2023 COASTAL MASTER PLAN

PROJECT CONCEPTS

APPENDIX F

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COASTAL PROTECTION AND
RESTORATION AUTHORITY
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COASTAL PROTECTION AND RESTORATION AUTHORITY

This document was developed in support of the 2023 Coastal Master Plan being prepared by the Coastal Protection and Restoration Authority (CPRA). CPRA was established by the Louisiana Legislature in response to Hurricanes Katrina and Rita through Act 8 of the First Extraordinary Session of 2005. Act 8 of the First Extraordinary Session of 2005 expanded the membership, duties, and responsibilities of CPRA and charged the new authority to develop and implement a comprehensive coastal protection plan, consisting of a master plan (revised every six years) and annual plans. CPRA's mandate is to develop, implement, and enforce a comprehensive coastal protection and restoration master plan.

CITATION

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ACKNOWLEDGEMENTS

This document was developed as part of a broader Model Improvement Plan in support of the 2023 Coastal Master Plan under the guidance of the Modeling Decision Team:

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LIST OF ABBREVIATIONS

ADCIRC .... ADVANCED CIRCULATION MODEL

AEP .... ANNUAL EXCEEDANCE PROBABILITY

BICM .... BARRIER ISLAND COMPREHENSIVE MONITORING PROGRAM

BIMODE .... BARRIER ISLAND MODEL

BISM .... BARRIER ISLAND SYSTEM MODE

BITI .... BARRIER ISLAND TIDAL INLET MODULE

CFS .... CENTRAL WETLANDS DIVERSION

CLARA .... COASTAL LOUISIANA RISK ASSESSMENT MODEL

CPRA .... COASTAL PROTECTION AND RESTORATION AUTHORITY

DEM .... DIGITAL ELEVATION MODEL

FWOA .... FUTURE WITHOUT ACTION

FWP .... FUTURE WITH PROJECT

HSI .... HABITAT SUITABILITY INDEX

ICM .... INTEGRATED COMPARTMENT MODEL

ICM-BI .... BARRIER ISLAND DIGITAL ELEVATION MODEL

MWL .... MEAN WATER LEVEL

NAVD88 .... NORTH AMERICAN VERTICAL DATUM OF 1988

SWP .... SURGE AND WAVE POINTS

1.0 RESTORATION PROJECTS

1.1 PROJECT IMPLEMENTATION

The initial conditions for the 2023 Coastal Master Plan analysis were derived from existing data for topography, bathymetry, and vegetative cover (see Attachment B1: Landscape Input Data), with projects added to landscape that were not represented in the initial data sets but are assumed to be in existence for the 2023 Coastal Master Plan future without action (FWOA) condition. The FWOA landscape included all projects, even if they were very small features (i.e., smaller than projects selected for consideration in the 2023 Coastal Master Plan). This was considered important to ensure that the performance of candidate projects included in the FWOA landscape. The modeling of individual candidate projects was based on a 50-year simulation.

The following attachments to this document provide more information on the project types and assumptions used to develop the project attributes provided to the modeling teams:

- Attachment F1: Project Definition
    - Supplemental Material F1.1: 2023 Future Without Action (FWOA) Project List
    - Supplemental Material F1.2: 2023 Coastal Master Plan Project Development Solicitation Guidelines & Criteria
    - Supplemental Material F1.3: 2023 New Project Development FAQ
    - Supplemental Material F1.4: 2023 Coastal Master Plan Candidate Project List and Map
    - Supplemental Material F1.5: 2023 Available Sediment by Borrow Source
- Attachment F2: Project Fact Sheets
- Attachment F6: Project Development Database Documentation
- Attachment F7: Project Costing Tool Documentation
    - Supplemental Material F7.1: Project Costing Tool Validation Study

This section describes how the candidate projects were added to the Integrated Compartment Model (ICM), Advanced Circulation model (ADCIRC), and/or Coastal Louisiana Risk Assessment model (CLARA), either through direct modification of topography/bathymetry (e.g., marsh creation), changes in how the model modifies land-water character (e.g., buffer behind a shoreline protection project to reduce marsh edge erosion), or through changes in model links that determine hydrologic exchanges (e.g., structure used for hydrologic restoration). Projects were incorporated as part of the model run "set-up" phase and were put into the landscape based on specific attributes, including the implementation year. For project-level analysis, some model runs contained more than one project, yet care was taken to assure these were sufficiently separated in the model domain to avoid project interactions. The set-up for each type of project is described below.

1.2 HYDROLOGIC RESTORATION

Hydrologic Restoration projects evaluated for the plan seek to improve hydrology at the basin and sub-basin scale. Small scale hydrologic restoration focusing on restoring more localized hydrologic patterns (e.g., utilizing plugs and control structures, canal backfilling, channel cleanout) are considered programmatically consistent with the master plan.

Hydrologic Restoration projects include the introduction of culverts, tide gates, locks, plugs, weirs, siphons, and pump stations into the model domain. These projects are primarily used to convey fresh water to proposed outfall areas or to improve water circulation and reduce saltwater intrusion within a hydrologic system. In most cases, the implementation of a Hydrologic Restoration project required the adjustment of existing model flow links or the addition of new links. The link type added or modified (channel, weir, lock, tide gate, orifice, culvert, or pump station) depends on the project specifics stated in the project attributes. In some cases, a project will include a plug, which requires blocking an existing channel link. To implement these projects, the modeler determines if a channel link is entirely blocked due to the plug, or if the channel link (whether representative of a single channel or composite channel) has a reduction in width due to the plug. For pump stations, tide gates, and other link types which feature controlled operations, it should be noted that the operation rules remain the same over all years of implementation within the model (i.e., the structure operation rules remain static over time even though actual operation can vary in response to conditions).

If at all possible, subdividing model compartments was avoided during project implementation. In some cases, this meant “projecting” the structure location near the boundary of the compartment for the establishment of link attributes. However, this procedure was only used if the hydraulic conveyance between the compartments was identical at the project location and at the compartment face. Effects of projects located within the interior of a compartment that do not affect exchange between two compartments were not captured within the ICM.

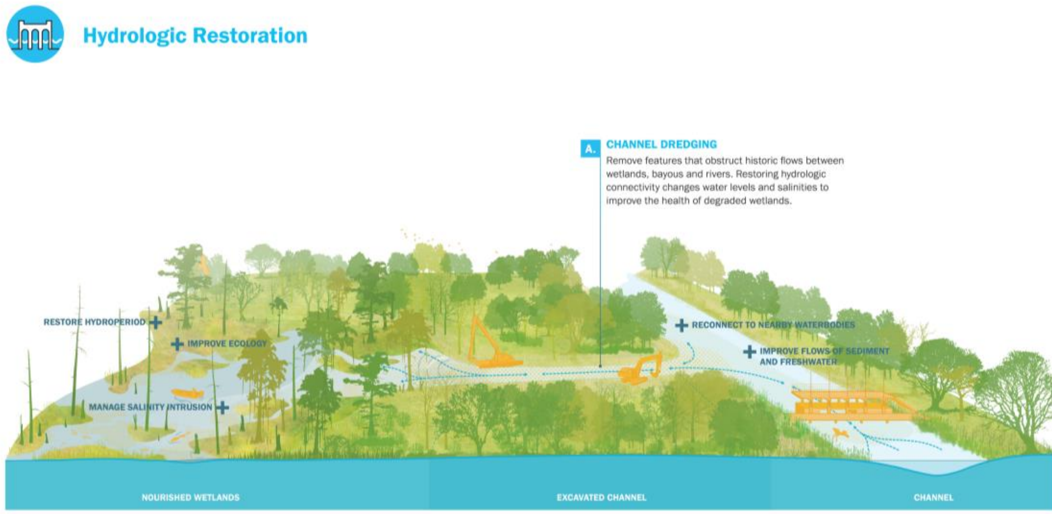

Figure 1. Conceptual visualization of Hydrologic Restoration project components.

1.3 RIDGE RESTORATION

Ridge Restoration projects re-establish historic coastal ridges and forested maritime habitat through sediment placement and new plantings. Restored ridges are high points during storm events, providing refuge for animals and potentially reducing storm surge. Ridge Restoration projects were implemented in the ICM using the same procedure and approach used for levee projects. Ridge Restoration projects were modeled via implementation in the landscape by adjusting the digital elevation model (DEM) as well as through modification/addition of hydrology links. The project was incorporated into the DEM based on the footprint shapefile and the project elevation specified in the project attributes. If a ridge was added to the landscape, existing links were inspected, additional links were added if needed, and the existing marsh or channel links were adjusted to reflect the dimensions after the ridge project was in place. Attributes such as ridge crest elevation and base width (per the project attributes) were carried over into the link attributes specified in the links input file. These links allowed for overtopping of the ridge in the ICM. They blocked the flow between compartments where a ridge was present if the stage was less than the ridge crest elevation. If the stage was greater than the ridge crest elevation, the ridge link allowed conveyance as a channel link would, until the stage dropped below that of the ridge crest elevation.

Ridge Restoration

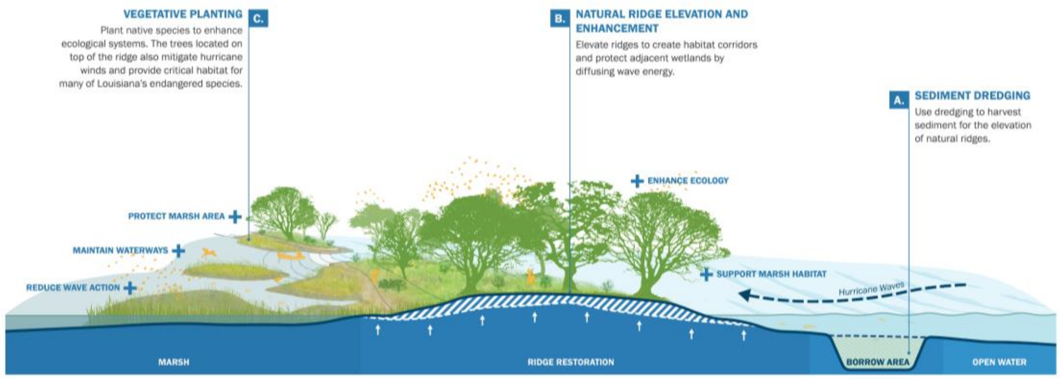

Figure 2. Conceptual visualization of Ridge Restoration project components.

1.4 MARSH CREATION

Marsh Creation projects restore landscape and ecosystem processes, enhance habitat, and provide additional storm surge attenuation. Marsh Creation projects created wetlands in shallow open water or areas with deteriorated marsh and re-graded existing marsh land through placement of dredged material and vegetative plantings. Marsh Creation projects were incorporated into the ICM via the DEM and hydrology links. The footprint shapefile of the Marsh Creation project was used to insert the project into the DEM, using the height-above-mean water level specified. When implemented on the landscape, Marsh Creation projects are built in locations only where the water depth was no deeper than 0.76 m (2.5 ft) at the year the project was implemented. This is done to both maintain existing bayous and other natural flowpaths, as well as to keep project costs down since building containment dikes for areas deeper than 2.5 ft have been shown to be cost prohibitive with real-world projects built by CPRA.

For the 2023 plan, the marsh platform design elevation was now defined relative to annual mean water level (MWL) during the year of implementation. This resulted in site- and time-specific marsh platform design elevations that also vary across environmental scenario. The height-above-MWL was determined for each Marsh Creation project *a priori* based upon the following assumptions:

- The subsidence rate assumed in the model simulation for the given project location
    - This rate would vary based upon location and assumed future environmental scenario (shallow subsidence)
    - For details on these rates refer to Attachment B3: Determining Subsidence Rates for use in Predictive Modeling

- The organic matter accumulation rate exists *under existing conditions* at the project site based upon the current predominant vegetation habitat type
- The tidal range at the project site (e.g., difference between daily mean high and daily mean low water elevations)
- The short-term (e.g., one-year) settlement of the dredge slurry would occur immediately after placement
- The marsh platform should settle into the intratidal zone ten years after construction[1].

An example Marsh Creation project is shown in Figure 3, where the design elevation (relative to mean water level) is determined based on the location- and scenario-specific rates of vertical land movement in the existing conditions landscape.

The hydrology links in the ICM were also adjusted to implement the Marsh Creation projects. Marsh links were added at compartment faces as needed and existing links were modified or removed due to the placement of the project. All channel links within the marsh creation polygons were converted to “maintained channel” links with a constant bottom elevation if they were intended to remain channel links following project implementation. Channel links were converted to “composite channel” links if they represented non-channelized flow in marsh areas. The cross-sectional area of these composite channel links was updated via the Marsh Creation project implementation code to adjust exchange as the composite link fills in with sediment.

As the implementation year (and therefore also the pre-construction elevation) varied per project, the fill volume was calculated at the time of implementation by ICM-Morph to more accurately determine the fill volume required to reach the desired marsh elevation. The project’s built area and required sediment volumes calculated by ICM-Morph are used for final cost estimation within the Project Costing Tool and correspond to the relevant environmental scenario and implementation period within which a project is assumed built. Unit costs for sediment within the Project Costing Tool represent pay-on-the-fill values.

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[1] The post-construction duration to reach intratidal elevations is a planning-level assumption made specifically for the master plan analyses. This duration is critical in balancing the competing goals of having functional marsh as soon as possible post-construction while at the same time building the marsh high enough so that it withstands rising relative sea level rise for many decades into the future. For example, we could select a marsh platform elevation high enough to ensure it would still be land after 50 years under multiple future scenarios. However, this would result in marsh being built well above the tidal frame – and would therefore not act as functioning wetland for many years. Conversely, we could assume a design elevation that would result in immediately functional marsh within the tidal frame – which would result in the newly built marshes have short durations and ephemeral benefits in the master plan analyses. To strike a compromise between these two competing goals, the master plan analysis assumed that all Marsh Creation projects should become functioning wetland (e.g., intratidal) ten years following construction.

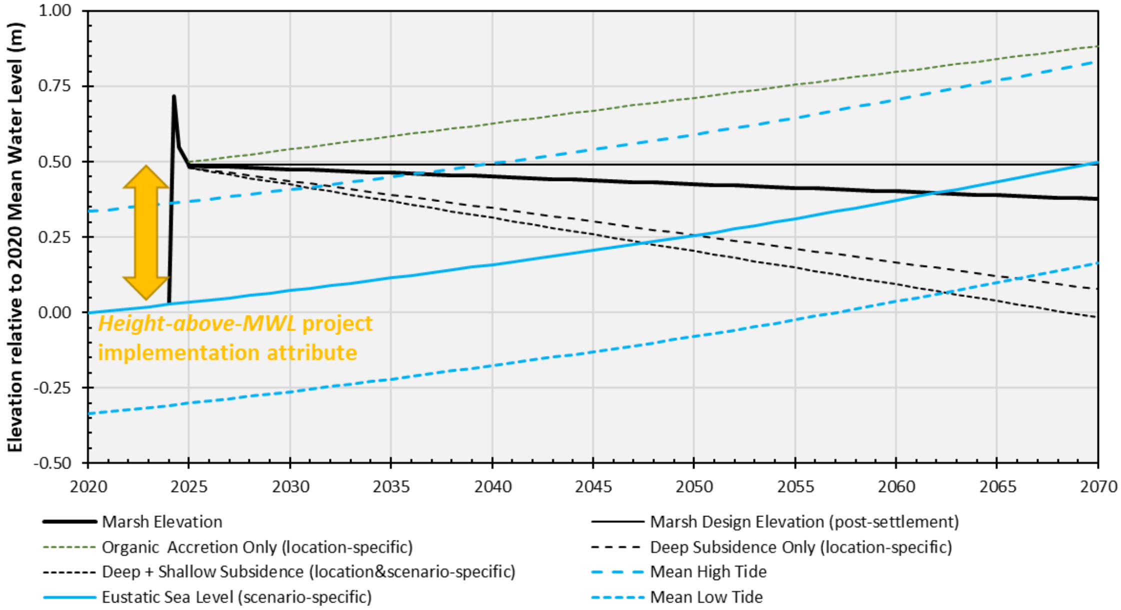

Figure 3. Example *a priori* determination of marsh design elevation attributes.

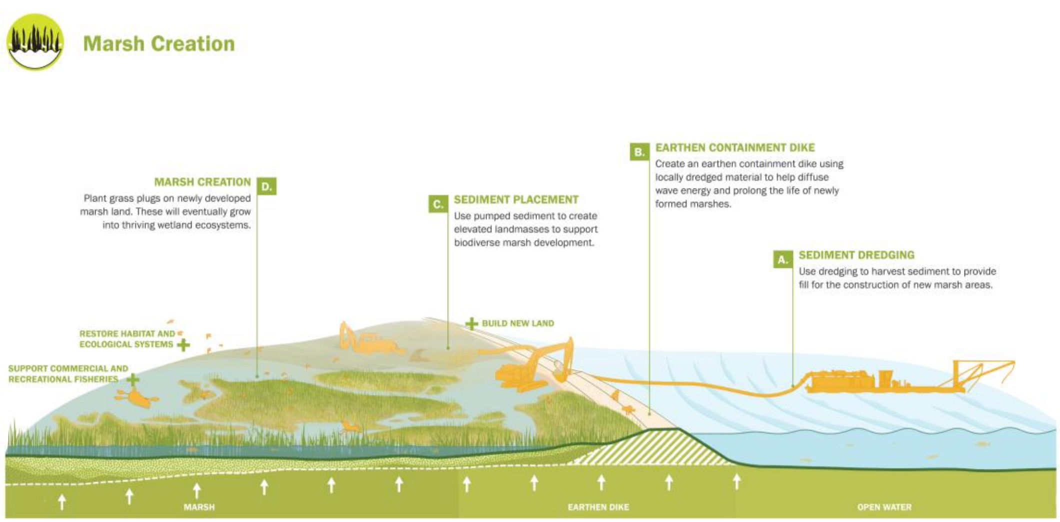

Figure 4. Conceptual visualization of Marsh Creation project components.

1.5 LANDBRIDGE

Landbridge projects are linear tracts of constructed land features oriented across coastal basins. Landbridges create habitat, attenuate waves, control the dispersal of sediment, and mitigate saltwater intrusion. Landbridge projects are integrated projects that combine elements of marsh creation, ridge restoration, and Hydrologic Restoration projects into a single landform.

Starting at the Gulfward side, the first feature of landbridge projects is a ridge element of higher ground that is intended to provide elevated ridge habitat. Behind this ridge element is an expanse of marsh creation. Unlike standalone Marsh Creation projects, the marsh component of landbridges assumes that the entire marsh footprint is filled; regardless of whether the water is shallow or deep. The intent here is to have hydrologic restoration benefits on the landward side of the landbridge projects, and this would require filling in all broken/deteriorating marsh areas and to ensure that any canals within the project footprint are backfilled to prevent salinity intrusion across the landbridge element. While existing canals are backfilled, and broken marsh will be nourished with dredge sediment, select historic flowpaths (e.g., natural waterways/bayous) will be maintained across the landbridge feature. These flowpaths will include reinforced channels to allow continued water exchange and navigation, while preventing them from increasing in width from bank erosion.

The overall intent of these projects is to provide a strip of ridge and marsh perpendicularly crossing a coastal basin, with historic (e.g., pre-canal) hydrologic connectivity so that tidal ingress and egress to the basin is maintained. While at the same time, broken marsh areas and canals are backfilled to provide a sturdy landmass at the Gulfward end of basins. These landbridge projects are placed to connect historic ridge features within each basin and were examined piecemeal so that portions of a landbridge may prove cost-beneficial in the analysis, even if the whole cross-basin landbridge form would have not been.

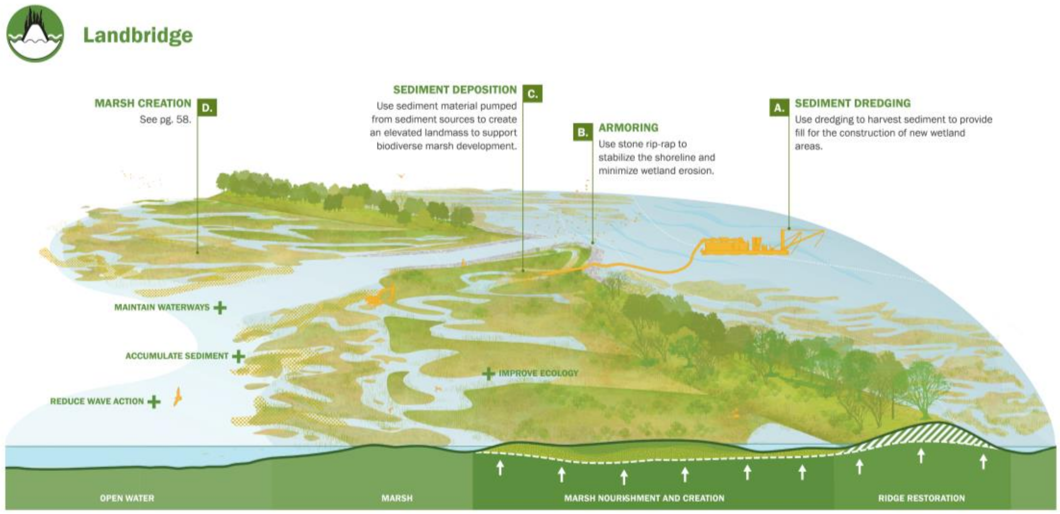

Figure 5. Conceptual visualization of landbridge project components.

1.6 DIVERSIONS

Diversions convey freshwater and sediment from rivers into adjacent wetland basins. These projects restore historic deltaic processes, build new land, nourish existing wetlands, and prevent saltwater incursion into the estuary. Diversion projects create new conveyance channels to divert fresh water and sediment from coastal Louisiana's rivers into adjacent basins. Diversion projects were modeled within the ICM in multiple ways, depending upon the upstream source of water to be diverted. Many of the modeled diversions involved diverting flow from the Mississippi River into the wetland areas adjacent to the river. A fixed amount of the Mississippi River flow is modeled as direct flow input into specific model compartments adjacent to the channel. For example, the model compartment representing Davis Pond received an influx of flow (with suspended sediment and water quality constituents) that is equal to a defined portion of the river flow as defined by the diversions assumed operational rules. This same approach was used to implement all of the diversion projects that propose to divert the Mississippi River and/or Atchafalaya River water into the adjacent wetland areas.

Some diversion projects were modeled at a relatively small but constant design flowrate, such as the 5,000 cubic foot per second (cfs) Central Wetlands Diversion (Project 14a). For these projects, the design flowrate was added as a direct, constant flowrate input into the receiving model compartment. However, the majority of the diversion projects were modeled with an assumed operation regime dependent upon the flowrate within the river. The flowrate of diverted waters were calculated from linear rating curves based upon the design flowrate defined by CPRA. Many diversions were operated such that during low river flow periods, the diversion was inactive. Once the Mississippi River was flowing at a rate greater than the low flow threshold, the diversion flowrate would increase linearly based upon the rating curve assigned. The design capacity of each diversion project, as well as the river flowrates used to define the design flowrate, and the low flow thresholds are available online via the CPRA Master Plan GitHub model source code repository[2].

For all diversion projects, the flowrate within the river immediately downstream of the diversion intake was updated to account for the removal of diverted flow. This residual main channel flow was then used for the next diversion point downstream (either proposed or an existing distributary).

All sediment diversions were implemented based upon the assumption that they would be designed such that a sediment-water-ratio of 1.0 was attained. The sediment-water-ratio is the ratio of suspended sediment concentration in the diverted outflow as compared to the channel-averaged suspended sediment concentration in the main channel of the river immediately upstream of the diversion intake structure. A sediment-water-ratio of 1.0 indicates that the river and diversion suspended concentrations are equal. A sediment-water-ratio less than 1.0 would indicate that the diversion structure is unable to convey all suspended material available in the river.

All diversion projects used a 50-year time series of flow and suspended sediment concentrations. These are described in Attachment B2: Climate-Driven Environmental Scenario Variables.

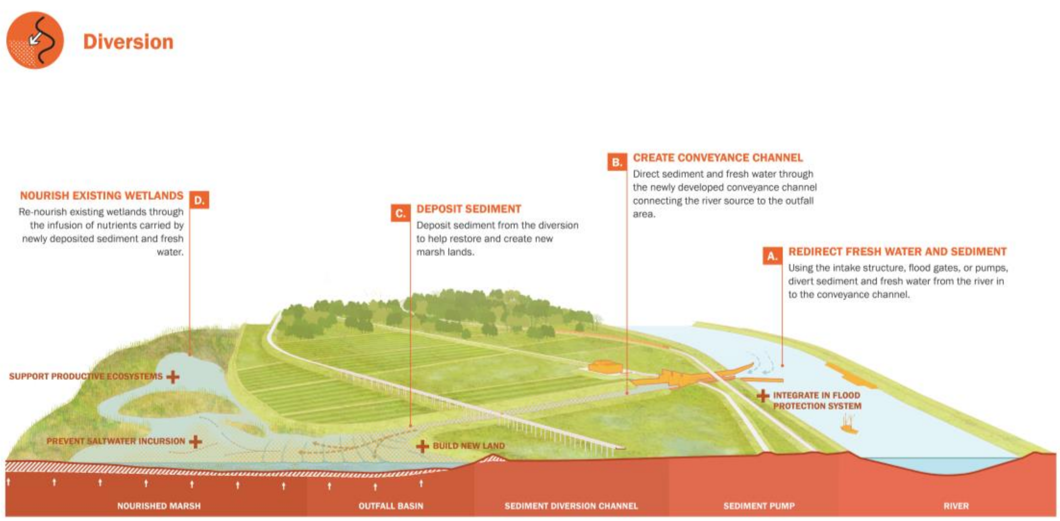

Figure 6. Conceptual visualization of sediment Diversion project components.

1.7 INTEGRATED PROJECTS

For the 2023 Coastal Master Plan, there is a focus on projects of regional scale and impact. To facilitate the analysis of larger, more complex project proposals, a new project type has been added

2 https://github.com/CPRA-MP/ICM/blob/master/diversion_flow_calculator_FWA.py

and is termed the Integrated Project. This project type will be used to examine proposed projects which comprise two or more of the traditional restoration project types listed above. Integrated projects may also include features from project types now considered programmatically, including Shoreline Protection, Bank Stabilization, or Oyster Reef Restoration projects. These programmatic projects are discussed in the following section.

2.0 PROGRAMMATIC RESTORATION PROJECT ELEMENTS

CPRA implements several project types that are not individually identified in the master plan. These projects are often smaller scale, designed to address site-specific issues, and typically provide highly localized benefits. One example includes repairing barrier island breaches caused by hurricane impacts. While these types of projects are not explicitly listed in the plan, they remain consistent with the master plan goals.

Even though these programmatic project types were not individually modeled for the 2023 Coastal Master Plan, several candidate projects were classified as integrated projects. If an integrated project included these programmatic elements, those features were added to the modeled landscape in the ICM.

2.1 SHORELINE PROTECTION

Shoreline protection projects are defined as near shore segmented rock breakwaters and are primarily used to reduce wave energies on shorelines in open bays, lakes, and natural and manmade channels. The project footprints were not included in the landscape Digital Elevation Model (DEM) or incorporated into the hydrology subroutine. These projects were implemented by adjusting the marsh edge erosion rate for any part of the compartment within the influence area behind the structure. This influence area was defined by a 200 m buffer on the landward side of the structure. The project effect on marsh edge erosion rate was applied at the 30 m grid level in the morphology subroutine. The amount of eroded sediment to be added to the compartment sediment pool was also proportionally reduced to account for the length of marsh edge within a compartment that would be protected by the project.

Within the 200m buffer, the marsh edge retreat rate in the model was set to zero; assuming that all edge retreat would be arrested post-implementation of the project, for the duration of the simulation. The new (zeroed-out) marsh edge erosion rate was then included in the revised compartment attribute input file to ensure mass balance of eroded sediments in ICM-Hydro was also updated.

2.2 BANK STABILIZATION

Bank Stabilization projects are defined as the onshore placement of earthen fill and vegetative plantings and are primarily used to maintain shorelines in open bays, lakes, and natural and manmade channels. The procedure for modeling bank stabilization projects followed the guidelines outlined above for shoreline protection projects. The project footprints were not included in the landscape (DEM) or incorporated into the hydrology subroutine, but a 200 m buffer was used to determine the influence area of the project.

2.3 OYSTER REEF RESTORATION

Oyster Reef Restoration projects construct bioengineered reefs with shell cultch or engineered/artificial substrate that promotes oyster colonization. Continued oyster recruitment and growth is expected to augment the constructed reef to enhance protection and coastal restoration benefits, including protecting shorelines from erosive forces, reducing saline intrusion, and reducing open water fetches. The oyster reef candidate projects for the 2023 Coastal Master Plan are landscape-scale projects with features and effects large enough to be resolved by the ICM.

Within the model, an oyster restoration project affected the landscape evolution with a reduction in the marsh edge erosion rate. The project footprints were not included in the landscape (DEM) or incorporated into the hydrology subroutine. Instead, a polygon shapefile bounded by the oyster reef crest and a 1 km inland buffer delineated the affected shoreline areas. The marsh edge erosion rates and the eroded sediment within the compartment were then updated in a manner identical to the implementation of shoreline protection projects.

Oyster reef restoration projects also directly impacted the oyster habitat suitability index model (see Attachment C10: 2023 Habitat Suitability Index (HSI) Model), where the HSI is a function of the computed salinity and the percent of the water bottom covered in oyster cultch. For model runs that incorporated oyster reef projects, separate HSI initial condition rasters were developed that increased the cultch bottom cover percentage within the oyster reef project footprint.

2.4 BARRIER ISLANDS

Barrier Island Maintenance projects use dredged sediment to rebuild and strengthen the beaches, dunes, and backbarrier marshes of degrading barrier islands. These projects enhance natural storm surge attenuation and maintain or improve critical wildlife habitat.

The 2023 Coastal Master Plan relies on realistic predictive modeling of the migration of coastal barrier islands and their effect on coastal basin hydrology, while incorporating periodic maintenance of barrier islands via assumed restoration. The ICM-Barrier Islands Improvement Team was tasked with recommending improvements to the 2017 Barrier Island Model (BIMODE), which were shared in Attachment D4: ICM-BI Model Improvements. Two main priorities were highlighted in the technical report, and as a result barrier islands are considered within the 2023 Integrated Compartment Model (ICM) using two separate modules: the Barrier Island Tidal Inlet Module (BITI), which models the evolution of tidal inlets along barrier islands as informed by basin hydraulics, and the Barrier Island Digital Elevation Model (ICM-BI), which models island configuration through time to support storm surge modeling. The BITI module is fully incorporated in the ICM, while ICM-BI informs the model at various timesteps.

The BITI module captures the positive relationship between tidal inlet cross sectional area and back barrier tidal prism. It uses the O'Brien-Jarrett-Marchi law to calculate an inlet's cross-sectional area using the basin's tidal prism. Due to the size of each coastal basin and the presence of multiple barrier island tidal inlets per basin, BITI calculates a fraction of the total tidal prism as it pertains to each tidal inlet using a partitioning coefficient. The module has the capability to evolve inlets as the size of the backbarrier basin and tidal prism increases over time and ICM-Hydro compartments convert to open water.

The second module, ICM-BI, has several key components. It uses historic barrier island cross-shore retreat rates under varying sea level rise scenarios to migrate barrier island transects. The transects migrate based on cross-shore retreat rates of index profiles selected to represent key geomorphic features along the coast. The second component of ICM-BI is the auto-restoration feature. This feature reflects the assumption that CPRA will maintain the integrity of the barrier island system through the Barrier Island System Management (BISM) program. In line with BISM, master plan predictive modeling efforts define barrier island integrity as preventing and repairing breaches and maintaining a critical width for each island. The auto-restoration feature represents this assumption by placing sediment on restoration units that drop below a critical width threshold. ICM-BI, after running the various components of the module passes a new DEM to the ICM and ADCIRC models at an annual timestep.

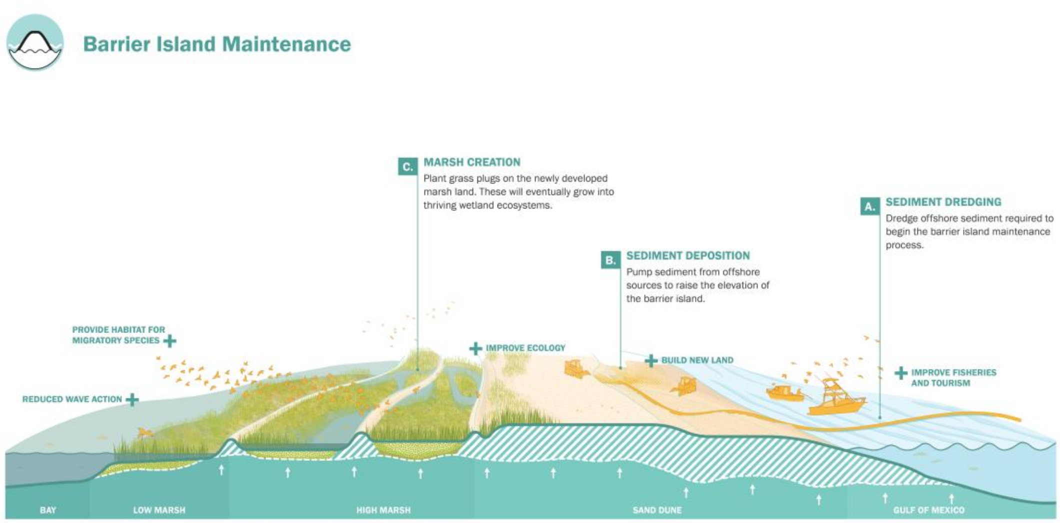

Figure 7. Conceptual visualization of barrier island restoration project components.

3.0 RISK REDUCTION PROJECTS

3.1 STRUCTURAL RISK REDUCTION

Structural Risk Reduction projects protect people and property with earthen levees, concrete T-walls, floodgates, and other structural components. They reduce the risk of storm surge-based flooding and damage within the protected area.

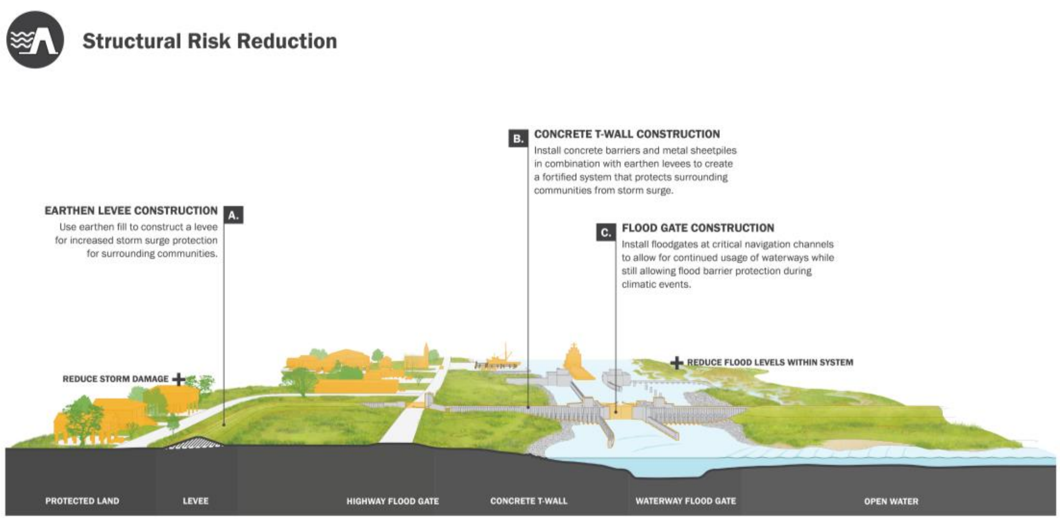

Figure 8. Conceptual visualization of structural risk reduction project components.

ICM

When levee features were implemented in the ICM as a component of structural protection projects, the approach described above for Ridge Restoration projects was used. In addition to the link deactivation as described in Section 1.4, a large number of hydraulic control structures were included with the structural protection projects. These newly activated control structures were implemented in the ICM in the same manner that was used for activating new control structures in the Hydrologic Restoration projects (Section 1.1).

ADCIRC+SWAN

Structural risk reductions projects evaluated include one or more of the following basic components: earthen levee, concrete T-wall, and floodgates. Floodgates are typically constructed at road, railroad, and water body crossings. Additionally, pump stations are included in the interior of ring levees. The ADCIRC+SWAN model was used to evaluate how structural protection projects affected water surface elevation (surge) and wave response throughout coastal Louisiana. To maximize computational efficiency, structural protection projects were divided into multiple model mesh groupings. Groupings were chosen such that projects would not interact and, therefore, could be studied in isolation though they were simulated in the same model mesh.

Project features (i.e., earthen levee, concrete T-wall, and floodgates) were implemented using ADCIRC's weir boundary condition. The ADCIRC weir boundary condition defines a feature that is too small to be captured accurately solely using finite elements in a particular model region. Overtopping volumes were computed using the formula for a broad crested weir when the computed stillwater elevation on either side of the boundary exceeds the specified crest elevation. Crest elevations are defined by the design elevations for each project feature. If the crest elevation is not exceeded, the feature appears numerically as a vertical wall. The SWAN model also implements these features as vertical walls; however, wave heights are assumed to be reduced to zero when crossing the feature before being allowed to redevelop on the opposite side of the boundary. Overtopping volumes due to waves were not computed within ADCIRC+SWAN. Many other such features are implemented in ADCIRC this way, including significant local levees and federal levees such as the Mississippi River levees, Greater New Orleans levees, and the levees encompassing Larose to Golden Meadow. For the purposes of this modeling effort, all structures were assumed to be in their closed position, and pumps were not operated.

CLARA

Structural risk reduction projects, including new or upgraded earthen levees, concrete T-walls, floodgates, and pumps were evaluated using the CLARA model to estimate their potential for flood depth and damage reduction.

Structural projects are represented as elevated weir features in surge and wave hydrodynamic modeling. These projects are each incorporated into one of six coastwide groups that include sets of projects expected to provide independent utility and benefits, so that the effects of one project in a group do not interact or conflict with another. In the case of unenclosed protection projects (i.e., fronting barriers), storm surge and wave results from ADCIRC+SWAN are used directly for statistical flood depth calculations in the CLARA model preprocessing module at each CLARA grid point.

For upgraded or newly enclosed protected systems, alternately, storm surge and wave results are provided with the project in place for a series of "surge and wave points" (SWPs) surrounding the protection system. In these cases, information about the new or upgraded system within the CLARA model flood depth module is also utilized to estimate flood depths in enclosed areas. The additional information includes structure heights, fill or armoring characteristics, geospatial alignment, and the location of transition features such as pumps or gates. Enclosed protected systems are then evaluated using the CLARA model flood depth module.

The CLARA model generates statistical estimates of flood depth annual exceedance probabilities at every CLARA grid point with both unenclosed and enclosed projects in place for each group to produce a final set of future with project (FWP) flood depths. This exercise is repeated for every combination of project group, environmental scenario, and fragility scenario.

Next, a series of geospatial polygons are used in identifying the area of influence for each structural project within a model group. These polygons are developed based on community boundaries and the location of linear structural risk reduction features. These polygons are used to estimate the effects of the individual structural projects within each group, with the assumption that only grid points within the polygon for a given project will change from the FWOA to FWP. Flood depth changes outside of the project influence zone are disregarded. In this way, a coastwide project group can be divided into a series of individual, regionally focused project effects. Furthermore, when evaluating enclosed protected systems, only changes to SWPs within the project influence zones are considered in the flood depth module; if a portion of the system lies outside of any project influence zone, the FWOA surge and wave values are used instead. This is done to reduce the potential impact of noise in the ADCIRC+SWAN models.

Finally, the CLARA model damage module is used to estimate direct damage from flooding with the project in place and summarized using the expected annual damage (in both dollars and structure equivalents) at each CLARA model grid point.

3.2 NONSTRUCTURAL RISK REDUCTION

Nonstructural Risk Reduction measures include the floodproofing, elevation, or acquisition of at-risk properties depending on projected flood depths. Nonstructural risk reduction measures are entirely voluntary and are undertaken in close collaboration with local stakeholders.

Nonstructural Risk Reduction

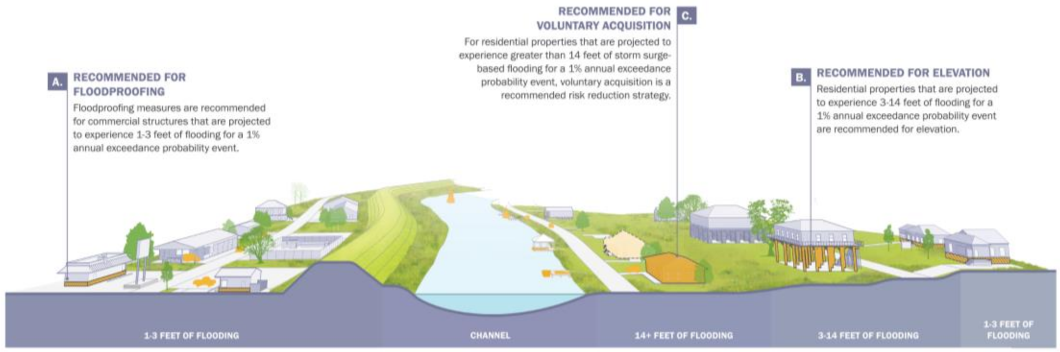

Figure 9. Conceptual visualization of nonstructural risk reduction project components.

Nonstructural Risk Reduction projects include non-residential floodproofing, residential elevation, and voluntary residential acquisition. These projects are based on the Federal Emergency Management Agency Base Flood Elevation plus 2 ft of freeboard or CPRA's recommended elevation height (1% annual exceedance probability (AEP) [e.g., 1-in-100-year] flood depths plus 2 ft freeboard), whichever is higher, to add a wider safety margin for future flood risk. They include:

- Floodproofing non-residential properties where the 1% AEP flood depth is 1-3 ft
- Elevating residential properties where 1% AEP flood depths are 12 ft
- Voluntary acquisition of residential properties where 1% AEP flood depths are greater than 12 ft

Note that elevating homes is limited to areas of 12 ft of flooding due to challenges with wind exposure if homes need to be elevated higher.