Appendix M
Civil Engineering

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Chapter 1: Existing Conditions

1.1 Project Study Area

Crains Island is bound between approximate River Miles 103 and 107 on the right descending bank of the Mississippi River. Crains Island, sometimes referred to as Mary's Island, is a natural formation between the previous and current main channel of the Mississippi River. The previous main channel formed the dividing line for the states of Missouri and Illinois, and later became the Missouri Chute side channel. Over the last century or more – namely in the 1930s – a series of dike structures were installed to aid in the river's use as an arterial navigable waterway. These and other changes in the river meander caused the Missouri Chute to close and reconnected the island to the mainland, though the island still remains within the Illinois border.

The timber pile-dikes that run through the island are presumed to be similar to those uncovered by the Winter 2015 Flood damage just upstream of the project area on the Mississippi River (shown in Figure 1). The dikes were constructed of timber soldier piles with lagging timbers placed between them, tied by wire rope. The dikes encouraged (primarily course-grained) sediment deposition, creating, altering, and reconnecting the pre-engineered island to the western bank. As such, the soils within the project area are expected to be largely sands, with pockets or small strata of fines interspersed.

Figure 1: Remnants of timber Dike, Ste. Genevieve 2 Levee.

As with most islands within the Mississippi River Flood Plain, the core of the island is composed primarily of course sediments, namely deposits of a fine, poorly-graded sand - commonly referred to as "sugar sand"

- interspersed with pockets of Gravels, Cobbles, Silts and Clays. The surface layer - roughly 10 feet in depth - is highly varied, and includes High- and Low-Plasticity Clays, Silts, and Sands.

1.2 Topographic and Gage Data

1.2.1 Topographic Survey Data.

Topographic surveys were conducted in 2012 as part of a "Low-Water Survey" covering a large portion of the Lower Reach, Middle Mississippi River. The survey was completed by aerial Light Detection and Ranging (LiDAR) equipment by a third-party contractor with a specified Confidence of 95%. The data was collected in UTM North Zone 16 North American Datum of 1983 (NAD83), North American Vertical Datum of 1988 (NAVD88) in units of meters and was converted to the design datum for this and parallel studies: Missouri State Plane East (FIPS 2401) in units of US Survey Foot NAD83, NAVD88. The Missouri datum was selected to coincide with the connected land-mass and other parallel projects, but since the island resides within the Illinois border, the Horizontal datum will be translated to Illinois State Plane West (FIPS 1202) during Preconstruction Engineering Design.

1.2.2 River Gage Data

Stage and elevation information for the Mississippi River for the planning-level design of this project are taken from the nearby Chester, IL Gage, approximately four miles upstream of the Island. Because of the age of the gages on the Mississippi River, and the difficulties in mass conversion between the two very different projections, the Vertical Datum for gage data used in this project remains the National Geodetic Vertical Datum of 1929 (NGVD29).

Survey data was collected in an effort to investigate the potential difference in elevation between the two datums, revealing that a reading in NGVD29 in this area is approximately one half foot greater than that same point in NAVD88. For the purposes of this study, this difference in elevation is considered (conservatively) within tolerance, and the two may be used interchangeably for the design of features recommended in this study. Daily average elevations at the Chester Gage are presented in Figure 4, below:

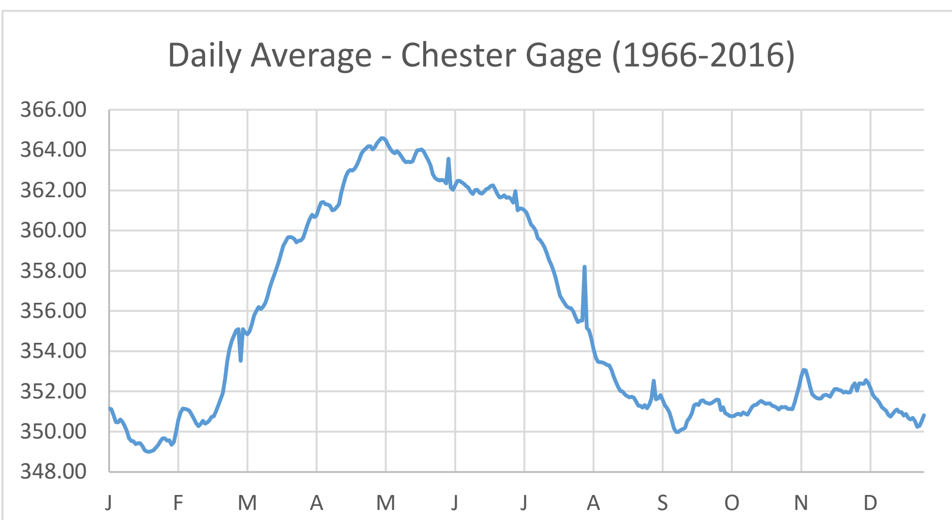

Figure 2: Daily Average Gage Elevation, Chester IL (NGVD 29)

During the primary growing season, spring through early summer, the land experiences frequent flooding and high water tables, providing hydric soil conditions conducive to wetland and floodplain forest habitat restoration, if appropriate growth-medium soils are present.

1.3 Project Area Constraints

1.3.1 Sponsor Requirements and Constraints

The Partner or Sponsor of this Project, the United States Fish and Wildlife Service (USFWS) owns and manages the Project Area as a Conservation Area, and the over-arching objective of this Project is to improve the habitat value of the Project Area. Furthermore, the USFWS as a Federal Agency has a limited budget and limited personnel to conduct active Operations and Maintenance (O&M) of the Project, and requested that any and all proposed features for this Project be designed to reduce the necessity of O&M. For this purpose, many controlled or managed systems, such as pump stations, culverts, etc. were not considered in lieu of mimicking natural forms and processes.

1.3.2 Site Access

The site is bounded on its land side by the Bois Brule Levee, on or over which land-based equipment will be required to travel to access the site. Damages to the levee will be required to be repaired by the Contractor. River access for dredging and dike modifications, where practicable, will be done using floating plant, using commercial portage and the Federal Navigation Channel.

1.3.3 Real Estate

The project area is owned in fee by the US Fish and Wildlife Service, but contains a privately owned inholding that is assumed to be unavailable for construction of project features, but may allow limited, temporary access agreements or temporary easements. It is also flanked in the southwest side by the Bois Brule Levee, from or over which the only land access is available. It is assumed that the Levee District will allow heavy construction equipment to cross or travel the levee, though river-based access for such pieces may reduce the contractor's liability in repairing damage to the levee from equipment access.

1.3.4 The Bois Brule Levee Underseepage Reevaluation

The Bois Brule Levee is currently under an engineering investigation to determine if the original or current design is effective in reducing the flood risk for the leveed area. As part of this study, a planning-level analysis of risk to Bois Brule by the project features was conducted, determining whether or not the HREP project would decrease the seepage energy path during a design flood. The analysis was conducted after the Tentatively Selected Plan (TSP) Milestone, and determined that no excavation should be conducted within 600 feet of the levee toe, with a preferred buffer of 1000 feet. The TSP feature locations were adjusted as needed according to these planning buffers, with only one excavation feature being recommended within the less optimum buffer zone, but no TSP features were removed from the project. All features will be further studied during Preconstruction Engineering Design (PED) to determine the acceptability of their associated risk to the Bois Brule Levee, as further discussed in Appendix B, Geotechnical Considerations.

1.3.5 Culturally Sensitive Area

There is a potential culturally sensitive area within the project boundaries that will be largely undisturbed by the project features anticipated at the time of this writing, but may encounter large equipment passage and placement of material above the existing grade. A survey was conducted to determine if artifacts of historic significance are present, with none being found. Additional information on this site can be found within the Cultural Appendix F.

Chapter 2: Measures

A suite of measures were developed during the scoping Charrette to determine what improvements could be made to the Island's habitat. These full list of measures and screening information is included in Chapter 4 of the Report. After screening, a select few measures were selected for Alternatives formulation, and received preliminary engineering design to determine their feasibility, effectiveness and approximate cost.

The Tentatively Selected Plan, previously alternative 2A, combined three measures to maximize ecosystem

benefits; a Side Channel, Sediment Deflection Berm, and Depressional Wetlands.

2.1 Side Channel Habitat

2.1.1 Measure Intent

During the scoping charrette, flowing side-channel habitat was identified as a high priority in this reach of the Mississippi River due to both the lack of currently functioning moderate-flow side channels, and the variety of species requiring or utilizing this habitat. The northeast portion of Crains Island is divided by a side channel that does not carry flow the majority of the year, but does provide an opportunity to improve, rather than create, a suitable side-channel, reducing the total quantity of soil removal.

The existing channel bottom elevation is roughly 357 feet NAVD88, placing it above the average river elevation for most of the year and leaving it dry when water is not impounded by beaver dams. The slopes of the banks are stable but steep, at between 1V:1H to 1V:2H, providing little diversity in the wetted perimeter of the channel.

2.1.2 Design Discussion

To maximize the fishery habitat benefits of the side channel, the PDT recommended an increase in overall size and diversity of the wetted perimeter. This is primarily done by reducing the steepness of side-slopes and/or adding benches within the slopes to improve diversity of channel habitats at differing flow elevations. Of the two alternative measures, the benched version shown in sheet C-301 was selected as providing the most net benefit over the simple, wide, trapezoidal side-channel. Both alternatives used slopes of 3 feet of run for each foot of rise (1V:3H), and the selected alternative introduced one or more benches of approximately 20 feet in width placed roughly midway through the bank. These benches and shallow slopes increase the hydraulic (wetted) perimeter and add diversity to the channel, but pose difficulties with construction, and will require roughly 40% of the channel to be excavated by land-based construction methods.

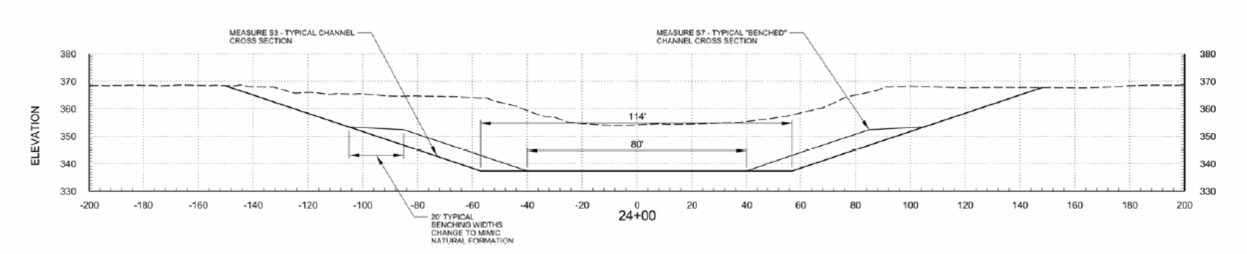

Figure 4: Comparison of Benched vs. Trapezoidal Channel Cross-Section

The current side channel formed between the stone-reinforced dikes along the Mississippi River Bankline, as well as above and around pile dikes through the island interior. Near the side channel exit a pile dike is visible as an earth mound, around which water has cut a bend before resuming the straight-line path formed by the force of high river flows. Timber dikes remain relatively intact for long periods of time, so long as

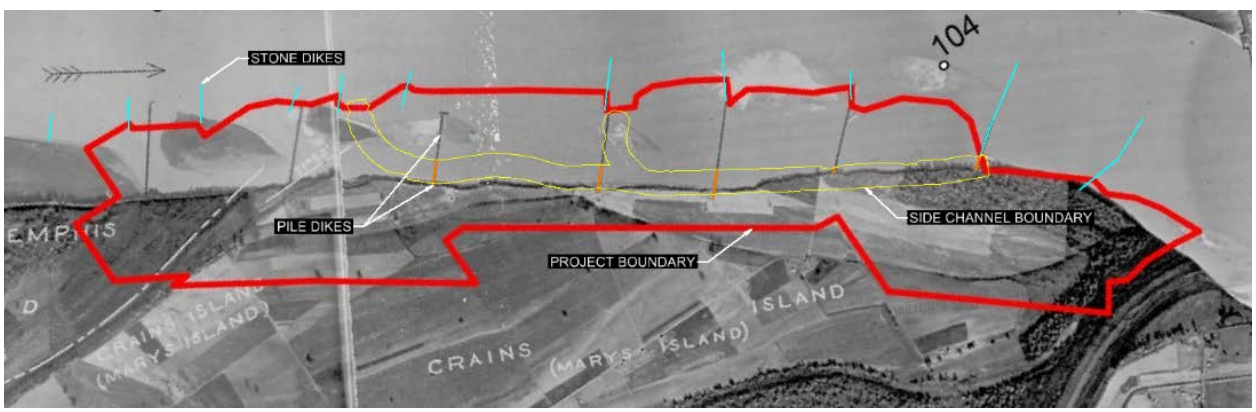

Figure 5: Historic Dike Locations in Project Area (1931)

they are not exposed to air, and this and other dike structures that are currently buried within the proposed channel cross-section will require partial removal by land-based excavation activities prior to the start of dredging efforts. One or more of the stone dikes established in the last few decades will also require partial removal to improve flow conditions.

To ensure aquatic habitat is available the majority of the year, the side channel bottom was also recommended to be lowered, and the channel widened overall to improve flow capacity and ensure the channel remains open and functional. The current configuration is open to high direct flows from the river, and collects a large quantity of debris at the entries, further reducing the channel's capacity and functionality.

Figure 6: Debris Pile Clogging a Channel Entry

The bottom elevation of the recommended channel profile is approximately 337 feet NAVD88, significantly lower than the current configuration, and likely to be below the river elevation the vast majority of the year. In addition to this, more gradual side channel openings were recommended by the USFWS as a potential method for reducing debris input into the system to a manageable level, keeping the system open and capable of supporting habitat throughout the life of the project.

2.2 Sediment Deflection Berm.

2.2.1 Measure Intent

Given that a large quantity of material is anticipated to be removed for the creation of the Side Channel, a sediment deflection berm, similar in concept to a levee, was recommended as a method of repurposing the material, and adding interior benefits to the site. The berm's functionality is based on evidence available from Wilkinson Island, which has been partially leveed in some form or other since the 1920s. These levees were breached multiple times, especially during the 1993 flood and were largely abandoned after. Shallow soil sampling by hand probe and similar methods has revealed that a layer of fine soils have accreted behind the levee, attributed to backwater flooding of the leveed area. These fine soils, classified by the United Soil Classification System (USCS) as C or M type soils (clays and silts) provide the necessary substrate for reestablishment of bottomland hardwood species and floodplain forest habitat.

Figure 7: Soil Probe Sample from Behind Wilkinson Island Breached Levee

The sediment deflection berm re-creates the backwater settling conditions during most flood events by deflecting the direct flow of the river and the course sediment (sand) carried by the high-velocity flows, and by providing an indirect path for flood water to enter at low velocities. Since the floodplain remains open, the sediment deflection berm will also maintain the flood-storage capacity of the island.

2.2.2 SD Berm Profile

Initially, multiple elevations were considered, each corresponding to an average elevation approximating a common flood level at the associated river mile, from a 50% exceedance flood (commonly referred to as a "2-Year" event) to a 10% exceedance ("10-Year") flood. A 10-Year elevation profile was selected as providing ample opportunity for settlement of fine sediments without a high likelihood of causing a rise in adjacent 100-Year (1% Exceedance) flood elevations based on a one-dimensional hydraulic model. The Profile Grade, based on a flow-frequency study is approximately 0.0001, ranging from elevations 377 to 379 across the length of the island. After concerns with the performance of the side channel necessitated the use of a two-dimensional hydraulic model, it was determined that a 10-Year profile was likely to create a small increase in 100-Year flood height that was above the allowable limit set by the state of Illinois. To reduce estimated flood heights to within the Illinois requirement, the berm profile was reduced to a 5-Year, 20%

Linear design techniques using InRoads Civil Information Modeling suite were used to develop the initial sediment deflection berm models, allowing future iterations of design to better develop mass-balance estimates for haul routes, and improve constructability on the whole.

2.2.3 SD Berm Reforestation

The SD berm will be planted with trees capable of surviving in the local soil conditions, assumed to be primarily sand.

A buffer area 50 feet from the Bois Brule levee will not be planted with trees, but will be seeded with a turf grass blend to ensure the project will not impact the levee district's ability to maintain its vegetation-free zone in accordance with USACE Levee Safety guidelines.

2.3 Depressional Wetlands

These features are designed similar to the Cottonwood Island HREP project "Pothole" features completed in 1997, and are intended to provide still-water wetland spawning habitat for reptiles and amphibians by reducing the quantity of fish species available to consume eggs and juveniles. This is achieved by cutting into the existing grade in benched sections, approximately 15 feet in width, and at two-foot vertical, six-foot horizontal (1V:3H) intervals to ensure the benches remain as distinct as possible. The one-foot high benches used at Cottonwood Island degraded to a relatively uniform, single slope by the time of the 2006 Performance Evaluation Report, but otherwise appear to be functioning acceptably.

Prior to a review by the Bois Brule Levee Design Deficiency analysis team, five depressional wetland units were proposed, spread across the island and SD Berm interior. The review resulted in a recommended planning buffer of between 600 and 1000 feet between the levee toe and any excavation activities so as to not provide a significant increase in underseepage risk to the levee. This limitation reduced the available area to place separate units, resulting in a recommendation to combine the units into two larger units. The upper unit excavation is outside of the 1000 foot planning buffer, while the lower unit is outside of the 600 foot planning buffer. Underseepage analysis for both wetlands will still be required during PED to ensure that they do not provide a seepage path; if it is determined that seepage risk is increased by either wetland unit, the options to reduce this risk include reduction in size and/or depth of the unit(s), and over-excavation of the unit, followed by construction of a clay lining. To construct the clay lining, purchase of offsite borrow or engineered clay product is assumed to be required, given the low quantity of fine-grained material found on Crains Island as of the time of this writing.

A bottom elevation of 358 feet NAVD88 was selected for the upper proposed wetland unit, and 354 feet for the lower proposed unit. These elevations are expected to allow groundwater infiltration into the wetland unit throughout much of the year while reducing the quantity of material necessary to excavate. To efficiently dispose of the excavated material – utilizing a small footprint to reduce existing wetland impacts, and doing so near the excavation to reduce haul distance - the Cottonwood Island Potholes spoiled the material in a low-elevation berm surrounding the excavated area, providing a secondary benefit of protection from low floods.

A similar berm is proposed for the Crains Island Depressional Wetland units, using minimal compaction effort to keep these berms stable, and will be built with an approximate crown width of 10 feet to provide maintenance and management access. The crown elevation for each unit is 372 feet NAVD88 to maintain the elevation beneath the berm crown elevation to ensure no additional flood effects are caused. When the available area for depressional wetland construction was reduced, the wetland units were moved against the SD berm backslope, and the portions of the berm that follow along the slope of the berm have an increased crown, such that they form a bench against the SD berm slope, and that the toe of the steeper depressional wetland berm is beyond where the SD Berm slope would intercept existing grade. Despite this, due to the height restriction, the depressional wetlands have a net negative cut-fill balance, such that much of the cut material will be used in the construction of the SD Berm itself, increasing the quantity of material to be dredged from the side channel.

The first bench of the wetland unit will be placed at the approximate original grade elevation to prevent runoff from the spoil material into the excavation until plantings and native turf are established. For the lower unit, this elevation is approximately 362 feet NAVD88, while the upper wetland unit is benched starting at elevation 366.

The berms and wetlands will be planted with native cover species to stabilize the soil and begin the natural processes of creating functional wetland habitat. Depressional wetland unit locations were selected from areas not currently covered by significant woody vegetation to reduce clearing costs and intermediate environmental/ecosystem impacts.

Chapter 3: Construction Sequence and Methods

With the high price-tag of the project, the construction will likely have to be divided into multiple contracts or construction periods coinciding roughly with Workplan funding. This will create many challenges for the PDT to ensure that the project remains within budget, as multiple-phase projects generally require multiple mobilization and demobilization payments, increasing the overall project cost without adding additional benefits. To reduce these risks, the PDT proposes the following construction phasing, to be further refined during PED:

3.1 Phase 1

While it is preferable to award this phase as one contract, it is possible to react to expected funding stream limitations by dividing the work into multiple contracts, or multiple task orders under a single, over-arching contract. Maintaining a single contract with multiple task orders or options provides the flexibility of choosing how much and when the work will proceed, in order to attempt to maintain a single mobilization for the entire contract. In general, if the work is to be divided into reaches, these will be prioritized from downstream toward upstream.

3.1.1 River-Based Dike Modification

It is recommended that the two stone dikes at the side channel exit of the proposed channel be notched during the first phase to improve flow and allow future dredge access. It may be possible to utilize existing river-based dike modification contracts, minimizing mobilization requirements and reducing the overall contracting time and labor burden. If timber piles are encountered during this phase, they will likely have to be removed during a subsequent phase of construction.

3.1.2 Depressional Wetland Construction, Side Channel Excavation, and SD Berm Placement

The Depressional Wetland Units will be constructed using land-based excavation and grading equipment, primarily dozers and tractors with attachments, including pan scrapers, tillers, compaction equipment, etc. One or more hydraulic excavators will also be necessary for establishing grades, removing debris, and incidental excavation. The material excavated for the depressional wetlands will be required for use in the SD Berm, and should be sequenced to reduce the haul distance to the fill location(s). The upper depressional wetland will likely be sequenced first, as the material excavated from it will be useful in constructing the transition and ramp from the Bois Brule levee crown to the SD Berm, as it is the nearest excavation to that point.

A portion of the side channel excavation will be completed with the same land-based equipment and methods as the depressional wetlands, and should be done, at least in part, in conjunction with that work. Unlike the depressional wetlands, the widening of the side channel and placement of portions of the SD Berm will require tree clearing. Clearing will be done by ground crews in conjunction with dozers and similar equipment, much of the timber being chipped for use in access roads or stockpiled for use as mulch during Reforestation. Trees with diameters too large for chipping may be stockpiled until able to be spread across areas not designated for access roads, cut, or fill to decompose naturally and begin creating habitat. Saleable timber is unlikely to be found in this reach, as the sand-tolerant floodplain species are not highly sought after for use as lumber. The topsoil and non-woody vegetation grubbed and stripped from the footprint of these features will be stockpiled behind the toe of the sediment deflection berm to await use as a capping material and growing medium for beginning the establishment of vegetation.

Once trees are cleared and vegetation, topsoil and tree roots are grubbed from within the footprint of the side channel and sediment deflection (SD) berm, the initial earthwork will begin for the footprint of the new channel inlets, benches and side-slopes. The upper trapezoidal section, covering the benches on either bank of the side channel, will be excavated primarily by pan scrapers and placed within the deflection berm footprint for shaping and compaction by dozers and compactors. The majority of the soil prism above the central channel - namely that at elevations above the benches - may be left in place for removal by the dredging operation to reduce costs.

Efforts will be made to reduce the haul distance and clearing required for access, and the path of the scrapers will coincide with recently placed material to reduce the compactive effort. Compaction requirements for the SD berm will be prescriptive rather than performance-based to reduce testing costs, and will be specified by the geotechnical or civil engineer as appropriate for the material to be placed. Compaction equipment will likely be “tow-behind” equipment, pulled by tractors or dozers, and will primarily be vibratory for the course grained soils, with ridged or sheeps-foot type rollers for the finer and organic capping materials.

Once the earthwork for a new channel entrance is substantially complete - allowing high flows from the river to move through the side channel - the historic entrance should be filled. Natural debris, namely driftwood and cleared trees, may be moved to the mouth of the existing entry channel to act as armor for the backfill soil placed behind. It will likely be acceptable for the contractor to leave gaps in the land-based fill operation for later placement of dredged material, so long as the entrance is effectively blocked, a stable foundation is established for the SD Berm, and an embankment is established along the new side-channel bank line to prevent dredged material from reentering the channels to require additional dredging. Minimal clearing will be required for this work, allowing existing trees to remain as seed source and scour protection.

3.1.3 Cross-Dike Excavation

Several cross-dikes, presumably constructed primarily of timber with incidental quantities of stone cover and wire rope ties will be excavated and removed from the footprint of the new side channel prior to the dredging operation to cut the remaining portions of the channel. This has the two-fold advantage of removing the obstacles from the path of the dredge and creating grade-control within the channel. Grade control structures are used to control a stream’s meander and may be able to direct the river’s flow sufficiently to scour material from the channel footprint, reducing the amount of material to be dredged.

The timber piles are likely degraded sufficiently to prohibit use of a vibratory pile extraction system, particularly in conjunction with the wire rope and lagging timbers as barriers to extraction. More likely, the removal will coincide with the excavation of the side channel benches until their target elevation is reached, at which point the continued removal will require deep excavation or trenching techniques in order to allow crews to access the remnant timber piles and cut them to the appropriate elevations. Trench boxes, shoring, or over-excavating will be necessary for the work of cutting and removal to be completed. Direct use of pumps from the excavation is likely to be the most cost-effective means of dewatering, possibly in conjunction with river-elevation based scheduling to reduce the source water into the excavation. Excavators with thumbs or, if deemed more economical, a crane with grabber attachment will be necessary to remove the pieces of lagging, and the cut timbers themselves. The timbers, once allowed to fully dry, will likely be allowed to be reburied or placed to decompose elsewhere in the project limits in the same manner as cleared trees, unless chemical preservation coatings are found that would preclude this practice due to health and safety concerns. Burial within the project's berm features will not be authorized in order to minimize risk to the function of the project.

3.2 Phase 2: Reforestation and Adaptive Management

During this phase, sand-tolerant trees will be planted along the slopes of the SD berm and depressional wetlands, above the previous channel entrance backfill, as well as other designated inland areas. Other species, such as oak and pecan may be planted on berms where suitable soil has been placed to offer a seed source for future forest development, but this is anticipated to be limited. Tree plantings will be mulched with previously-chipped trees and other woody vegetation. Additional seeding may be required where land-cover vegetation has not been fully established, or in conjunction with invasive species removal.

Adaptive management may begin after the first feature is completed, and will continue after construction is complete.

3.3 Phase 3: Dredging

Since the side channel bottom will be under water the majority of the time, and the large quantity of material to be removed from the channel, it is likely to be most effective to dredge the remaining material from the channel cross-section. A cutter-head suction dredge is likely to be the contractor's selected method, as it provides a high degree of accuracy for cutting the shallow-side slopes and bottom, and by offering ease of continuous disposal through flexible pipelines. The dredge will remove material along the central prism attempting to cut the sides at approximately 1V:3H. The material to be dredged will be primarily course-grained, and is expected to self-adjust to an angle of repose similar to the designated 1V:3H slope, but a subsequent operation may be required to do final grading of the slopes.

Suggested disposal sites have been identified, some of which may offer ancillary ecosystem benefits by supporting other restoration programs through sandbar island creation and nourishment. Additionally, temporary islands may be created by filling the scour zone of the nearby chevrons, reducing the likelihood of impacting the navigation channel. These islands will be scoured away by floods that rise above the chevron crest elevation, moving the material further downstream, but delaying its introduction into the river until flows to adequately mobilize the material are reached.

The dredging operation will primarily move from the downstream end of the island upstream, barring any required work on the entrances from the River. Dividing the dredging operation into multiple contracts should be avoided, if at all possible to avoid the additional mobilization costs associated with each period, as each mobilization/demobilization of such a large piece of equipment is extremely expensive.