaded via spider barge, or a combination thereof depending on distance to barrier island fill site) and transported through SWP and across the Barataria Bight directly to each island where an unloader would be stationed (Figure 13). This alternative would require programmatic coordination between USACE and CPRA to ensure scheduling of barrier island project engineering and design (E&D) and permitting is synchronized with HDDA cleanout needs and schedule.

The rationale behind each of the alternatives was that the USACE removes a volume of sand annually from HDDA, whereas CPRA has an infrequent, less-consistent demand for sand for barrier projects from year to year. Direct transport via barge or transfer and stockpiling facilities outside of HDDA could create a constant, reliable supply of restoration-quality sand accessible to CPRA for its needs. However, as described above in alternatives group 3, coordination between CPRA and USACE to align barrier island restoration project construction with HDDA cleanouts is also considered. As previously noted, this is the lowest-cost alternative including when compared to traditional barrier island restoration methods using dedicated dredging of offshore borrow areas.

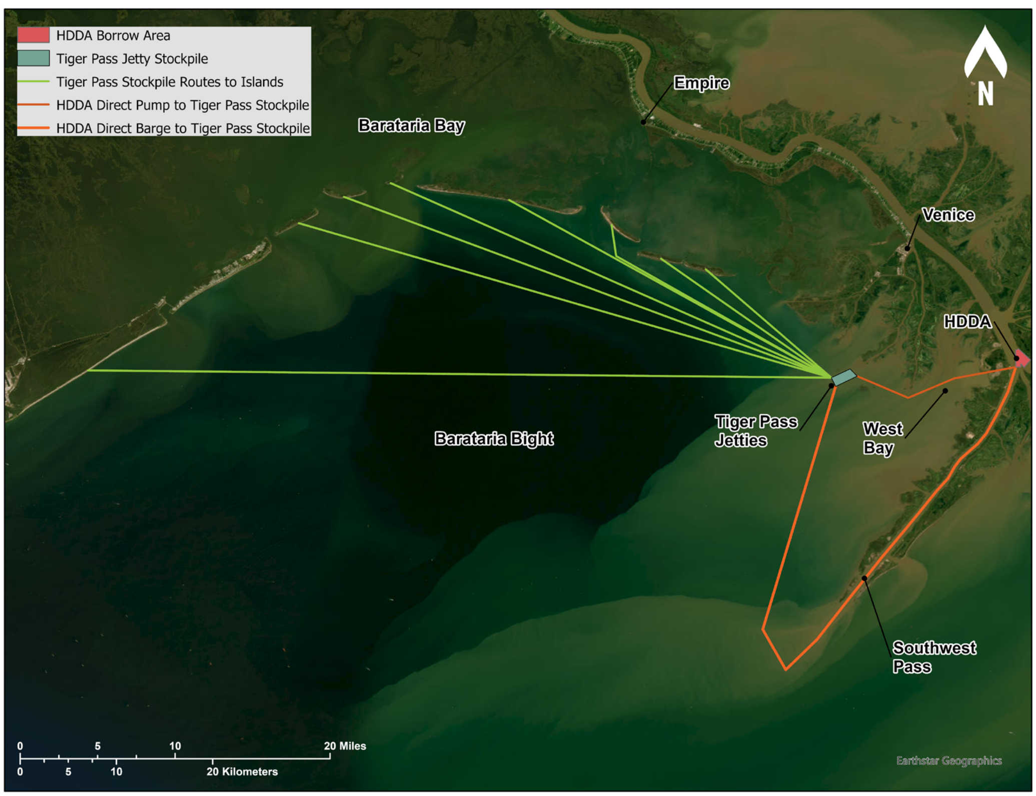

Figure 11. Tiger Pass sand stockpile alternatives group.

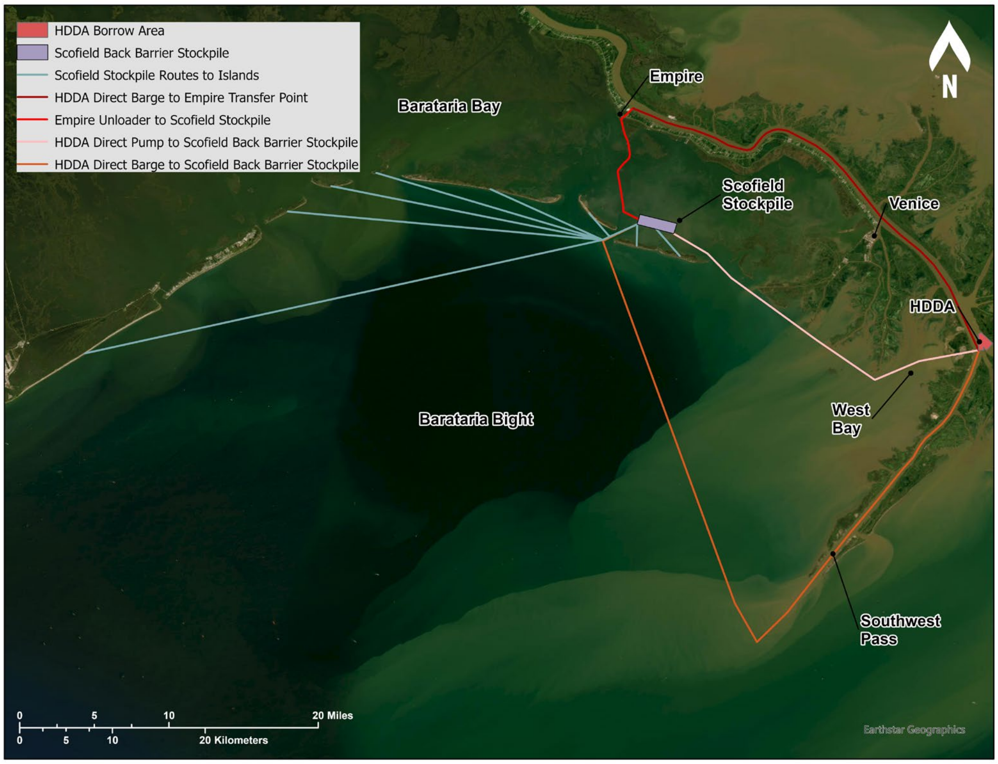

Figure 12. Scofield Island sand stockpile alternatives group.

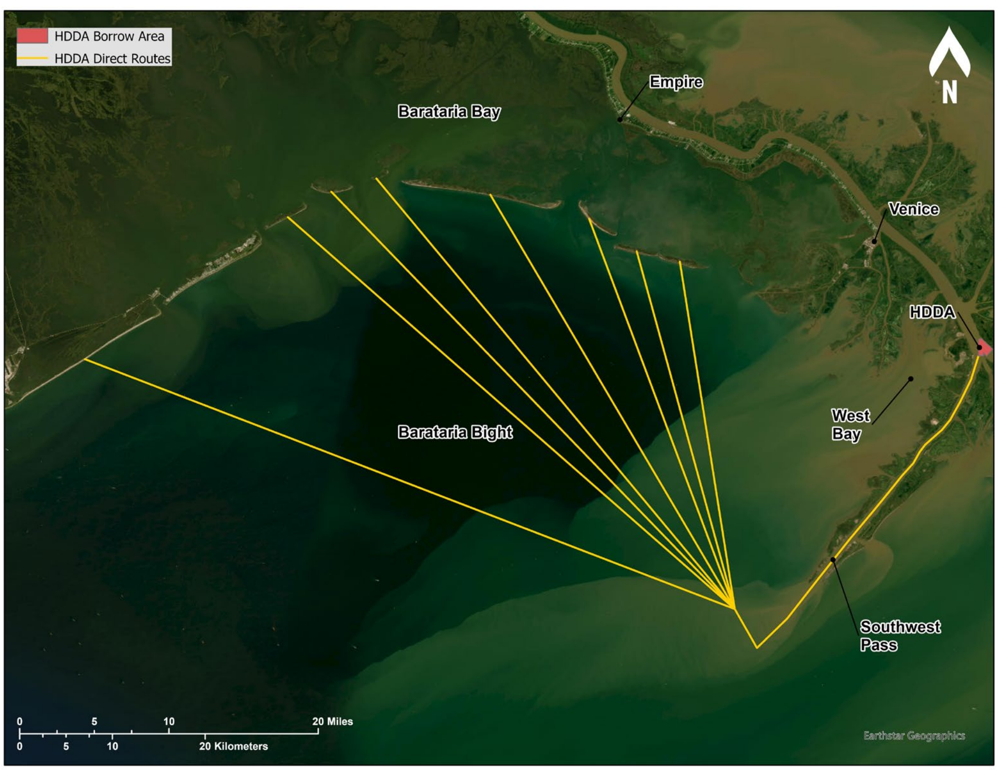

Figure 13. Direct sand transport via CSD and barge alternative.

3.3. ALTERNATIVE FORMULATION ASSUMPTIONS

Many detailed assumptions were made to support the cost estimates. These may vary across each alternative and are discussed further in Appendix A. Although the analysis estimates costs over 50 years (i.e., 2023–2073), all costs are reported in 2023 dollars. Inflation is not included in the estimates. A set of higher-level governing assumptions was made to generate the general alternative characteristics, including:

- All costs are assumed to start from the point of a CSD stationed in HDDA, inclusive of the mobilization and demobilization (mob/demob) and dredging operations costs for CSD. Typically, this is covered under USACE contracts for HDDA cleanout. See Table 1 for historical annualized costs.
- Dredging plant and equipment (e.g., dredges, discharge pipe, booster pumps, scow barges, unloaders, etc.) are always available on the market for the work.
- Parametric estimating percentages were used for E&D, Construction Management (CM), and O&M based on percentages stated in CPRA's 2023 Coastal Master Plan (CPRA, 2023a). A contingency of 30% was used based on CPRA's Marsh Creation Design Guidelines for planning-level analysis (CPRA, 2017b) and in consultation with CPRA Engineering Division staff.
- All costs are assumed to end at a point just offshore of each island. For CSD pipeline transport alternatives, that point is the end of a discharge pipe. For barge transport alternatives, that point is an unloader stationed offshore of the island. All on-island costs to construct and shape material to some specified geometry within the fill template are not included.
- The density of oil and gas industry pipeline infrastructure, compiled by the Bureau of Ocean Energy Management, is too dense to allow for excavation of an access channel and stockpile within West Bay itself, as shown in Figure 14.
- Stockpile placement in offshore locations of the Barataria Bight, including those locations previously mined by CPRA for barrier shoreline restoration projects was deemed infeasible for several reasons. Offshore stockpiling is considered high risk for material loss due to the shallow nature of the Barataria Bight and susceptibility to loss associated with currents generated during tropical cyclones and winter frontal (meteorological) passages. Furthermore, research of other offshore borrow areas mined for barrier shoreline restoration in coastal Louisiana has shown that the borrow pits are likely to infill rapidly, first with fluid mud (Xue et al., 2022), making placement or re-excavation of materials difficult and potentially compromising sand resource quality.
- Capital costs to establish proposed stockpiles, such as pre-dredging access channels and sump areas for sand storage, are included in each relevant alternative's cost estimate.
- In discussion with CPRA Engineering staff, it was decided that any alternative involving mobilization of dredge pipe should assume that for each dredging event (direct pump to restoration or stockpile) the pipe is fully mobilized and demobilized. That is, it is not left in place over long periods for use programmatically across multiple projects. This assumption was deemed less of a liability for the pipe owner than leaving large sections of pipe in place.

Furthermore, CPRA staff communicated that dredge industry representatives strongly prefer to only use their own pipe and would resist accepting the risk or uncertainty of using others' pipe. Cost estimates do not directly capture the unique risk that may be anticipated with deploying long distances of pipe for long periods of time across the open waters of the Gulf but are partially captured in the high contingency value used in the estimates. This is an area of uncertainty that requires refinement in future analyses.

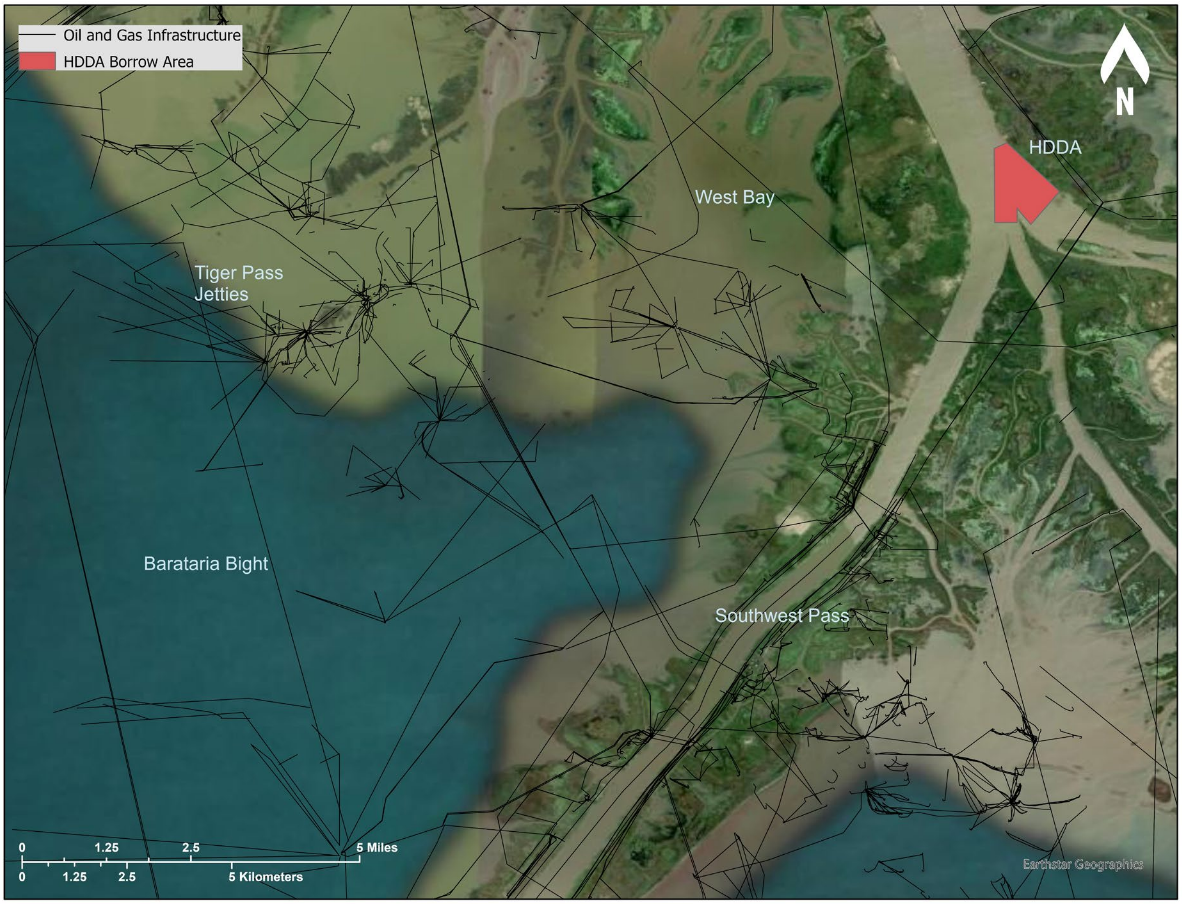

Figure 14. Location of oil and gas pipeline infrastructure in the vicinity of West Bay, LA.

4.0 COST ANALYSIS RESULTS

Cost analysis of the alternatives was performed by Royal Engineers and Consultants, LLC (Royal) under the guidance of The Water Institute. This section presents a summary of the 50-year costs estimated for each alternative (Table 7), presented in 2023 dollars. Detailed cost estimation assumptions, procedures, and background data may be found in Appendix A and its attachments, as well as an accompanying data file.

Please note, these estimates in Table 7 include the cost of mobilizing a dredge to HDDA and the cleanout of HDDA, which must occur regardless of where the sand is transported. This is because the estimates were constructed to optimize equipment selection for long-range transport of sediment within the 14 alternatives. Extrapolating the historic cost to clean out the HDDA and beneficially use sand at nearby locations to 50-year costs yields approximately $750.7M. The HDDA cleanout cost component ranges from 10% to 26% of the total 50-year costs listed in Table 7. While Table 7 values were derived using optimized long-range transport equipment and methodologies assumptions and vary across alternatives, this cost is already incurred by USACE to cleanout HDDA as part of their MRSC maintenance strategy, a process that will continue to be required (with potentially increased volumes based on recent trends Esposito et al., 2021) regardless of barrier shoreline restoration activities. (Esposito et al., 2021) regardless of barrier shoreline restoration activities. Central to the vision of this RSM strategy is that those HDDA cleanout activities and costs are leveraged so that the sand produced can be used for barrier island restoration. Therefore, the annualized cost for HDDA cleanouts is subtracted from the cost of each alternative presented here to derive the programmatic 50-year costs of using HDDA sand for barrier island restoration.

Table 7. 50-year cost estimate for all alternatives in 2023 dollars, rounded to the nearest million.

Alt.	Name	Total 50-year alternative cost (2023 dollars from Appendix A)	Total 50-year alternative cost (2023 dollars, with 50-year HDDA cleanout costs removed)	Alternative cost versus historic comparison	Alternative cost with HDDA cleanout costs removed versus historic comparison
1	CSD transport from HDDA to Tiger Pass stockpile, CSD transport from stockpile to islands.	$3,940,000,000	$3,189,000,000	176%	142%
2	CSD transport from HDDA to Tiger Pass stockpile, barge transport from stockpile to islands.	$4,619,000,000	$3,868,000,000	206%	172%
3	Barge transport from HDDA to Tiger Pass stockpile, CSD transport from stockpile to islands.	$6,471,000,000	$5,720,000,000	288%	255%
4	Barge transport from HDDA to Tiger Pass stockpile, Barge transport from stockpile to islands.	$7,150,000,000	$6,399,000,000	318%	285%
5	CSD transport from HDDA to Scofield stockpile, CSD transport from stockpile to islands.	$4,611,000,000	$3,860,000,000	205%	172%
6	CSD transport from HDDA to Scofield stockpile, barge transport from stockpile to islands.	$4,925,000,000	$4,174,000,000	219%	186%
7	Barge transport from HDDA to Scofield stockpile via SWP, CSD transport from stockpile to islands.	$6,674,000,000	$5,923,000,000	297%	264%
8	Barge transport from HDDA to Scofield stockpile via SWP, Barge transport from stockpile to islands.	$6,985,000,000	$6,234,000,000	311%	278%
9	Barge transport from HDDA to Empire via the Mississippi River, CSD transport from the river to the Scofield stockpile, CSD transport from Scofield stockpile to islands.	$7,050,000,000	$6,299,000,000	314%	281%
10	Barge transport from HDDA to Empire via the Mississippi River, CSD transport from the river to the Scofield stockpile, Barge transport from Scofield stockpile to islands.	$7,362,000,000	$6,611,000,000	328%	294%
11	Direct barge transport from HDDA to islands.	$3,529,000,000	$2,778,000,000	157%	124%
12	Direct transport via CSD from HDDA to islands.	$2,934,000,000	$2,183,000,000	131%	97%
13	Optimized Alternative 1 – Optimized stockpile.	$3,940,000,000	$3,189,000,000	176%	142%
14	Optimized Alternative 2 – Optimized Direct transport to islands.	$2,919,000,000	$2,168,000,000	130%	97%

5.0 DISCUSSION AND NEXT STEPS

5.1. COST DISCUSSION

The objective of this task under LMRMP was to assess the feasibility of utilizing HDDA sand programmatically for barrier island restoration and to conduct a high-level cost analysis to compare this approach to traditional dedicated dredging using offshore or riverine sediment resources. A cost advantage of using HDDA is that costs are already being expended for a dredge to conduct HDDA cleanouts under contract by USACE as part of their standard MRSC maintenance activities. The final estimates provided in Table 6 of this report account for this by subtracting the annualized HDDA cleanout contract cost from the estimates that include mob/demob and dredging in HDDA. Likewise, activities related to development of traditional offshore or riverine sand resources for barrier island restoration projects are not needed with HDDA sand resource, so costs for activities such as sand search, borrow area design, environmental clearance and mitigation activities, and obtaining federal sand use negotiated agreements are not included in the calculations.

Of alternatives 1–12, direct transport via CSD from the HDDA to the islands is the lowest-cost alternative (Alternative 12 in Table 7). If the 20-year costs (i.e., historical costs) presented in Table 5 were multiplied by 2.5 to extrapolate to a comparable 50-year cost, it would equate to $2.25B, excluding the $251M ($354M in 2023 dollars) spent on oil spill emergency berms in 2010–2011. The alternative costs presented in Table 7 range from 130% to 328% the times the extrapolated historic 50-year cost but do not account for savings related to HDDA cleanouts that would not occur. Subtracting HDDA cleanout costs reduces the extrapolated 50-year cost to 97% to 294% of what traditional dedicated dredging approaches would cost. This means that the lowest cost alternatives using HDDA sand could be of comparable or lower cost to the traditional approaches using offshore or riverine borrow areas with dedicated dredging.

Stockpile alternatives are more costly than direct delivery alternatives due to an additional rehandling step. The Tiger Pass stockpile alternatives were generally cheaper than the Scofield Island alternatives. Alternative 14 was the cheapest overall, which optimized a direct transport scheme that utilized a CSD to directly pump sand to the nearest islands extending west and including to the Chaland Headland, at which point barge transport becomes more economical. It is important to note that this alternative would require significant programmatic coordination between stakeholders to synchronize timing of barrier island restoration projects with HDDA cleanout events and demonstrates the value of embracing RSM concepts in cost savings.

5.1.1 Comparison to Historic Cost per Cubic Yard

When historic CPRA barrier shoreline projects within the Barataria Bight are converted to 2023 dollars, the cost per CY ($/CY) averaged $27/CY, with a maximum cost of $41/CY. However, these prices are generated by dividing the total project cost by the total CYs of sand delivered to the project location. Thus, they include ancillary activities, such as borrow source identification and permitting and on-island sand shaping.

Historic bid tabulation from CPRA itemizes fill $/CY independent of other ancillary design or construction costs (like E&D or containment dikes, etc.). For example, BA-0143, Caminada Headland

Beach and Dune Restoration – Increment II had a winning contract bid item of $24.25/CY ($30.45/CY in 2023 dollars). Dividing its total construction cost ($137,015,162) by the CY delivered to the project location (5,025,671 CY) would lead to an estimated $27.26/CY ($34.23/CY in 2023 dollars). Considering the total sand demand assumed to be required to maintain the Barataria Bight shoreline for 50 years (114.8 MCY), estimated values for ranged from $19/CY for Alternative 14–$58/CY for Alternative 10 after the HDDA cleanout activities are removed from the cost total, and $25–$64/CY before HDDA cleanout activities are removed.

The estimate for the optimized Alternative 14 is lower than the historic cost experienced for the Caminada Phase II project due to

- programmatic economies of scale,
- advantages of working in HDDA (with minimal disruptions due to sea-state, reduced costs for development of traditional borrow areas, and leveraging funds already being allocated to dredge mob/demob and production for HDDA cleanouts), and
- efficiencies in the suites of equipment and operations used for the estimate.

Of the $25B CPRA restoration budget identified in its 50-year Master Plan, $2.5B has been identified to fund programmatic restoration projects including BISM, small-scale hydrologic restoration, shoreline protection, and oyster reef restoration (CPRA, 2023a). The estimates in Table 7 (which do not include estimates for the upkeep of the Terrebonne chain or any other sandy shoreline in the state) are often significantly more expensive than what the 2023 Coastal Master Plan currently budgets for barrier maintenance and restoration, further illustrating a need for state and federal stakeholders to work to align areas of sand resource supply and demand to minimize cost.

5.1.2 Discussion of Cost Efficiency Inflection Points for Transport Distance

A long-held uncertainty within the scientific and engineering community has been understanding where geographic or transport distance breakpoints may exist for sand transport. Theoretically, CSD transport is cheaper to some distance, from which barge transport becomes cheaper, since increasing distance for CSD transport requires additional booster pumps and pipeline equipment. The cost estimates generated for this analysis were studied to plot where these breakpoints occur for sand transport to the Barataria Bight shoreline from the HDDA. The cost per CY versus distance comparisons for both barge and CSD transport methods were plotted across the three groups of alternatives to compare the relationships of transport method versus distance (Figure 15). Additional plots and analysis can be found in Appendix A.

When considering fully loaded costs per CY, the point at which it becomes more cost efficient to barge rather than pump from the stockpile to the islands tends to occur at a distance of approximately 50 miles (circled in blue in both figures) as shown in Figure 15 and Figure 16. For the direct delivery alternatives, the point at which it becomes more cost efficient to barge rather than pump from the stockpile to the islands is a complex case. Barging directly requires traversing through SWP and then in some cases, back toward islands close to the HDDA, such as Scofield, Pelican, and Shell. Thus, the minimum distance required for barging is significantly more than the minimum distance for pumping via CSD and boosters. CSD transport can deploy pipeline to cut across West Bay, reducing the minimum distance to nearby islands. The barged distance at which point it becomes more cost effective to barge sand would be significantly less than 50 miles for direct transport cases if traversing through SWP were not necessary.

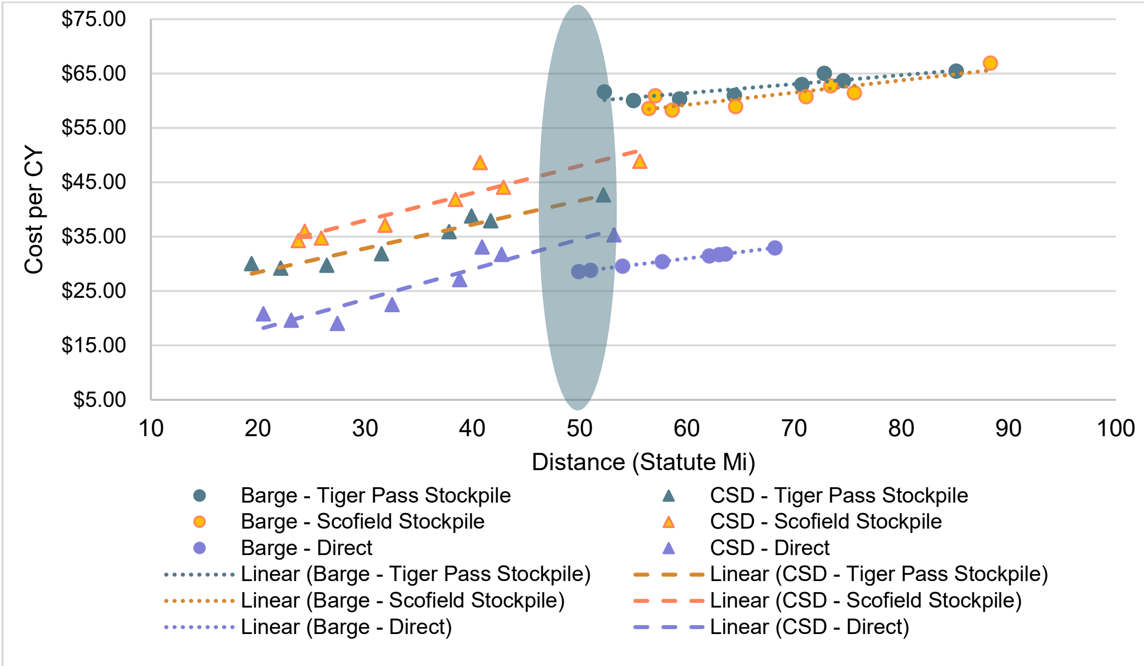

Figure 15. Total cost/CY comparison for all alternatives. Please note, these costs are inclusive of the 50-year costs to clean out the HDDA.

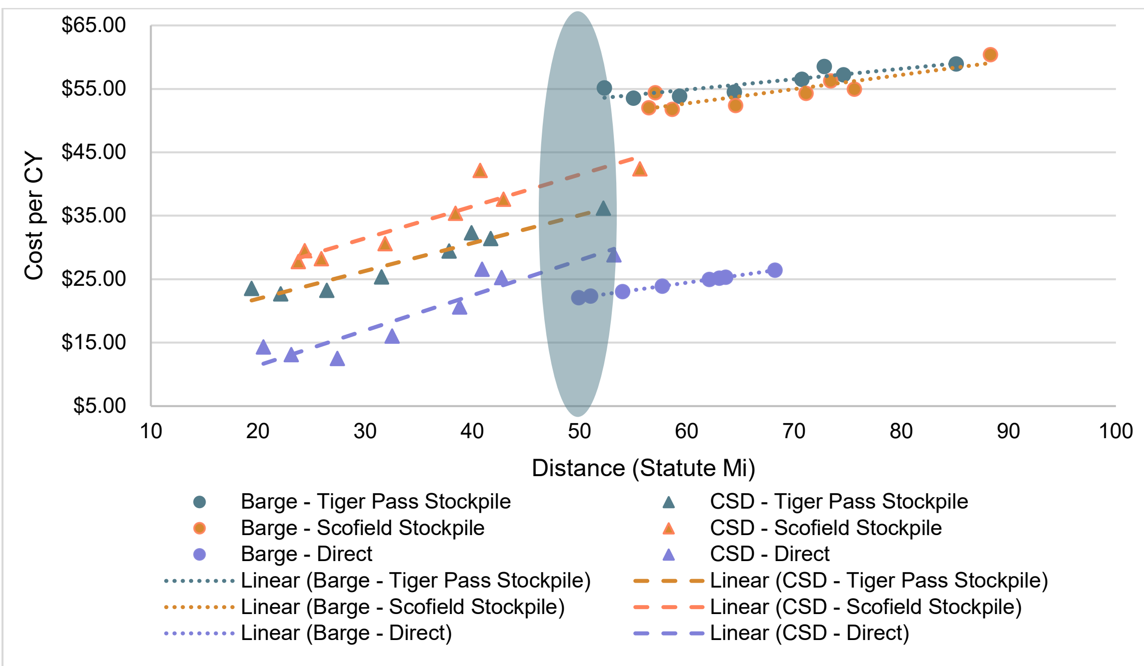

Figure 16 Total cost/CY comparison for all alternatives. Please note, these costs exclude the 50-year costs to clean out the HDDA.

5.2. APPLICATION TO BARRIER ISLAND SYSTEM MANAGEMENT

CPRA's Coastal Master Plan assumes barrier shoreline maintenance will occur once critical thresholds in barrier island integrity are reached, usually after storm impacts. However, through the life of the program, there may not be enough sand available from identified offshore reserves to quickly accomplish such a task unless new sand search expenditures occur, and new sand borrow source discoveries are made. CPRA's BISM program is a holistic system-wide approach—based on regional sediment management principles—to manage the entire barrier island and headland chain programmatically through restoration and maintenance, replacing a project-based prioritization approach that is currently implemented by CPRA. Processes are under development to identify:

- How restoration of barrier islands should be prioritized;
- How to best manage sand within and where to introduce new sand into the active littoral system;
- Best use of available sediment resources for restoration implementation;
- Methods for leveraging existing synergistic programs within CPRA, such as LASMP (including the Louisiana Sand Resources Database [LASARD] and Louisiana Sediment Availability and Allocation Program [LASAAP]) and the Barrier Island Comprehensive Monitoring program; and,
- Strategies for optimizing program implementation.

The findings of this report demonstrate that existing and ongoing dredging activity to maintain the MRSC in its lowermost reaches provides for a viable and semi-renewable, restoration-quality sand resource for barrier islands offering a potential solution for BISM as other sand resources are exhausted.

6.0 CONCLUSIONS

The most optimal approach for a long-term delivery regime of the restoration-quality available sand to the shoreline of the Barataria Bight is a federal-state coordination utilizing the HDDA as the sand source. This approach for programmatically sourcing sand would:

- Deliver the restoration-quality sand available in coastal Louisiana, most capable of resilience to erosion, inducing further ecological and cost benefits over the long-term.
- Utilize a renewable sediment source, unlike many historic barrier shoreline restoration practices.
- Leverage sand that is already being dredged and removed from the LMR for navigation purposes.
- Require significant coordination between state and federal agencies both at the borrow location (HDDA), across transport corridors managed by both, and at unloading and placement locations along the shoreline.
- Require the BISM program or similar to identify a multi-decade sand placement prioritization strategy for the entire barrier islands system.
- Create opportunities to restructure contracting and spending for direct-to-island sand delivery from HDDA cleanouts.

The Mississippi River has traditionally been managed separately, in a partitioned manner, for navigation, flood risk reduction, and ecosystem restoration. Management strategies for each business line are typically based on their individual priorities and congressional authority, but all three attempt to manage the same water and sediment to meet these goals. The findings of this report support the assertion that collaborative regional sediment management in the LMR below Venice can be accomplished in a way that enhances benefits to both navigation and coastal protection and restoration, under existing authorities.

The findings of the cost analysis demonstrate that utilization of renewable HDDA sand would not be cost prohibitive, with the most efficient combined method of direct CSD transport and barging estimated to be comparable to historic costs. Alternative 14 (Optimized Alternative 2 – Optimized Direct transport to islands.) was found to be the least cost alternative, with a 50-year estimated cost of $2.2B–2.9B (depending on the inclusion of 50 years of HDDA cleanout costs), which is comparable to the extrapolated 50-year cost of historic barrier shoreline restoration practice of $2.5B. Costs were shown to vary by transport mechanism, with an approximate breakpoint of 50 miles at which point transport becomes more efficient by barge than CSD. The cost analysis does not capture other considerations acknowledged above which could significantly decrease long-term costs and increases in long-term benefits associated with higher quality sand.

The cost savings and reduced uncertainty regarding supply of sand recognized with a programmatic approach to barrier island maintenance and restoration requires a structured and clearly coordinated partnership between federal and state agencies to devise and implement a programmatic permitting and design framework that synchronizes HDDA cleanout activities with barrier island restoration projects.

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APPENDIX A. DETAILED ALTERNATIVES ANALYSIS

This appendix contains all detailed cost calculations and assumptions generated by Royal Engineering in partnership with The Water Institute. Additional background calculation materials are available in a .pdf data file upon request.

APPENDIX A – Detailed Alternatives Analysis

TECHNICAL MEMORANDUM - DRAFT

Date: November 16, 2023

From: T. Mitch Andrus, P.E., Ph.D, Executive Vice President, Royal Engineers and Consultants, LLC

To: Brett McMann, P.E., CFM, Project Manager, The Water Institute

CC: Mike Miner, Ph.D, Director of Applied Geosciences, The Water Institute
Ancil Taylor, President, Ancil Taylor Dredging Consulting
Zachary Romaine, P.E., Royal Engineers and Consultants, LLC
Katherine Foreman, P.E., Royal Engineers and Consultants, LLC

Subject: Lowermost Mississippi River Management Support (LMRMP) – Cost Estimating Support

Royal Engineers and Consultants, LLC (Royal) in association with Ancil Taylor Dredging Consulting (ATDC) is pleased to provide this technical memorandum to the Water Institute of the Gulf (TWI) for the Lower Mississippi River Management Plan, Regional Sediment Management project detailing its findings on potential sand resource management alternatives. Royal's work included development of sand transport and stockpile alternatives, evaluation of the developed alternatives, and development of 50-year project costs for each alternative.

Study Need and Purpose

This study explored possible future management alternatives to offshore sand sources for barrier shoreline restoration in Louisiana. CPRA's Master Plan currently assumes barrier shoreline maintenance will occur once critical thresholds are reached, usually after storm impacts; however, there may not be enough sand available to quickly accomplish such a task, using offshore sand sources from the Barataria Bight (CPRA, 2023). The intent of this study is to develop potential sand resource management alternatives and estimate costs for moving sand from the Mississippi River to barrier islands along the Louisiana coast spanning from the Caminada Headlands to Sandy Point.

The analysis did not explicitly compare the developed management alternatives to current restoration practices such as mining of offshore sand sources relatively nearshore. Rather, it sought to look beyond current practices and develop a general understanding of future project restoration alternatives and costs with the Mississippi River as the primary renewable sand source.

Study Bounds

The study includes several key assumptions to bound the scope of analysis. This was seen as necessary to limit the conceivably wide range of project alternatives that could be analyzed.

The first assumption provides the volume of sand available for barrier island construction. Records quantifying the volume of sand removed yearly from the U.S. Army Corps of Engineers (USACE) Hopper Dredge Disposal Area (HDDA) since 2004 were obtained. The average yearly removal rate was found to be 4,375,000 CY (Table 1). Rounding down to be conservative, the total available volume of sand available to the project was assumed to be 4,000,000 (4 MCY) per year. Though a general trend of increasing sand volume removed can be seen, it is recognized that the river is dynamic and that these volumes cannot be depended upon on a yearly basis.

Table 1. Historical HDDA Sand Removal Volumes

Fiscal Year	HDDA Removal (CY)
2004	4,124,598
2005	0
2006	0
2007	4,266,078
2008	4,013,912
2009	0
2010	6,793,848
2011	1,538,859
2012	787,274
2013	7,235,381
2014	0
2015	9,646,404
2016	0
2017	8,432,365
2018	4,891,195
2019	9,525,553
2020	4,008,790
2021	13,480,852
Average	**4,374,728**

Eight barrier islands were assumed to be maintained under this program. From West to East these include Caminada Headland, West Grand Terre, East Grand Terre, Grand Pierre, Chaland Headland, Shell Island, Pelican Island, and Scofield Island each including a unique sediment (sand) demand (*Figure 1*). To establish this demand for this study, an inventory of past project construction events from 2005 to 2021 in the Barataria Bight was taken by TWI (*Table 2*). Satisfaction of sand demand was handled in two approaches: 1) a historical approach which reconstructed entire island templates at prescribed intervals and 2) an average yearly approach governed by the 4 MCY availability from HDDA. Approach 1 involves constructing a stockpile area to have enough sand to build each entire island for maintenance events at approximately 10- or 20-year recurrence intervals. Approach 2 involves delivering the yearly available quantity of sand directly from the HDDA to islands. The total in place volume of sand needed to meet the demand is estimated to be 114.8 MCY. Sand retention factors for stockpile areas and in place on the beach were assumed to be 0.8 and 0.85, respectively, to calculate required borrow volumes. These account for typical losses due to coastal processes in the placement area seen on other projects for open water areas vs. in beach and dune templates during construction.

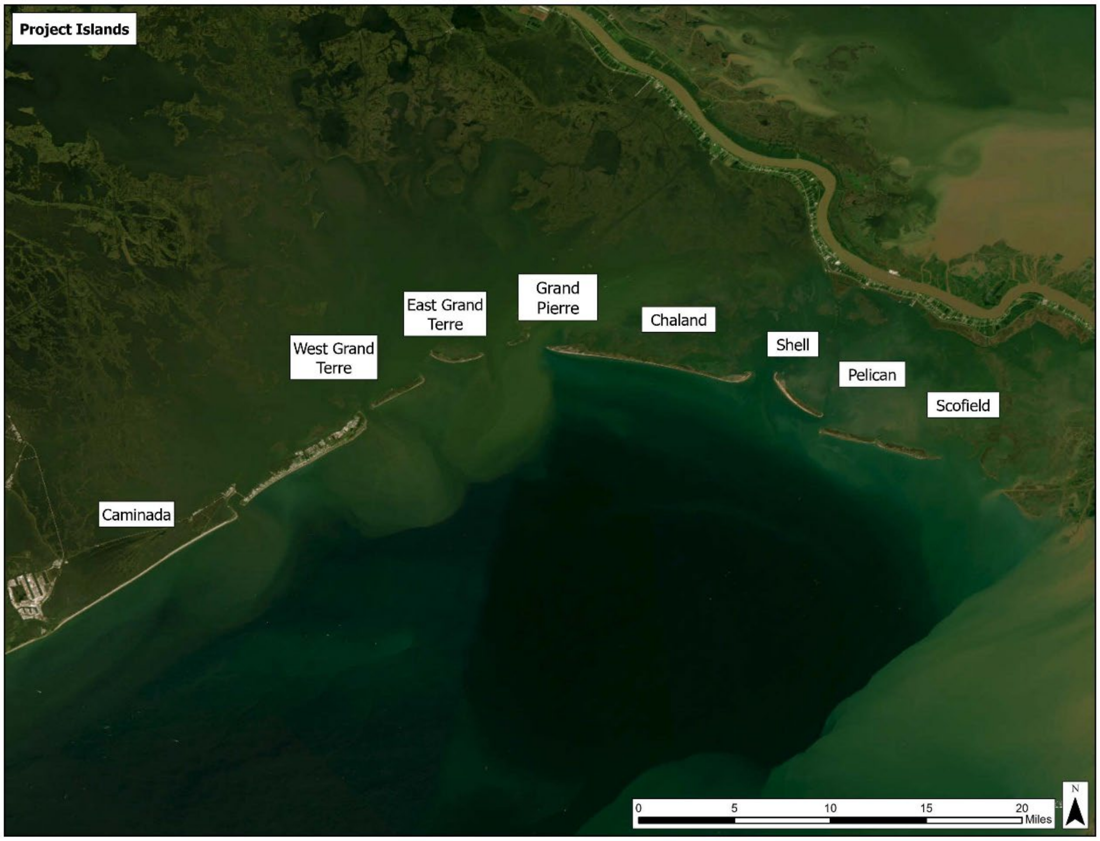

Figure 1. Project Islands Included in Analysis

Table 2. Sand Demand by Island

Island	Sand Demand per Maintenance Event (cy)	No. of Dredging Events	Total In Place Volume (cy)
Caminada Headland	9,120,000	2	18,240,000
West Grand Terre	5,310,000	2	10,620,000
East Grand Terre	2,735,000	3	8,205,000
Grand Pierre	4,743,000	3	14,229,000
Chaland Headland	6,376,000	3	19,128,000
Shell Island	4,685,000	6	28,110,000
Pelican Island	3,486,000	3	10,458,000
Scofield Island	1,940,000	3	5,820,000
		TOTAL:	**114,810,000**

A historical sand demand approach was utilized for most of the alternatives assessed. In this approach, the sand demand for each project island was applied to discrete out-years at approximately 10- or 20-year recurrence intervals (*Table 3*). Sand was assumed to be placed on an island during 18 distinct years. Stockpile(s) were assumed to be managed such that necessary sand volumes were available for each project island maintenance event. The stockpile was capped at 15.25 MCY, which is the minimum volume required to ensure each construction cycle had ample sand available. Accounting for a stockpile retention factor of 0.8, a maximum of 3.2 MCY could be placed in it each year. However, in some years, the cap was reached and less than 3.2 MCY of sand was placed into the stockpile, including some years with no placed material. The total volume of sand dredged from HDDA is 168.9 MCY to place an overall retained stockpile volume of 135.1 MCY to meet the 114.8 MCY demand using a retention factor of 0.85 for placement at the islands.

Table 3. Assumed Maintenance Events Utilizing Historical Demand Approach

	Project Islands							
	Caminada Headland	West Grand Terre	East Grand Terre	Grand Pierre	Chaland Headland	Shell Island	Pelican Island	Scofield Island
Project Years	2039	2041	2030	2028	2027	2027	2032	2033
	2059	2061	2050	2048	2047	2037	2052	2053
			2070	2068	2067	2047	2072	2073
						2057		
						2067		
						2073		

The second approach assumed that a constant volume of sand would be mined from the HDDA on a yearly basis and placed on a project island within the chain, working fully, sequentially, and continuously from one island to the next, then restarting once all islands have been maintained. The volume of sand placed per year was assumed to be the yearly average totaling up to the same in place volume of 114.8 MCY as in the historical demand approach to provide a direct comparison to the stockpile options. Total sand demand by project island was assumed to remain consistent with *Table 2*, though the recurrence differed from the historical demand approach. Total volume dredged from HDDA for this approach was 135.1 MCY using a retention factor of 0.85 for placement at the islands.

Definitive records of sand characteristics within the HDDA were not able to be obtained during the analysis. However, Ancil Taylor with ATDC provided anecdotal evidence from past projects noting that sand can be generally classified as well-graded with a D_{50} of 180 µm (Taylor, 2023). This assertion tracked well with the project team's assumptions as material in the HDDA would have already been hopper dredged, decanted, and placed in the HDDA, all processes of which will result in the loss of fine-grained sand and leaving coarser sand.

All project costs are provided in 2023 dollars.

Sand Delivery Alternatives

Sand transport for the historical demand approach would occur incrementally via a transfer/staging facility located at one of 2 stockpile alternatives for a selected group of combined project alternatives. The rationale behind this idea is that the USACE tends to have a steady and predictable availability of sand to remove from the HDDA, whereas the historical demand and assumed maintenance events from *Table 3* is less frequent. A transfer and stockpiling facility located outside of the HDDA (for sand mined and transported from HDDA) could create a constant, reliable source of high-quality sand accessible when needed for maintenance events.

<u>Stockpile Area Alternatives</u>

Several stockpile areas were identified at the onset of the project (*Figure 2*). These included: 1) the south end of West Bay; 2) behind Scofield Island; 3 near the mouth of Tiger Pass; 4) an offshore dump stockpile at approximately the -50ft NAVD88 contour, south-west of Scofield Island; and 5) a series of several small stockpiles in prior-dredged borrow areas near islands including Caminada, East and West Grand Terre, Pelican, Ronquille, Pass Chaland, Shell, Scofield, and Grand Liard. A high presence of oil and gas activity, including wells and pipelines, was discovered in the vicinity of the West Bay alternative. As such, re-dredging of stockpiled material in this area appeared unfavorable and this alternative was screened. The offshore dump stockpile appeared to offer the largest capacity of the alternatives considered and could receive sand from a full suite of dredge options (including hoppers); however, due to the potential risk of sand migration during storm events, this alternative was not carried forward into the next phases of evaluation. Previously mined borrow areas were excluded as alternatives due to the need to re-permit/lease these areas and the fact that these areas likely possess since-deposited fluid mud that is undesirable for barrier island restoration. The remaining two stockpile alternatives were selected for the next phase of analysis: Scofield stockpile and Tiger Pass stockpile. Though oyster leases are currently found in the area identified for the Scofield stockpile, the cost to buy out the leases relative to the total estimates was negligible, and thus not considered in the analysis.

Figure 2. Identified Stockpile Areas

The Scofield and Tiger Pass stockpiles were assumed to be sub-aqueous holding facilities similar to the HDDA (*Figure 3*). This facility is designed to hold large volumes of dredge material at elevations below the tidal zone. The size of the stockpile is approximately 500 acres, based on the constructed elevation of -26ft NAVD88 to meet the required capacity of ~15 MCY. The assumed existing water-bottom elevation, as well as a constructed stockpile top elevation, is -6 ft NAVD88.

Figure 3. Stockpile Areas Selected for Evaluation

Transport Method Alternatives

Each alternative relies on its own unique combination of Phase 1 transport type via either Cutter Suction Dredge (CSD) or Barge to a stockpile location (Scofield or Tiger Pass), Phase 2 transport type via either CSD or Barge from a stockpile to the islands, or directly to islands, and transportation route of either Southwest Pass (SWP), Tiger Pass, or Buras to the Empire waterway. *Table 4* lists all the Phase 1 and 2 combinations and alternatives evaluated which are also shown in *Figure 4* through *Figure 15*. Alternatives 13 and 14 are optimized for lowest cost transport methods for the stockpile and direct to island approaches, respectively.

Table 4. Combined Project Alternatives

Alternative Number	Stockpile Area or Direct	Transport Method
1	Tiger Pass	1) CSD 2) CSD
2	Tiger Pass	1) CSD 2) Barge
3	Tiger Pass	1) Barge 2) CSD
4	Tiger Pass	1) Barge 2) Barge
5	Scofield	1) CSD 2) CSD
6	Scofield	1) CSD 2) Barge

7	Scofield	1) Barge 2) CSD
8	Scofield	1) Barge 2) Barge
9	Empire/Scofield	1) Barge/CSD 2) CSD
10	Empire/Scofield	1) Barge/CSD 2) Barge
11	Direct to Islands	Barge (HDDA → Islands)
12	Direct to Islands	CSD (HDDA → Islands)
13	Optimized Stockpile Option	Optimized Transport Method
14	Optimized Direct to Islands	Optimized Transport Method

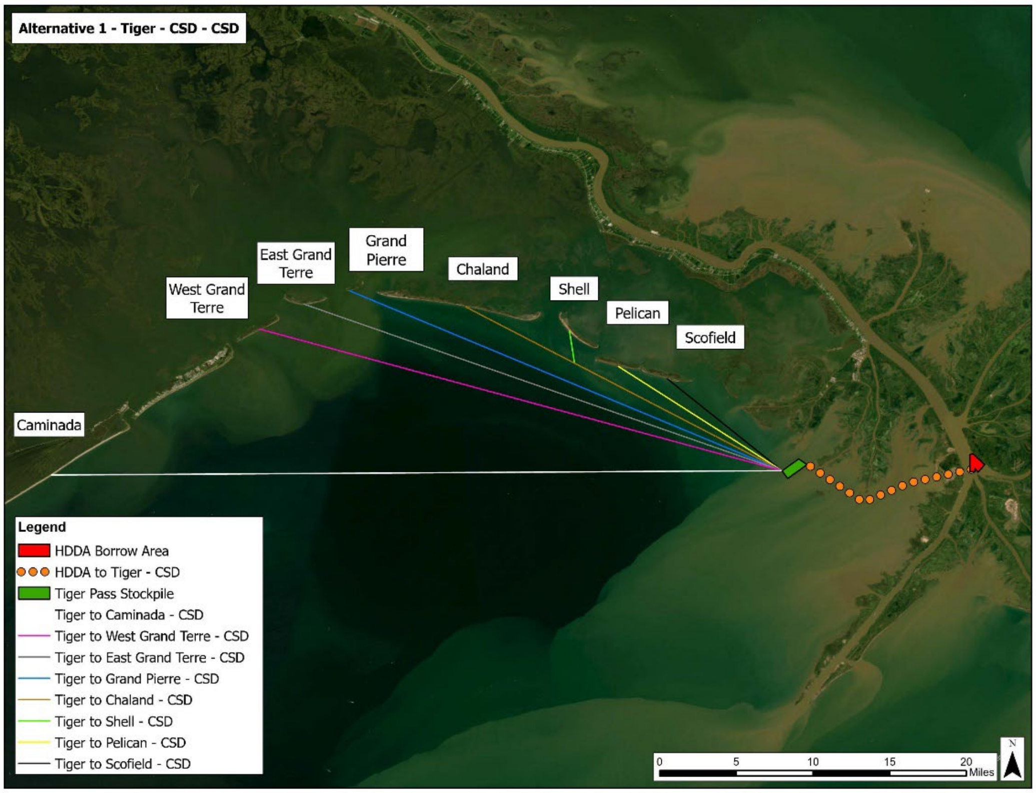

Figure 4. Alternative 1 Transportation Methods

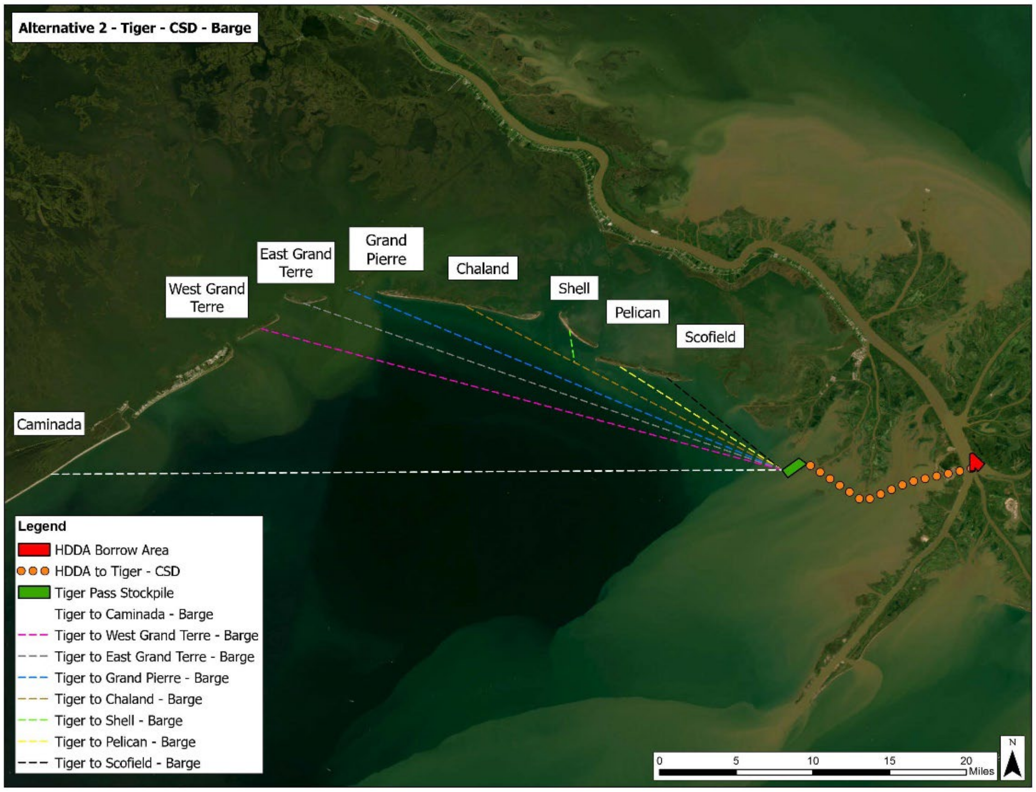

Figure 5. Alternative 2 Transportation Methods

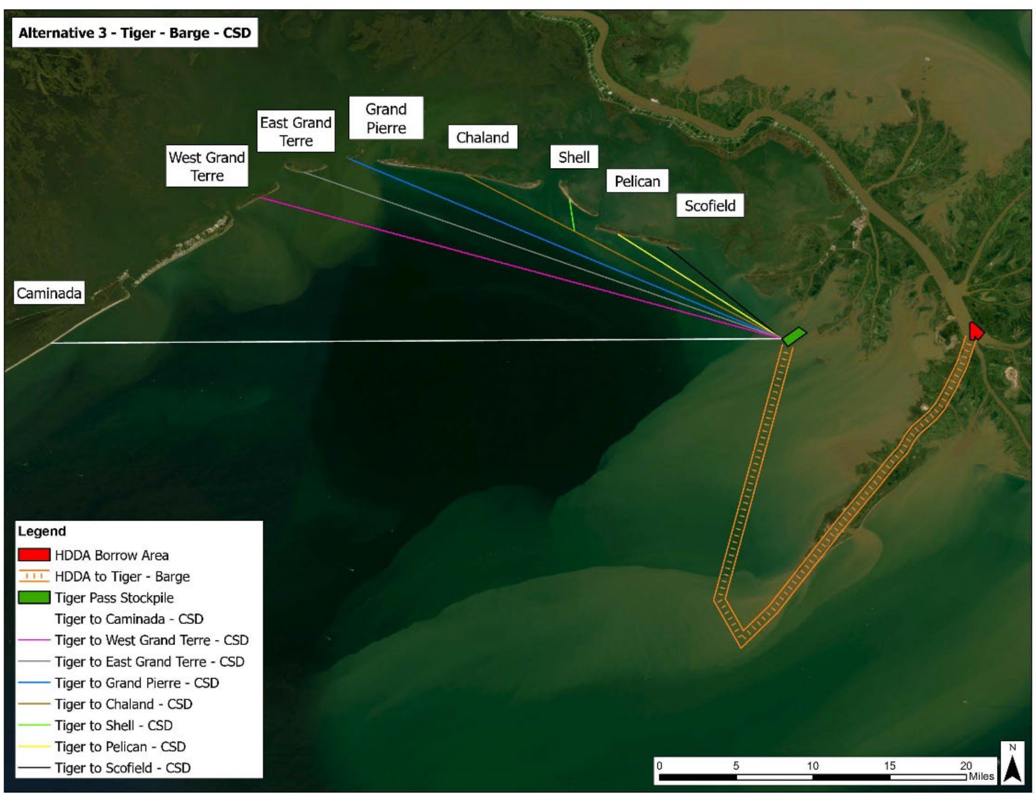

Figure 6. Alternative 3 Transportation Methods

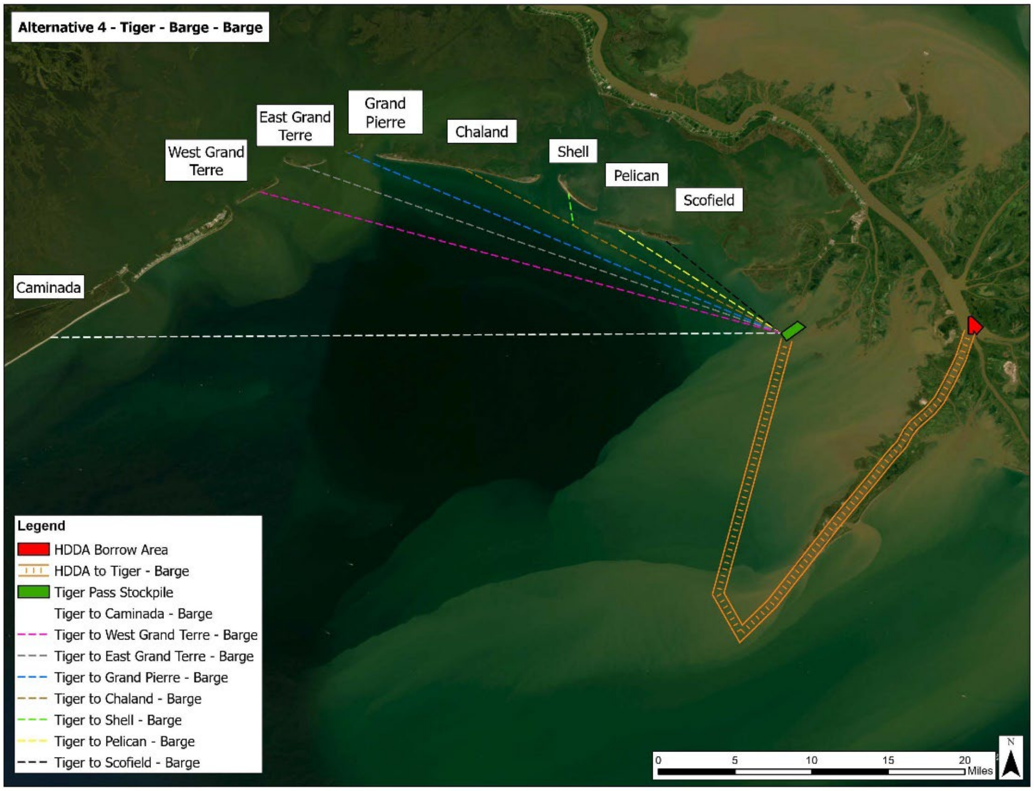

Figure 7. Alternative 4 Transportation Methods

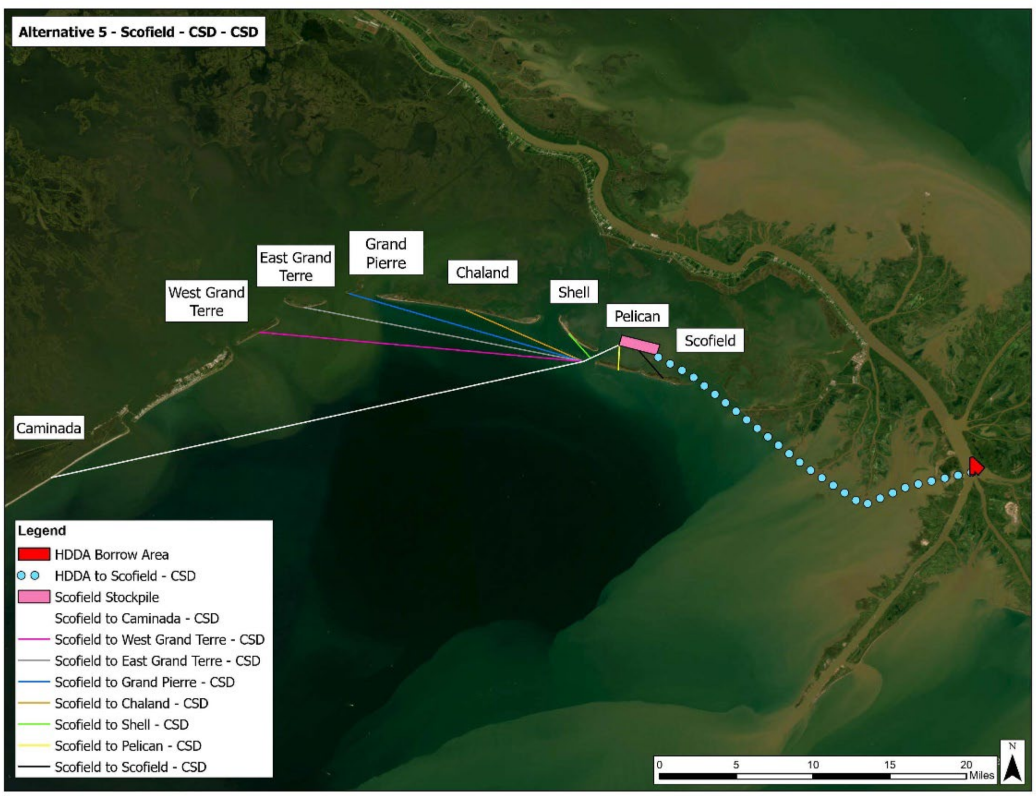

Figure 8. Alternative 5 Transportation Methods

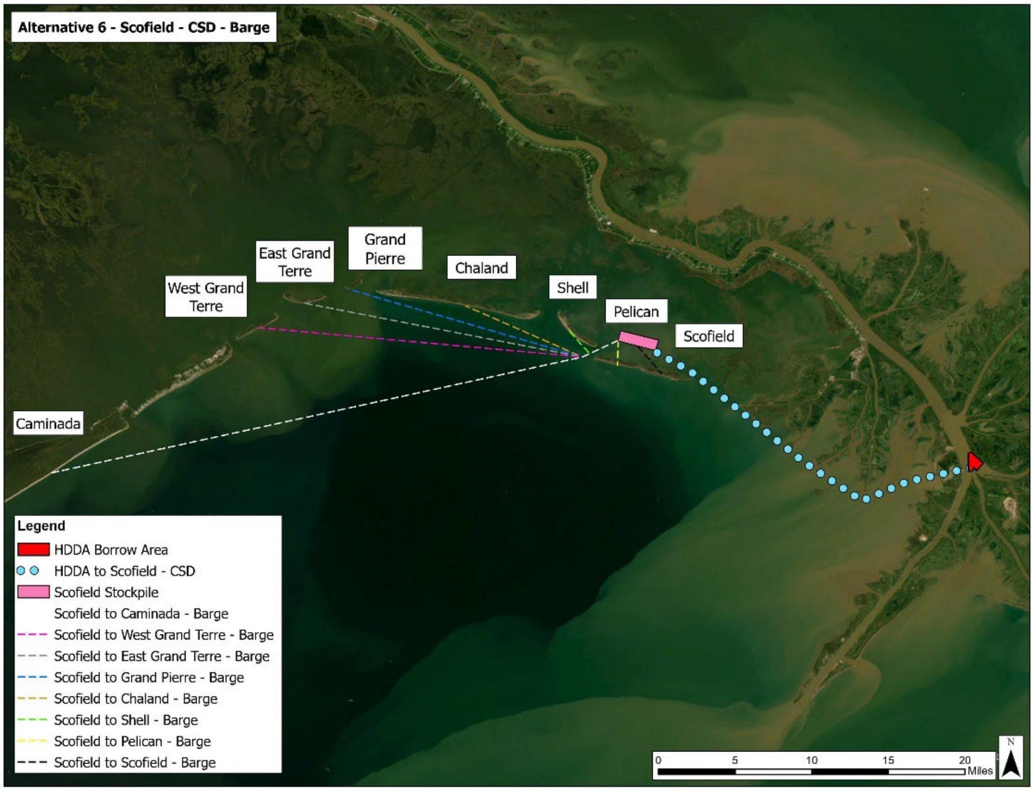

Figure 9. Alternative 6 Transportation Methods

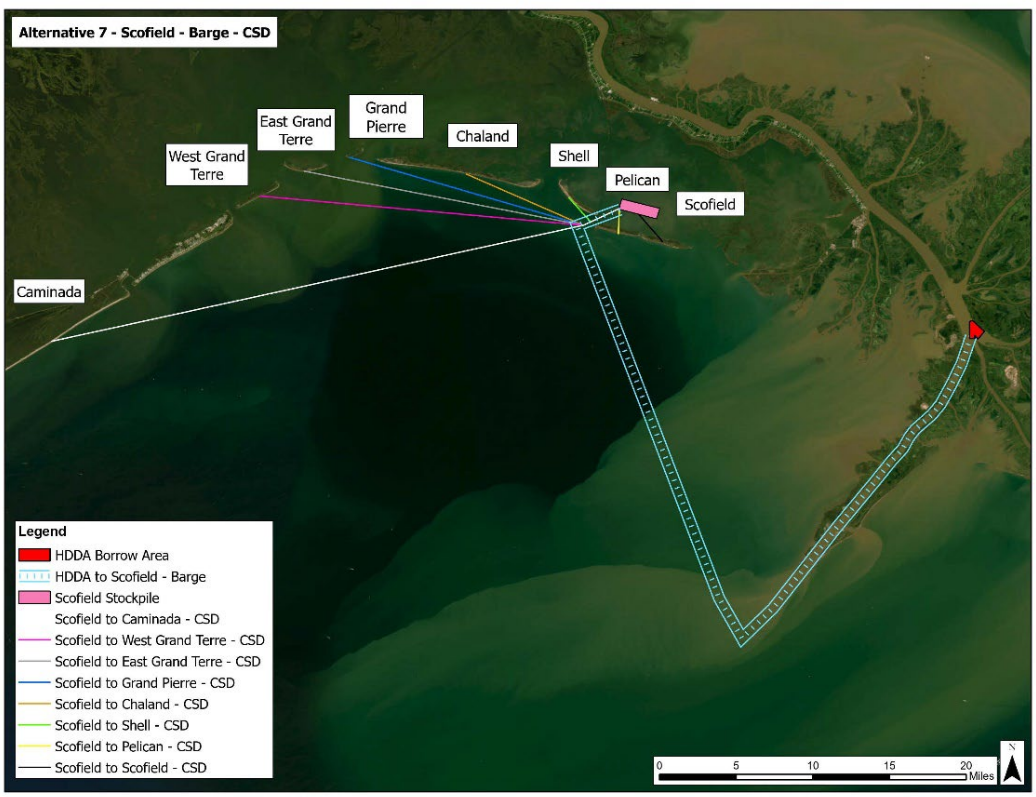

Figure 10. Alternative 7 Transportation Methods

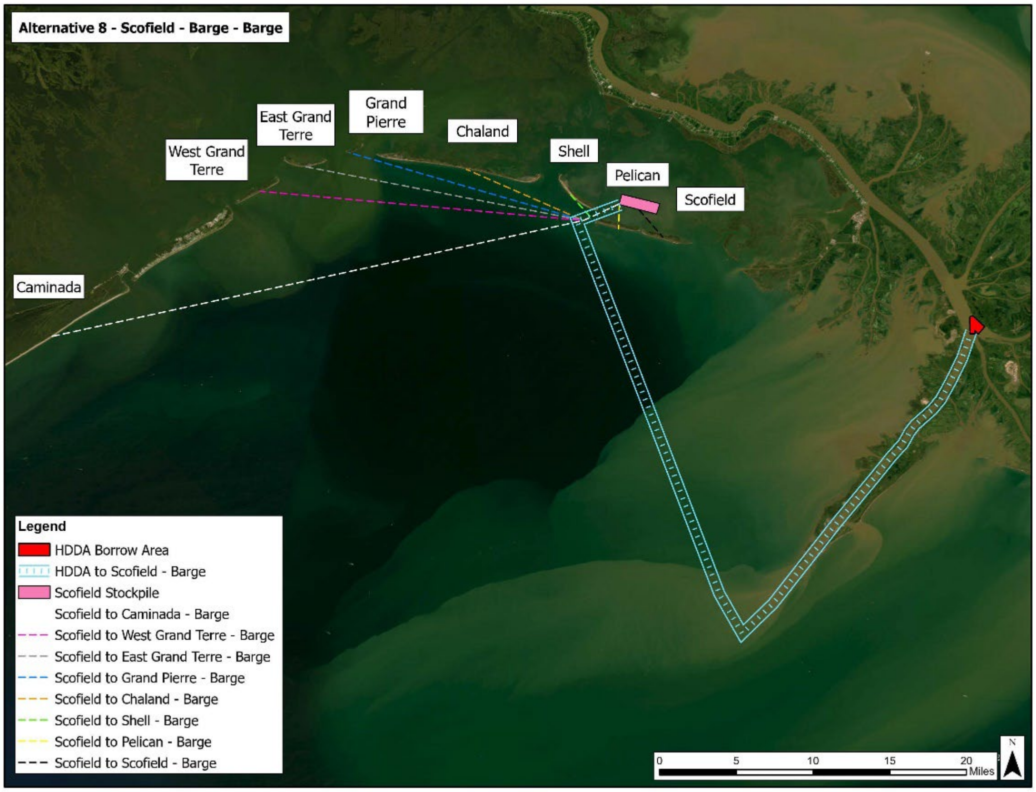

Figure 11. Alternative 8 Transportation Methods

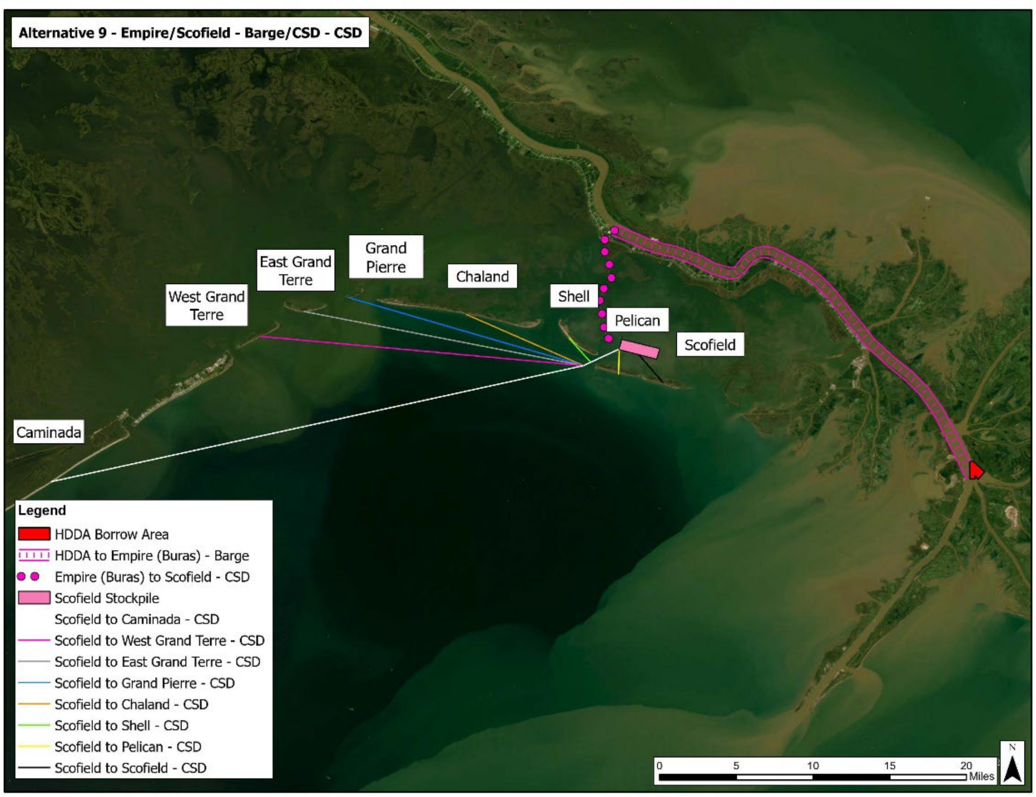

Figure 12. Alternative 9 Transportation Methods

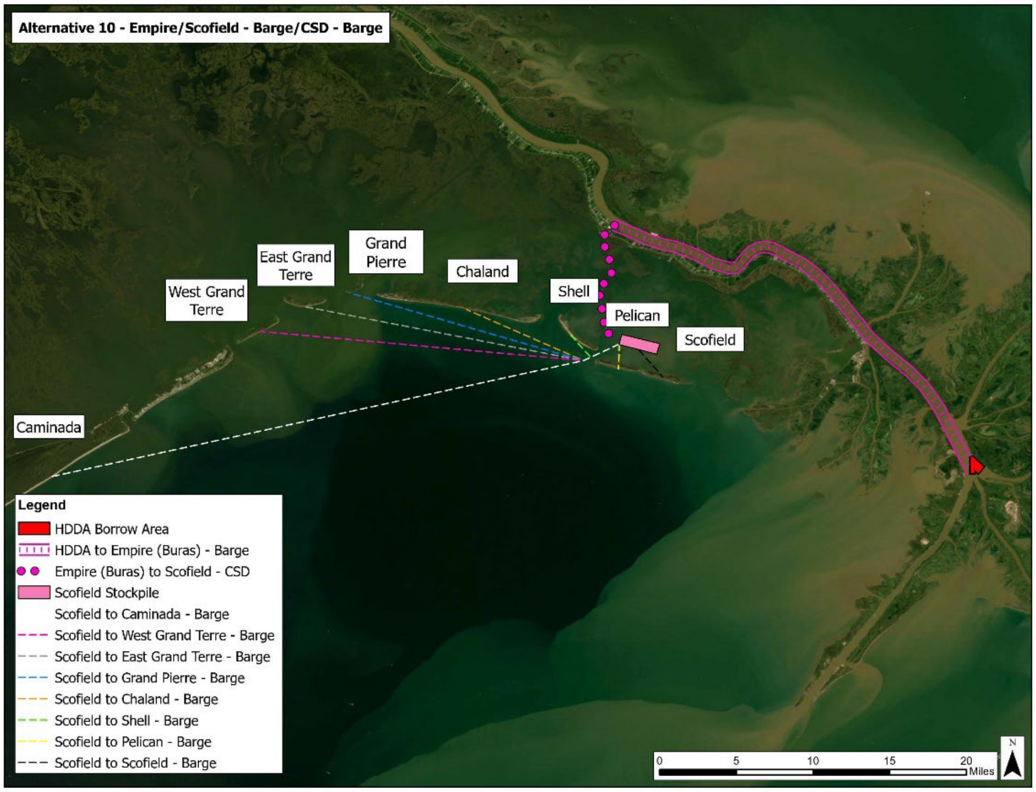

Figure 13. Alternative 10 Transportation Methods

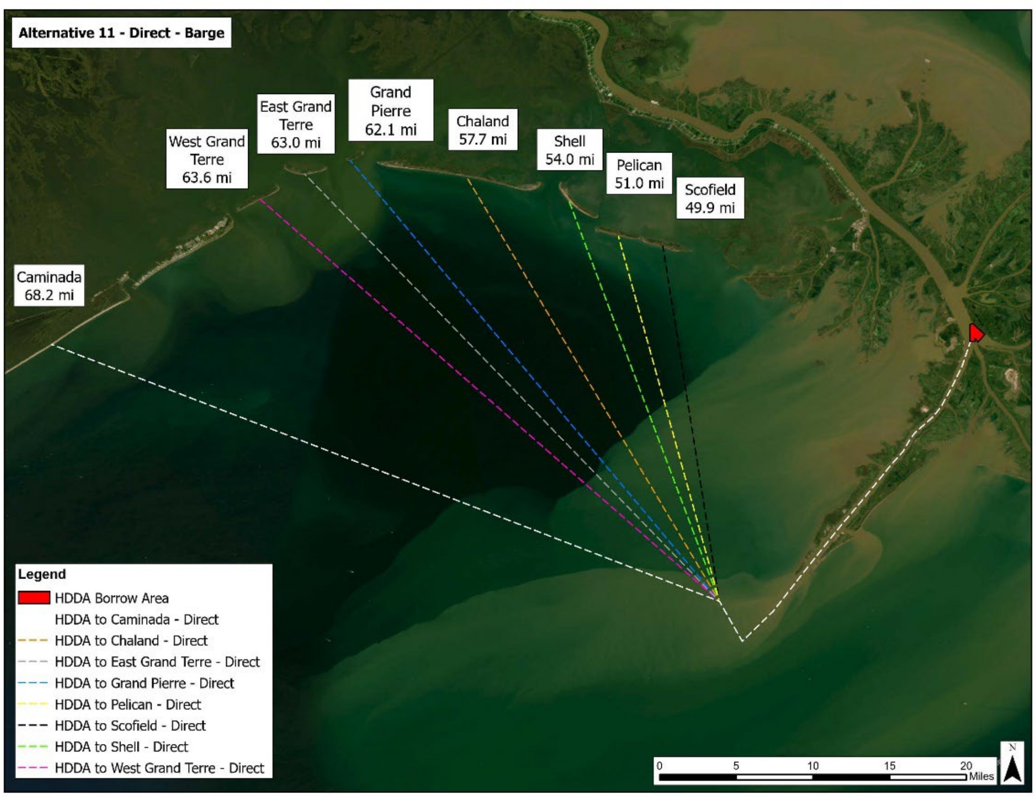

Figure 14. Alternative 11 Transportation Methods

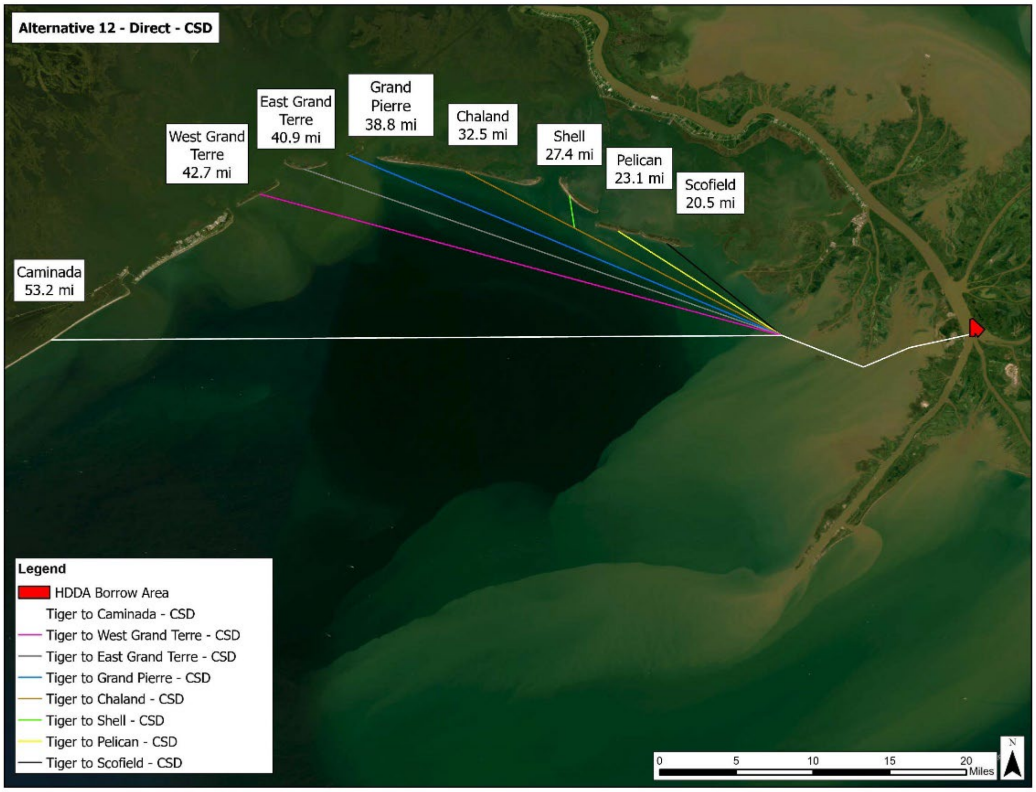

Figure 15. Alternative 12 Transportation Methods

Tables 5-7 list sand transport distances associated with each phase and alternative.

Table 5. Sand Transport Distance from HDDA to Stockpile Location (Phase 1)

CDF	Cutter Suction Dredge Distance (Statute Miles)	Barge Distance (Statute Miles)	Barge + Cutter Suction Dredge (Buras) Distance (Statute Miles)
Scofield	22.1	54.8	28.9 + 8.5
Tiger Pass	10.6	43.5	-

Table 6. Sand Transport Distance to Project Islands from Stockpile Locations (Phase 2)

Project Island	Scofield Stockpile Distance (Statute Miles)	Tiger Pass Stockpile Distance (Statute Miles)
Caminada Headland	33.5	41.6
West Grand Terre	20.8	31.1
East Grand Terre	18.6	29.3
Grand Pierre	16.3	27.2
Chaland Headland	9.7	20.9
Shell Island	3.8	15.8
Pelican Island	1.7	11.5

Scofield Island	2.2	8.8

Table 7. Sand Transport from HDDA to Barrier Islands via Barge or CSD

	Sand Transport Distance (Statute Miles)	
Project Island	**Barge**	**CSD**
Caminada Headland	68.2	53.2
West Grand Terre	63.6	42.7
East Grand Terre	63.0	40.9
Grand Pierre	62.1	38.8
Chaland Headland	57.7	32.5
Shell Island	54.0	27.4
Pelican Island	51.0	32.1
Scofield Island	49.9	20.5

Sand Transport Assumptions

It was necessary to make several assumptions during the cost estimating process, in which a bottom-up approach was utilized, which is described in more detail in the following sections and supported by detailed breakdowns in Attachment A1. The project team assumed for all transport methods and alternatives that all necessary equipment is available on the market throughout the life of the project. Custom commodity-carrying vessels are assumed to be used for all barge transport alternatives. These sealed hopper barges with 2500 CY capacity and dimensions of approximately 250 ft x 54 ft x 14 ft depth hull would cost a fraction of a dump scow considering the use of long-term contracts for construction. The use of these barges by extension requires the assumption that all sailing routes would be adequately maintained. All transport methods also assume 20% lost time due to weather conditions. For CSD alternatives, the number of booster pumps varies based on horsepower requirements associated with material type, specific gravity, and transport line length. The specific gravity of the slurry is assumed to be in the range of 1.10 to 1.30.

Phase 1 Transport Methods

Phase 1 is the phase of this analysis that focuses strictly on transporting sand from the HDDA to a Stockpile location (either Scofield or Tiger Pass). For estimating purposes, it is assumed there is no cost-sharing between the State and USACE for dredging operations at the HDDA. Phase 1 will accomplish the transportation of sand by utilizing either a 30” cutter suction dredge (CSD) (Alternatives 1,2,5,6) or with 2500 cubic yard hopper barges (Barge) (Alternatives 3,4,7,8) or with a combination of the two (Alternatives 9 & 10).

The CSD option for Phase 1 will utilize a primary spread of 1 - 30” CSD, 2 tender tugs, 1 assist tug, 3 deck/derrick barges, 1 crane barge, auxiliary equipment such as crew and survey boats, and the necessary lengths of floating, submerged, and shore pipeline to construct and operate the pipeline for sand transport. The pipeline route will travel west from the HDDA, crossing the Mississippi River with a submerged section, and then travel west towards the stockpile locations with a floating line. The Phase 1 pipeline is designed to be a short-term line that will only be mobilized during required dredging years and then demobilized once dredging is complete for that year.

The Barge option for Phase 1 will utilize a spread of 2 – 24” CSD hydraulic loaders/unloaders, 2 tender tugs, 8 to 14 hopper barges (2500 cubic yards) depending on the alternative, 7 to 13 transport tugs, 1 spider barge, and auxiliary equipment such as crew and survey boats to transport sand from the HDDA to a stockpile. The hopper barges will be loaded in the HDDA via a 24” CSD loader. Once fully loaded, the barge will sail south through Southwest Pass or North to Empire (depending on the alternative) to supply sand to either stockpile. Barges will be unloaded into the stockpile via a hydraulic unloader.

The Empire/Buras transportation route utilizes both the CSD and Barge during Phase 1 to bring material to the Scofield Stockpile. This transportation method consists of barging sand from the HDDA northward to the Mississippi River side of the Empire locks where the sand will be transferred into a CSD sump via a hydraulic unloader. The sand will then be transported south through the CSD pipeline via the Empire Canal to the Scofield Stockpile.

Phase 2 Transport Methods

Phase 2 is the phase of the analysis that focuses strictly on transporting material from either stockpile (Scofield or Tiger Pass) to a barrier island. Phase 2 will accomplish the transportation of sand by utilizing either a 30” cutter suction dredge (CSD) (Alternatives 1,3,5,7,9) or with 2500 cubic yard hopper barges (Barge) (Alternatives 2,4,6,8,10).

The CSD option for Phase 2 will utilize a primary spread of 1- 30” CSD, 2 tender tugs, 1 assist tug, 3 deck/derrick barges, 1 crane barge, auxiliary equipment such as crew and survey boats, and the necessary lengths of floating, submerged, and shore pipeline to construct and operate the pipeline for sand transport. The Phase 2 pipeline is designed to be a one-time use line for each dredging event which produces a mobilization and demobilization cost for each dredging event listed in *Table 3*. The use of long lengths of submerged pipeline across the Gulf floor and numerous oil and gas lines would have regulatory requirements which are not considered in the cost estimate. As such, the Phase 2 pipeline presents some cost uncertainty which is not a concern for the barge alternatives.

The Barge option for Phase 2 will utilize a spread of 2 - 24” CSD hydraulic loader/unloaders, 2 tender tugs, 2 to 11 hopper barges (2500 cubic yards) depending on the alternative and island, 1 to 10 transport tugs, 1 spider barge, and auxiliary equipment such as crew and survey boats to transport sand from the stockpile to the barrier islands. The hopper barges will be fully loaded in the stockpile via a hydraulic loader and then sail directly to the island where the barges will be hydraulically unloaded.

Costs for shore crews to manage outfalls at the islands are not included for either transport method.

Direct to Island Methods

The "Direct to Island" options consist of transporting sand directly from the HDDA to the barrier islands either via barge or CSD methods previously described. For estimating purposes, it is assumed there is no cost-sharing between the State and USACE for dredging operations at the HDDA. Barrier islands will be completed from East to West by dredging 4 MCY per year for three 12-year cycles with two 7-year breaks in between cycles.

Alternative 11 includes transporting sand via barge by sailing through Southwest Pass. The loading and unloading of sand for this option will be similar to the process outlined in Phase 1 barge options, except the barges will sail directly from HDDA to the barrier islands and be unloaded hydraulically onto the islands instead of into the stockpiles. The equipment spread needed to complete this option will be a spread of 2 - 24" CSD hydraulic loader/unloaders, 2 tender tugs, 13 to 18 hopper barges (2500 cubic yards) depending on the island, 12 to 17 transport tugs, 1 spider barge, and auxiliary equipment such as crew and survey boats to transport sand from the stockpile to the barrier islands. The hopper barges will be fully loaded in the stockpile via a hydraulic loader and then sail directly to the island where the barge will be hydraulically unloaded.

Alternative 12 will transport sand from HDDA through Tiger Pass and directly to the barrier islands utilizing a primary spread of 1 - 30" CSD, 2 tender tugs, 1 assist tug, 3 deck/derrick barges, 1 crane barge, auxiliary equipment such as crew and survey boats, and the necessary lengths of floating, submerged, and shore pipeline to construct and operate the pipeline for sand transport. The pipeline is designed to be a one-time use line for each dredging event which produces a mobilization and demobilization cost for each dredging event.

Costs for shore crews to manage outfalls at the islands are not included for either "Direct to Island" transport method.

Cost Estimating

Construction Cost

The construction cost estimate is based on a bottom-up method in which costs for individual construction line items were built-up from detailed assumptions on the equipment, distances, production rates, sediment qualities, etc., rather than a planning-level parametric approach using limited historic data points from past projects. Individual construction line items included mobilization and demobilization of equipment and personnel (e.g., the cost to bring equipment and personnel to and from the job site), slurry pipeline construction, dredging costs, and stockpile excavation. Items factored into dredging costs included: daily rates for the dredge; supporting equipment such as tugs, crew boats, cranes, barges, survey vessels, and booster pumps; items such as fuel, maintenance, repair, overhead and ownership costs; and all personnel-related costs. Daily costs for equipment, fuel, and crews are based on current 2023 industry rates, including overhead and fees. A cost summary of all investigated alternatives and detailed breakdowns for each alternative are provided in Attachment A1. The detailed breakdowns itemize Phase 1 costs by mobilization, pipeline construction (where applicable), and dredged fill. Phase 2 costs are itemized similarly for each barrier island. Further detailed estimate documentation is available upon request.

Contingency

Base cost estimates are formulated by identifying known project components between planning, preliminary, and final design phases. CPRA's Marsh Creation Design Guidelines state that for a planning / feasibility level study, the contingency range should be set between 30-40%. This analysis applies a 30% contingency given the feasibility-level nature of the estimate (CPRA, 2017). Barrier Island sand fill quantities are based on past projects but have not undergone further data collection, modelling, or engineering studies to assess future coastal landscape changes or processes. Some uncertainty was mitigated by consulting with ATDC on the feasibility of the proposed construction methodologies, therefore the lower end of the planning level contingency range was used. CPRA Engineering Division staff agreed with this assessment.

Additional Items of Work

Percentages of total cost for Engineering and Design (E&D), Construction Management (CM), Operation and Maintenance (O&M), were applied in accordance with values provided by the CPRA Projecting Costing Tool from Appendix 7 of the 2023 Master Plan (Sprague et al., 2021). CPRA's Project Costing Tool (PCT) provides a value of 10% of project construction cost for Engineering and Design services, and a value of 5% for Construction Management. The CPRA PCT provides a value of 5% for 50 years of O&M. Since this project has a feasibility design life of 20 years, a value of 2% was assigned for O&M. That value of 2% for a project life of 20 years was extrapolated from the value of 5% for 50 years given by the CPRA PCT. This concludes with a value of 17% of total project construction for Engineer and Design Costs, Construction Management Costs, and Operation and Maintenance Costs.

Summary and Conclusion

Total project cost estimates include a summation of all costs expected for the engineering and design, construction, construction management, admin, operational maintenance, and a level of contingency associated with each alternative. Total project costs are listed by alternative in *Table 8*. A full summary breakdown of each alternative categorized by island and by project component can also be found in Attachment A1 – Detailed Cost Estimates.

Combined Project Alternative Total Costs

Table 8. Combined Project Alternative Total Costs

Alternative Number	Alternative Name	Total Project Cost	Cost per CY Sand In Place
1	Tiger Pass – CSD – CSD	$3,940,000,000	$34.32
2	Tiger Pass – CSD – Barge	$4,619,000,000	$40.23
3	Tiger Pass – Barge – CSD	$6,471,000,000	$56.36
4	Tiger Pass – Barge – Barge	$7,150,000,000	$62.27
5	Scofield – CSD – CSD	$4,611,000,000	$40.16
6	Scofield – CSD – Barge	$4,925,000,000	$42.90
7	Scofield – Barge – CSD	$6,674,000,000	$58.13
8	Scofield – Barge – Barge	$6,985,000,000	$60.84
9	Empire/Scofield – Barge/CSD – CSD	$7,050,000,000	$61.40

10	Empire/Scofield – Barge/CSD - Barge	$7,362,000,000	$64.12
11	Direct – Barge	$3,529,000,000	$30.74
12	Direct - CSD	$2,934,000,000	$25.55
13	Optimized Stockpile	$3,940,000,000	$34.32
14	Optimized Direct	$2,919,000,000	$25.42

The optimized direct to island alternative (Alternative 14) at a total cost of $2.9B is the most economical alternative investigated. The cost per CY of dredged fill for this alternative ranged from $9.53 to $22.18 for sand transport only (before contingency), or $19.15 to $33.69 considering total cost, including the 30% contingency and 17% markup for Engineer and Design Costs, Construction Management Costs, and Operation and Maintenance Costs. Alternative 14 sought to optimize the direct to island methodology by using the barge transport method for the islands farthest from the HDDA (Caminada Headland, West Grand Terre, and East Grand Terre) and the CSD transport method for the remainder of the islands. This optimization introduced additional mobilization costs due to the use of both transport methods which utilize different equipment spreads; these additional costs were ultimately offset by selecting the most economical transport methods for each island based on the distance from the HDDA.

The Tiger Pass – CSD – CSD alternative (Alternative 1) at a total cost of $3.9B is the most economical of the stockpile alternatives 1 through 10. Alternative 13 sought to optimize this cost further by using the Phase 2 transport method that is most cost effective for each island; however, the CSD transport method was found to be most cost effective for all islands. The cost per CY of dredged fill for Alternative 1 ranged from $7.24 to $16.13 for sand transport only, or $13.19 to $26.67 considering total cost of Phase 2, including the 30% contingency and 17% markup for Engineer and Design Costs, Construction Management Costs, and Operation and Maintenance Costs. Generally, the CSD alternatives were more economical than the barge alternatives due to shorter transport distances and the overall need for less pieces of equipment to handle each yard of sand. However, the costs between CSD and barge alternatives began to converge as project distance increases.

The stockpile alternatives are more costly than the direct to island alternatives. The stockpile alternatives have more mobilization costs resulting from a second phase of dredging operations introduced by the stockpiling of material, which also inherently requires multiple handling events. Additionally, the total volume of sand required to be dredged from the HDDA is higher for the stockpile alternatives due to the assumed losses at the stockpile, further increasing the cost disparity. If it is determined that a stockpile is needed because program restraints dictate that islands should be completed all at once at prescribed intervals as opposed to progressively due to limited annual sediment availability, the additional cost is approximately $1B between optimized alternatives (13 and 14).

The cost of leaving dredge slurry pipelines in place for the CSD alternatives rather than installing and demobilizing the pipeline for each dredging event was investigated based on the estimated number of required QA/QC days and estimated daily cost. The longer pipeline lengths for the Phase 1 pipeline to Scofield Stockpile resulted in greater estimated cost savings, as much as

$217.1M. Table *9* summarizes the potential cost savings for the Phase 1 and 2 pipeline alternatives. For all Phase 1 pipeline routes, cost savings could be realized by leaving the pipeline out. For Phase 2 alternatives, Tiger Pass stockpile alternative could save an estimated $48.0 M by leaving the dredge slurry pipelines in place while the Scofield stockpile alternative was found to be more economical to install and demobilize the pipeline for each dredging event rather than leaving the pipeline out. This is a function of shorter pipeline lengths which result in higher dredged fill production rates, shorter required production duration, and higher overall QA/QC costs. This analysis did not consider the costs associated with the risk of leaving a dredge slurry pipeline in place for as much as five years at a time without use.

Table 9. Estimated Cost Savings to Leave Pipeline Out. Positive values are cost savings. Negative values are cost increases.

Stockpile Alternatives	Phase 1	Phase 2
Tiger Pass Stockpile	$56.6M	$48.0M
Scofield Stockpile	$217.1M	($30.3 M)
Empire Route to Scofield Stockpile	$27.8M	N/A

The total estimated project costs per cubic yard of fill were calculated for each alternative based on the total volume of sand delivered to the barrier islands (*Table 9*). For stockpile alternatives, these costs per cubic yard include both Phase 1 and Phase 2 portions of the sand transport and dredging at both the HDDA and stockpile. These unit costs do not capture the variations in cost resulting from different sand transport distances for different phases and barrier island destinations.

Dredged fill costs per cubic yard for both barge and CSD alternatives were tabulated and graphed as a function of distance in miles from the borrow source to the destination island. Figures 16 to 18 show the unit cost per cubic yard of sand (measured on the fill) as shown in the Detailed Cost Estimate for each alternative. Figures 19 shows the total cost per cubic yard of sand (measured on the fill), inclusive of mobilization and pipeline construction where applicable, 30% contingency, and 17% markup for Engineering and Design Costs, Construction Management Costs, and Operation and Maintenance Costs. For the stockpile alternatives, the costs reflect the material handling and sand transport for both the Phase 1 and Phase 2 portions of the project, and the distance is the distance from the HDDA to the islands. For the Direct to Island alternatives, the distance is the direct distance from the HDDA to the islands. Equations for the linear regression lines shown in Figure 19 are provided in *Table 10*.

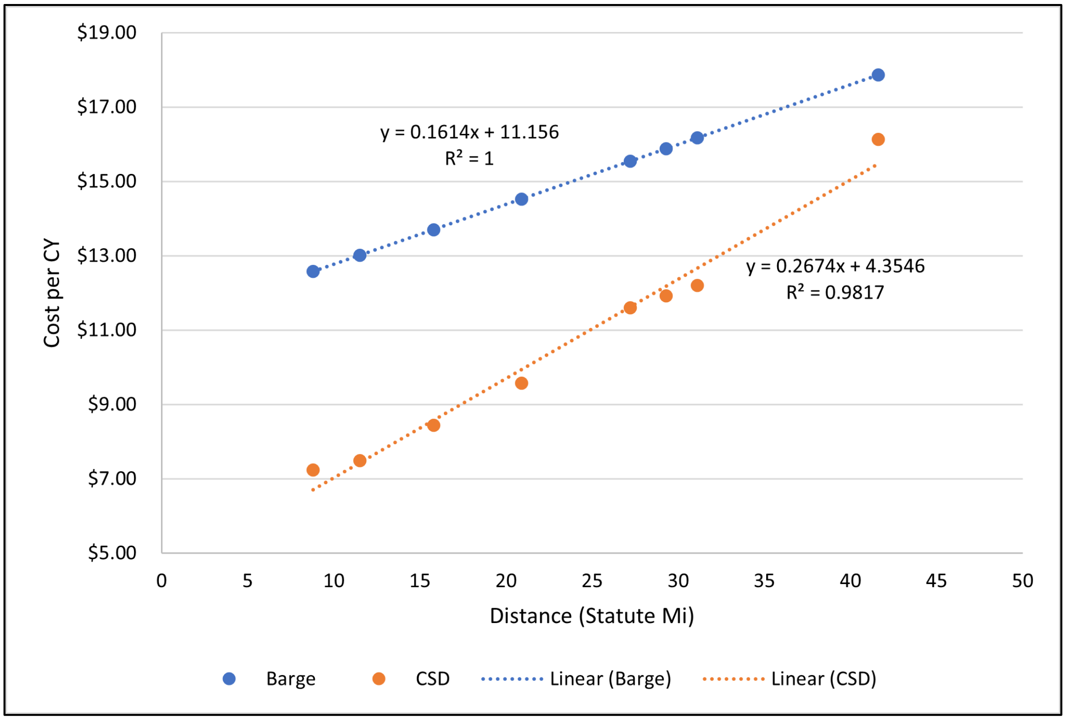

Figure 16. Dredged Fill Unit Cost ($/CY) (Ph. 2 Sand Transport from Tiger Pass Stockpile)

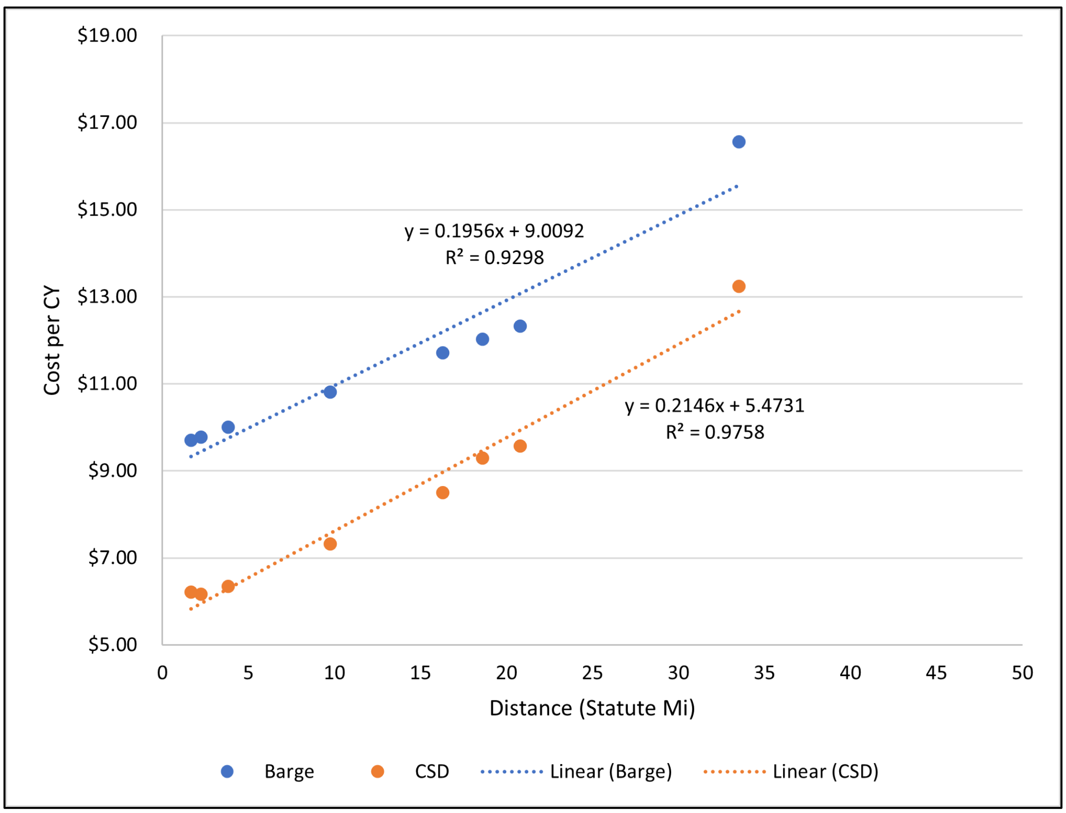

Figure 17. Dredged Fill Unit Cost ($/CY) (Ph. 2 Sand Transport from Scofield Stockpile)

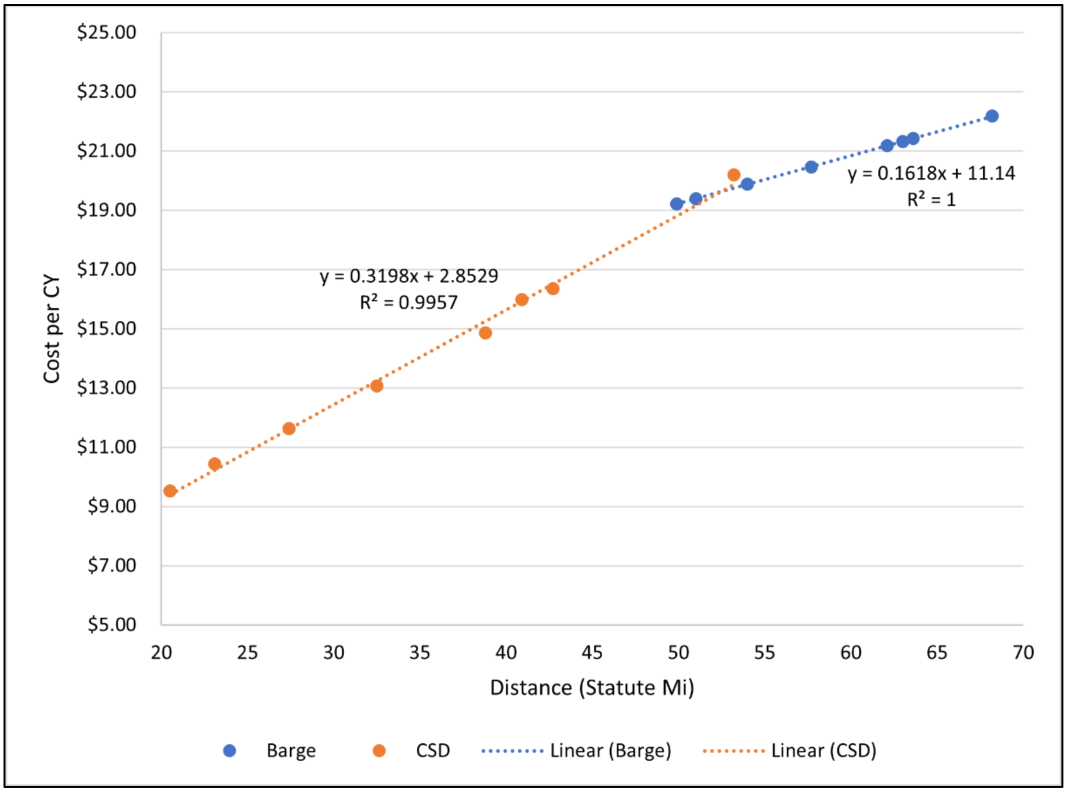

Figure 18. Dredged Fill Cost Unit Cost ($/CY) (Direct to Island Sand Transport)

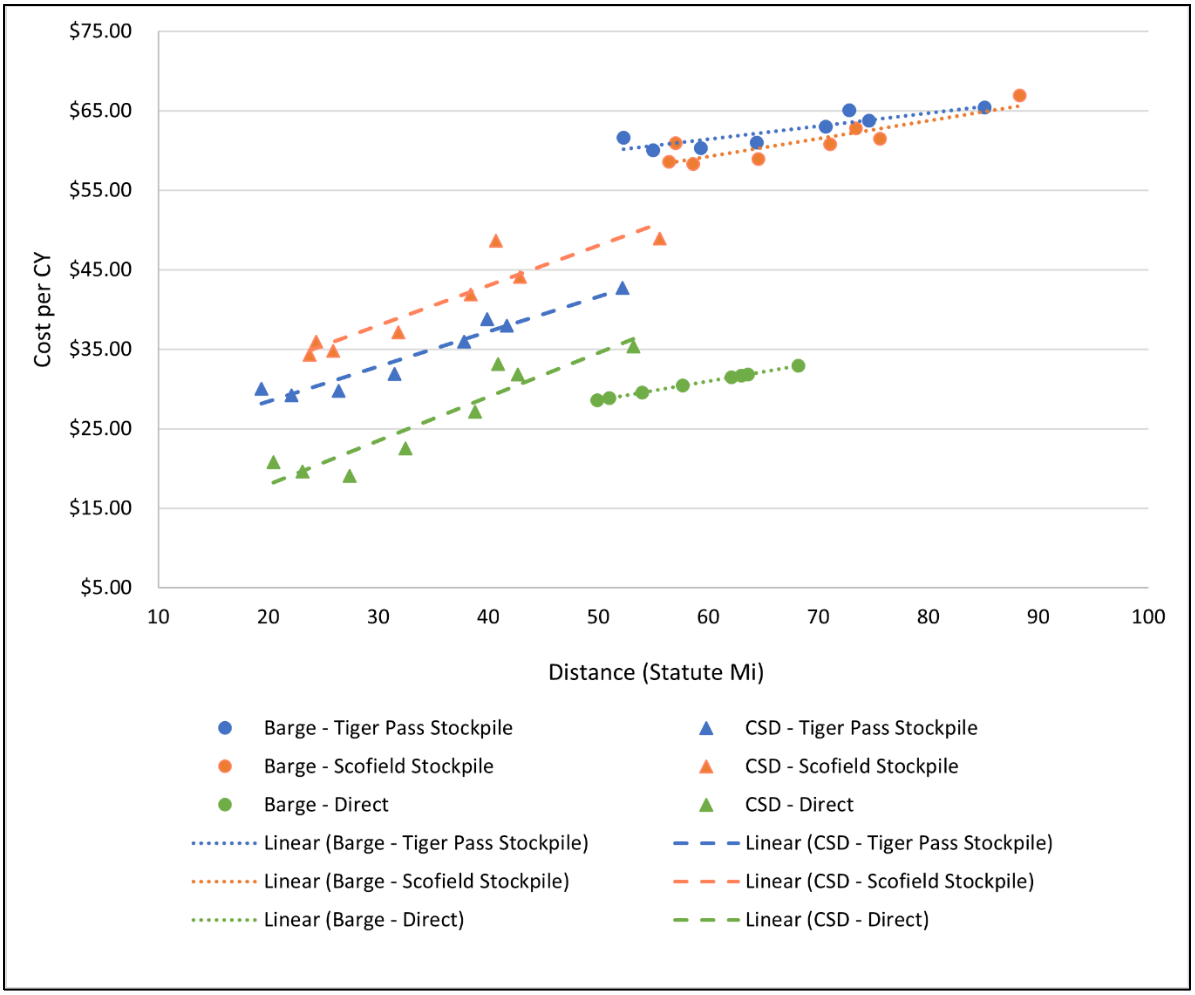

Figure 19. Total Cost per CY including 30% contingency & 17% for E&D, CM, O&M

Table 10. Linear Regression Equations for Total Cost per CY including 30% contingency & 17% for E&D, CM, O&M

Alternative	Barge		CSD	
	Linear Regression	R^2	Linear Regression	R^2
Tiger Pass Stockpile	y = 0.1651x + 51.504	0.7663	y = 0.439x + 19.677	0.9369
Scofield Stockpile	y = 0.2249x + 45.756	0.7797	y = 0.502x + 22.935	0.8524
Direct to Island	y = 0.2378x + 16.727	1	y = 0.5536x + 6.8701	0.8733

In conclusion, the optimized direct to island alternative (Alternative 14) is the most economical alternative investigated. The cost per CY of dredged fill for this alternative ranged from $9.53 to $22.18 for sand transport only (before contingency), or $19.15 to $33.69 per CY considering total cost, including the 30% contingency and 17% markup for Engineer and Design Costs, Construction Management Costs, and Operation and Maintenance Costs. The most economical optimized stockpile alternative, Alternative 1, was estimated to cost $7.24 to $16.13 per CY of dredged fill for sand transport only, or $13.19 to $26.67 per CY considering total cost of Phase 2, including the 30% contingency and 17% markup for Engineer and Design Costs, Construction Management Costs, and Operation and Maintenance Costs. The total cost including Contingency, Engineer and Design Costs, Construction Management Costs, and Operation and Maintenance Costs for the optimized direct to island alternative and the optimized stockpile alternative are $2.9B and $3.9B, respectively. Therefore, it is estimated that a total cost of approximately $1.0B is incurred by the decision to stockpile sand outside of the HDDA.

References

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4. Coastal Protection and Restoration Authority (2017). Marsh Creation Design Guidelines, Version 1.0. Baton Rouge, Louisiana. 43 pp.

ATTACHMENT A1

Detailed Cost Estimates