Appendix C

Engineering Design Analysis

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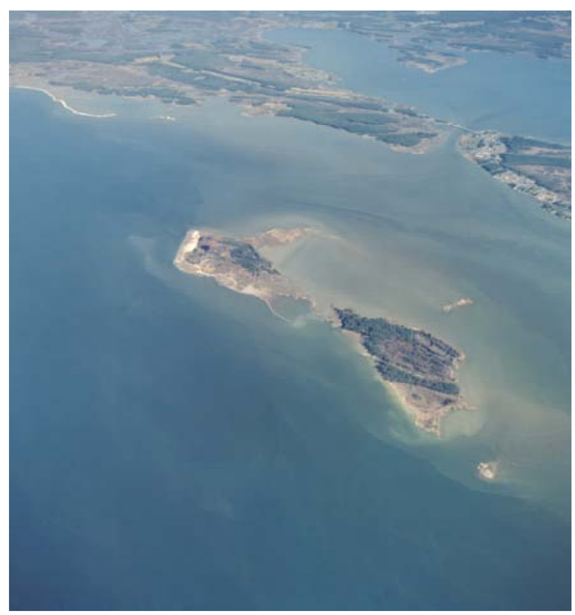
US Army Corps
of Engineers
Baltimore District

MID-CHESAPEAKE BAY ISLAND ECOSYSTEM RESTORATION PROJECT

CHESAPEAKE BAY, MARYLAND

Feasibility Report

Engineering Appendix



May 2008

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MID-BAY ISLAND FEASIBILITY REPORT
ENGINEERING APPENDIX

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1. PROJECT BACKGROUND

1.1 Study Purpose. The purpose of this study is to determine the technical, economic, and environmental feasibility of protecting, restoring, and creating aquatic, intertidal wetland, and upland habitat for fish and wildlife at Mid-Chesapeake Bay Islands using clean dredged material from the Baltimore Harbor and Channels federal navigation project. Specifically, this feasibility study will (1) examine and evaluate in detail the problems and opportunities related to the restoration of island habitat through the beneficial use of dredged material; (2) formulate plans to address these problems and opportunities; and (3) recommend cost-effective solutions for implementation of a projects or projects that will restore island ecosystem habitat and address dredge management options recommended in the Dredged Material Management Plan.

1.2 Study Area. The Mid-Chesapeake Bay study area includes the eastern half of the Chesapeake Bay, from the Chester River to the MD/VA state line. See Figure 1. Within the study area, 105 islands are present, all of which were considered in the plan formulation process. Due to the large study area, an initial screening of islands was conducted to minimize the scope of the detailed study portion and to determine existing conditions of only those sites selected for restoration.

1.3 Project Requirements. Based on the current estimate of site capacity of other disposal sites in the Chesapeake Bay, it would be beneficial to develop additional placement capacity by approximately 2010. Hart-Miller Island is scheduled to be closed around 2009 and disposal at the Pooles Island site is required to be stopped by the end of 2010. Developing additional capacity by 2010 would help to avoid the point at which the existing Poplar Island site will have to be consistently overloaded to accommodate the average annual 3.2 million cubic yards (mcy) of dredged material. In addition, the environmental goals involve creating and protecting island habitat, wetlands, and submerged aquatic vegetation (SAV). Therefore, this project would be required to adequately handle 3.2 mcy of dredged material per year once operational, as well as provide the necessary environmental benefits.

2. SCREENING OF ALTERNATIVES

2.1 General: It was necessary to screen the potential site options from the 105 islands in the study area to a much smaller number on which to perform more detailed analyses. It was thought that one or two sites could be recommended for restoration at the end of the feasibility study. An initial screening phase was performed, followed by a more rigorous ranking process of the remaining islands. The top two sites had additional alternatives analyses performed to arrive at the recommended plan.

2.2 Initial Screening: Using the project's engineering and environmental requirements, the initial 105 islands were reduced to 21 islands to further analyze. This initial screening relied mainly on professional judgment and existing information to eliminate as many sites as deemed reasonable. The remaining 21 islands were grouped into 8 sites for further analysis and screening. The 8 sites remaining were Barren (2 islands), Holland (3 islands), Hooper (5), James, Ragged, Little Deal, Smith (5 islands), and South Marsh (3 islands).

2.3 Island Engineering Ranking: An engineering ranking system was used to further rank the existing 8 sites. The ranking system was based on experience gained at Poplar Island. The criteria included restoration size, dredged material disposal capacity, foundation conditions, on-site borrow material, water depth at site, length of access channel, tidal range, armor stone size requirements, dredged material hauling distance, and possibility of finding unexploded ordnance (UXO's). Each criterion was scored 0-5 and a weighting factor was given to those criteria which were more critical.

Table 2-1: Island Screening Criteria

Criteria	Description	Ranking	Weighted Factor
Possible restoration size (acres)	<300	0	2
	300-700	2	
	700-1000	4	
	1000-2000	5	
Possible Dredged Material Disposal capacity (mcy)	< 10	0	4
	11-20	1	
	21-30	2	
	31-40	3	
	41-50	4	
	>50	5	
Foundation material	Soft silt/clay	0	2
	Medium silt/sand	3	
	Stiff clay or silty sand	4	
	Sand	5	
Borrow material found on site	Clay or silt	0	2
	Covered sand	3	
	Sand	5	
Water depth range at site (ft MLLW)	<5	0	2
	5-8	2	
	8-10	5	
	10-12	2	
	>12	0	
Length of access channel (mi)	< 0.5	5	2
	0.5-1	3	
	1-2	1	
	>2	0	
Mean Tidal Range (ft)	<1	0	1
	1-1.5	3	
	>1.5	5	
Armor Stone size Required (lbs)	<1500	5	1
	1500-3000	3	
	>3000	1	
Dredged Material Hauling Distance (mi)	<30	5	3
	31-40	4	
	41-60	3	
	61-70	2	
	>70	0	
Possibility of finding UXO's	Yes	0	1
	Potential	3	
	No	5	

The range of scores was as follows: James (77), Barren (74), Hooper (49), Ragged (49), Holland (47), Smith (45), South Marsh (39), and Little Deal (29). Since the Bay Enhancement Work Group (BEWG) ranked James and Barren Islands highly for their environmental restoration potential, James and Barren Islands were chosen for concept plan formulation.

3. PLAN FORMULATION

3.1 James and Barren Islands Initial Plan Formulation: Five different island alignments were analyzed for James Island and four for Barren Island. The James Island alignments were numbered 1 through 5, and the Barren Island alignments were lettered A through D. The alignments varied in area, shape, and orientation with respect to the existing island remnants. The alignments were evaluated as stand-alone projects as well as combinations of the two sites (e.g. James 5 and Barren A combined). Evaluation of the alternatives during the plan formulation process included environmental, cultural, real estate, engineering, agency comment, public comment, and other considerations. Evaluations focused on placement capacity, environmental benefits and impacts, and construction cost. In addition to building islands at each site, the upland/wetland ratios were assessed for each alignment and combination. The engineering process applied to the plan formulation phase included:

(a) Review of existing information. The majority of the existing information included the contents of the reconnaissance reports prepared for the Maryland Port Administration for potential island alignments at James and Barren Islands.
(b) Screening the potential schemes to identify the preferred island locations.
(c) Identification of the minimum project area required to satisfy typical annual dredged material placement needs.
(d) Analysis of the hydrodynamics and sedimentation in the vicinity of James and Barren Island to identify potential impacts of alternative alignments on environmental resources and erosion of the existing island and mainland shorelines.
(e) No additional subsurface investigations and laboratory testing of foundation soils and potential dike fill materials were performed prior to completing the initial formulation phase. Screening was based on the subsurface information acquired during the reconnaissance study. Additional investigations and testing were performed on the initial preferred alignments.
(f) No bathymetric surveys were obtained for this phase. NOAA Electronic Navigational Charts (ENC's) were used.

The engineering evaluation consisted of an engineering screening process for the alternative alignments and combinations, supplemented by a series of generic placement analyses and analysis of the potential source of dike construction materials. These evaluation elements were the basis for defining the minimum island area and capacity that would be required to efficiently accommodate average annual dredged material placement needs, and to identify the optimum location for the island(s).

3.2 Description of Alternative Alignments: Following is a description of each preliminary alignment with an assessment of the foundation and borrow factors associated with each site (GBA, 2002). See Figures 2 and 3 for the alternative alignments.

3.2.1 James Alignment 1. The alignment 1 layout is the smallest of the James Island alignments. It is bounded by James Island to the east and extends roughly parallel to the existing James Island remnants. The uplands are located on the western side, and the wetlands are located on the eastern side. The total baseline perimeter dike is 32,100 feet long. The estimated the size of the alignment at 979 acres.

3.2.2 James Alignment 2. The alignment 2 layout is bounded by James Island to the east, deep water to the west, a natural oyster bar (NOB) to the north, and a local navigation channel to the south. The uplands are located on the western side, and the wetlands are located on the eastern side. The total baseline perimeter dike is 48,810 feet long. The estimated the size of the alignment at 2127 acres.

3.2.3 James Alignment 3. The alignment 3 layout is bounded by James Island to the east, NOB to the north, and Taylors Island to the south. The uplands are located on the western side, and the wetlands are located on the eastern side. The total baseline perimeter dike is 44,500 feet long. The estimated the size of the alignment at 1586 acres.

3.2.4 James Alignment 4. The alignment 4 layout is bounded by James Island to the east, deep water to the west, NOB to the north, and connects to Taylors Island to the south. The uplands are located on the western side, and the wetlands are located on the eastern side. The total baseline perimeter dike is 48,960 feet long. The estimated the size of the alignment at 2202 acres.

3.2.5 James Alignment 5. The alignment 5 layout is bounded by James Island to the east, NOB to the north, deep water to the west, and a local navigation channel to the south. The uplands are located on the western side, and the wetlands are located on the eastern side. The total baseline perimeter dike is 45,590 feet long. The estimated the size of the alignment at 2072 acres.

3.2.6 Barren Alignment A. The Alignment A site layout has a boundary of Barren Island to the east. A tidal gut of 200'-500' is provided between the existing and proposed islands. The wetland portion is on the northern neck and eastern side and the upland portion is on the western half of the widest section. The total baseline perimeter dike is 32,100 feet long. The size of the alignment is approximately 1330 acres.

3.2.7 Barren Alignment B. The Alignment B site layout is the largest layout and a variation to alignment A. The eastern dike and tidal gut are identical to alignment A. However, the western boundary has been shifted to the west to provide additional storage capacity. The wetland portion is also on the northern neck and eastern side and the upland portion is on the western half of the widest section. The total baseline perimeter dike is 31,640 feet long. The total site is approximately 2059 acres.

3.2.8 Barren Alignment C. The Alignment C site layout is a variation to alignment B. in that the western boundary and southern boundaries have been reduced to provide an island larger than Alignment A, but smaller than Alignment B. The upland portion is on the western side and the wetland portion is on the eastern side of Barren Island Habitat Restoration Project. The total baseline perimeter dike is 32,100 feet long. The total site is approximately 1125 acres.

3.2.9 Barren Alignment D. The Alignment D site layout is the smallest layout, an all wetland plan and a variation to alignment A. The eastern boundary is the same, but the western boundary has been shifted east to provide an average width of 1600 feet. The total baseline perimeter dike is 32,100 feet long. The total site is approximately 610 acres.

3.3 Preliminary Placement Analysis. Concurrent with the engineering screening process, preliminary analysis of dredged material placement was performed to determine whether the proposed alternatives could accommodate the anticipated average annual placement quantity of 3.2 mcy, and whether some alignments or combinations could handle the quantity more efficiently than others.

The placement analysis included sites ranging in size from 600 to about 2700 acres to include the range of actual alignments considered feasible from an engineering perspective. Initially, it was assumed that the sites would consist of 50% upland habitat and 50% wetland habitat, similar to the existing Poplar Island project. Subsequently, other placement analyses were performed for some of the alternatives at wetland proportions of 0%, 30%, 50%, 70%, and 100%. Later refinements added analyses of 40% upland and 60% wetland and 45% upland and 55% wetland. The results of the analysis indicated that 60% wetland habitat is a practical upper limit that is consistent with efficient dredged material placement. Higher proportions of wetlands often result in very inefficient placement of very small quantities of dredged material after the upland portion of placement site has been exhausted.

3.3.1 Purpose of Dredged Material Placement Analysis. During the initial years of placement of dredged material into the Poplar Island site, it has been generally understood that development of habitat, particularly wetland habitat, requires the carefully controlled placement of dredged material in a sequence that assures that the wetland cells will not be overfilled. This is accomplished by placing material into wetland cells in gradually diminishing increments over a period of years. It is also recognized that efficient use of upland capacity requires dredged material to be placed in relatively thin lifts so that the dredged material can be consolidated to a significant extent during the year or two before the surface is inundated by subsequent dredged material placement. This helps to maximize upland placement capacity.

It had been anticipated that the average annual placement of dredged material at Poplar Island would be approximately 2 mcy. During the initial year of placement, more than 6 mcy was placed into upland Cell 2 resulting in an extremely thick initial lift that was 3 to 4 times the desired lift thickness. This raised the concern that the upland placement capacity might be exhausted before placement of dredged material into wetland cells could be completed. Although the need to balance placement between upland and wetland cells was generally understood, it had not been formally or precisely quantified. The placement model was developed using the existing placement procedures at Poplar Island as the basis for the assumptions. The primary purpose of the analyses was to determine:

- The minimum project size that would support future dredged material placement requirements.
- The maximum percentage of wetlands that can be efficiently developed in the various island alternatives.

3.3.2 Placement Criteria. The placement analysis consists of a mathematical model of the incremental placement of dredged material beginning with empty cells until the entire upland and wetland placement capacity has been exhausted. In order to complete the analysis, it was necessary to establish criteria by which all of the potential sites would be evaluated. These criteria focused primarily on dredged material placement needs and habitat development constraints that were developed during the initial 3 years of placement and site development at the existing Poplar Island project. A detailed description of the criteria used to develop the placement analysis is presented in Attachment C – *Placement Analysis.*

3.3.3 Analysis of Island Alternatives: Dredged material placement analyses were conducted for potential island alternatives having areas of 600, 700, 1000, 1200, 1354, 1400, 1500, 1586, 1600, 1800, 2072, 2500, 2700 and 2756 acres. These areas represented the plan formulation alternative alignments and combinations along with several additional areas to assess optimum site size. Analyses were performed for varying upland-wetland proportions. Upland/wetland ratios investigated were 70%/30%, 50%/50%, 45%/55%, 40%/60%, and 30%/70%. These analyses were used, along with the engineering screening process, to ultimately identify the recommended plan that could maximize wetland creation while supporting dredged material placement needs in an efficient manner.

3.3.4 Plan Formulation Alternatives at 55% Wetlands: An environmental goal stated by the study team was to maximize wetland creation as part of the project. The placement analysis indicated that a 45%/55% upland/wetland ratio could be accomplished with several of the island sizes analyzed with the uplands built to +20 ft Mean Lower Low Water (MLLW). An island or island combination with an area of 2000 acres or greater could efficiently handle dredged material inflows while creating wetlands covering more than 50% of the overall island area. The estimated overall capacities for these sites ranged from 72 million cubic yards (mcy) to near 92 mcy. All other island sizes would require the uplands to be built to higher than +20 ft MLLW, or would require an accelerated wetland development schedule (more than 2 wetland cells developed per year) to allow for greater than 50% wetlands.

The study team had identified the goal of limiting the final upland elevation to +20 ft MLLW if possible. Therefore, two alternatives were deemed feasible based upon the James and Barren Island alignments discussed previously. Alignment 5 at James Island was considered feasible for 55% wetland creation as well as a combination of Alignment D at Barren Island with Alignment 5 at James Island. All other alternatives investigated in the placement analysis did not meet the criteria of achieving greater than 50% wetlands or keeping the uplands elevation to a maximum of +20 ft MLLW.

3.4 Subsurface Investigations. The results of reconnaissance-level borings performed by E2CR, consultant for MPA, were used in the initial analyses. Additionally, for this feasibility study, 61 new geotechnical borings were completed at James Island and 27 new borings were performed at Barren Island. These borings provided general information for each of the project areas with respect to foundation conditions for potential dike alignments and sand borrow materials for dike construction. Two drilling phases were performed at James Island and one phase was performed at Barren Island. The first phase at James Island and the Barren Island phase were drilled in time for use in the plan formulation and alternative selection portions of the study. The second phase of drilling was performed at James Island after the recommended plan was chosen. See Figures 4 and 5 for the reconnaissance and feasibility study borings performed at James and Barren Island, respectively. Laboratory testing was performed with a primary focus on grain size distribution of materials in the potential borrow areas. Some undisturbed samples were obtained in the second phase of the James Island drilling in order to obtain material strength and compressibility properties for further evaluation and analysis of foundation conditions along the dike alignments.

3.5 Preliminary Sand Borrow Evaluation. The source of sand borrow material for containment dike construction is also a critical factor in the engineering screening process. To make the project economical, sand for the dikes needs to be dredged from areas near or within the project. Additionally, it is considered very preferable environmentally to obtain borrow material from within the actual project footprint. To provide a basis for comparing alternatives, an evaluation of each potential borrow source was performed as it applied to each of the alignment alternatives. The borrow evaluation compared the quantity of borrow material available for construction that could be obtained from within the alignment footprint to the quantity required to construct the dikes for that alternative. Initial analyses based on the reconnaissance level drilling performed by E2CR and the initial Baltimore District drilling for James Island and Barren Island indicated that sand borrow quantities required to build the containment dikes may be difficult to obtain within the created island footprint. Based on the boring information, the northeast portion of James Island Alignment 5 was expanded to the east to attempt to capture more borrow material within the project footprint. The remainder of the alignment was adjusted to maintain the same overall acreage. The Barren Island sites appeared to have more sand borrow available within the created island footprint. The alignments appearing to require borrow areas outside of the footprint limits received a lower ranking. To arrive at the borrow assessments, initial sand quantity estimates were performed for the various alignments. A factor of two was used to determine the borrow quantity required in relation to the sand dike volume required. This was based on experience obtained at Poplar Island.

Analyses at Poplar Island have estimated that 1.5 times the sand quantity required for dike construction has been dredged. However, obtaining adequate sand quantities have been a problem throughout the life of the project. Dike raisings, cross-dikes, erosion repairs, and other uses have stretched the available sand to its limit at Poplar Island. Therefore, it is considered prudent to increase this "factor of safety" to 2.0 for this project. If estimates of borrow sand show that twice the amount of sand required is available, then it is assumed that adequate borrow material will be available for the life of the project. A more detailed presentation of the borrow analysis is presented in Attachment B – *Borrow Analysis*.

3.6 Preliminary Hydrodynamic and Sedimentation Analysis. Hydrodynamic and sediment transport modeling in the vicinity of James and Barren Islands was performed by Moffet and Nichol Engineers to determine the effect of alternative island alignments on water levels, current velocities, and sedimentation and accretion of the bay bottom surrounding the islands. The purpose of this analysis was to identify potential impacts of the alternative alignments on water quality and environmental resources including oyster bars and submerged aquatic vegetation. The analysis was also used to make preliminary judgments on the effect of the proposed project on reducing erosion of the existing James and Barren islands and providing sheltering to the mainland shorelines of Taylors and Hoopers Islands.

Overall, the results of the modeling did not shown any major differences in the impacts of the alternative island configurations at James and Barren Islands on hydrodynamics and sedimentation. The results of the hydrodynamic analysis indicate that there will be no impacts on the local tidal elevations for any of the alternatives at James and Barren Island. There will be minimal changes in the local current velocities and sedimentation patterns for alternatives. Peak ebb and flood currents in the main bay are not predicted to change with any of the alternatives. A summary of the preliminary hydrodynamic and sedimentation analysis of alternatives at James and Barren Island is presented in Attachment F – *Coastal Hydraulics Analysis*. Detailed hydrodynamic and sedimentation modeling reports for James and Barren Island are presented in Attachment G - *James Island Hydrodynamics and Sedimentation Modeling* and Attachment H - *Barren Island Hydrodynamics and Sedimentation Modeling*.

3.7 GIS Analysis. An overlay analysis was performed for each of the two sites (James Island and Barren Island) using Geographic Information System (GIS) software. The analysis was based upon eight equally weighted engineering and environmental factors which were used to determine the optimal project location at the two sites. Following is a description of the eight factors used in the overlay analysis.

a. **Proximity to existing island remnants.** Experience gained from the Poplar Island Environmental Restoration Project (PIERP) seems to indicate that the optimal separation between existing island remnants and the project footprint is between 250 and 500 feet. Lesser separations may restrict tidal flow and limit the establishment of certain desirable habitats. Greater separations could result in increased erosion from wave energy.

b. **Proximity to Natural Oyster Bars (NOBs).** Construction activity in and around NOBs has the potential for negative impact on existing oyster habitat. Locations further away from existing NOBs were deemed more optimal than locations within and directly adjacent to the legally defined limits of NOBs.

c. **Presence of submerged aquatic vegetation (SAV).** SAV beds are a critical component of a healthy Chesapeake Bay. Any area falling within the limits of an existing SAV bed (as determined by the 2001 SAV survey conducted by the Virginia Institute of Marine Science) was specified as an unacceptable project location.

d. **Foundation material.** The cost of containment dikes and breakwaters for the various alternatives will be affected by the foundation conditions. Suitable conditions would include foundation material consisting of sand with minimal silt or clay content, silty or clayey sand, and stiff clay materials with high shear strength and low compressibility characteristics. Unsuitable conditions would include very soft clay and silt materials where both shear strength and compressibility are unacceptable. These unsuitable materials must be removed and replaced with suitable sand obtained from borrow sources at additional cost to the project.

e. **Quality of borrow material.** Project cost is affected by the quality of materials available for dike construction. Suitable borrow material includes material that consists of sand with less than 50% silt and clay fines. Higher quality borrow material has a smaller percentage of silt and clay fines than lower quality borrow material. It is desirable to have less than 30% fines for dike construction. Unsuitable borrow material consists of material containing more than 50% silt and clay fines.

f. **Constructability of a perimeter dike with a toe dike.** Project costs can be impacted by the difficulty of construction resulting from environmental conditions such as water depth. Past experience has shown that the optimal water depth for the construction of a perimeter dike with toe dike is between 5 and 8 feet. Construction of this type of dike becomes more difficult in water that is shallower than 5 feet and deeper than 8 feet.

g. **Constructability of a perimeter dike without a toe dike.** Past experience has shown that the optimal water depth for the construction of a perimeter dike without toe dike is less than 2 feet. Construction of this type of dike becomes more difficult in water that is deeper than 2 feet.

h. **Navigation restrictions.** Areas identified as restricted on nautical charts were determined to be unacceptable locations for the proposed project. Dredge spoil areas were also deemed to be less than optimal since they may contain unsuitable foundation material. Unrestricted areas were considered to be the most optimal location for the project.

Existing vector-based datasets containing information for each of the eight factors were converted to raster format. Each of the eight raster datasets was reclassified as ordinal level data using a normalized scale as shown in Table 3.1. The reclassified raster datasets were overlaid and a composite raster dataset was created by summing the values of all spatially coincident raster cells. Raster cells contained in the composite dataset with the highest value represented the most optimal location for the project based on the eight factors used in the overlay analysis.

Table 3.1: GIS Analysis Ranking Criteria

Criteria	**Description**	**Ranking (0-10, with 10 being optimal)**
Proximity to existing island remnants	<100’	0
	100-250’	2
	250-500’	10
	500-1,000’	7
	1,000-1,500’	2
	>1,500’	0
Proximity to Natural Oyster Bars	within boundary	0
	within 500’ of boundary	5
	beyond 500’ of boundary	10
Presence of submerged aquatic vegetation	within bed	0
	outside of bed	10
Foundation material	Suitable	10
	unsuitable	0
Borrow material quality	unsuitable borrow	0
	suitable borrow of lower quality	5
	suitable borrow of higher quality	10
Constructability of a perimeter dike with a toe dike (based on water depth)	<2’ deep	2
	2-5’ deep	4
	5-8’ deep	10
	8-10’ deep	7
	10-12’ deep	4
	>12’ deep	0
Constructability of a perimeter dike without a toe dike (based on water depth)	<2’ deep	10
	2-5’ deep	5
	>5’ deep	0
Navigation restrictions	within a restricted area	0
	within a dredge spoil area	4
	in an unrestricted area	10

3.8 Recommended Alternative: During the latter stages of the plan formulation, it became apparent that the existing environmental benefits were much greater at Barren Island than at James Island. Additionally, dredged material placement from the Approach Channels would be more expensive at Barren than James due to the longer barging distance. Therefore, it seemed that creation of an island at the James Island site would be most economical. However, the environmental restoration effort was still needed at Barren Island to keep the existing island from eroding and to protect the large SAV beds to the east of the island. An environmental restoration alternative was then developed for implementation at Barren Island.

Based on the screening processes used, both engineering and environmental, the recommended alternative was selected as a modification of James Island Alignment 5 with an environmental restoration alternative at Barren Island. The James Island alternative will provide the required dredged material disposal capacity and environmental restoration, while the Barren Island restoration alternative will consist of a stone sill/breakwater which will protect the existing island from erosion, create wetlands, and protect areas of SAV from high wave energy. The James Island recommended alternative consisted of 2072 acres, with the final arrangement allowing for 45% upland acreage and 55% wetland acreage. Estimated dredged material disposal capacity from this alignment is 78 mcy, with an additional amount of capacity created by dredging within the island footprint for borrow material. The total capacity when factoring in the borrow excavation will be in excess of 90 mcy. This equates to a project life in excess of 28 years assuming an average inflow rate of 3.2 mcy per year.

4. DEVELOPMENT OF RECOMMENDED ALTERNATIVE: JAMES ISLAND

4.1 Introduction.

4.1.1 Results of Plan Formulation. As a result of the plan formulation process, a 2070 (rounded down from 2072) acre area located west of the existing James Island remnants was identified as the preferred location for an island creation project. The engineering placement analyses concluded that in order to provide at least 55% wetland habitat while accommodating 3.2 mcy of dredged material per year, the island alternative should be approximately 2000 acres. At 55 percent wetlands, the 2070-acre James Island Modified Alignment 5 was determined to be acceptable with respect to its capacity to accommodate required annual dredged material placement, and marginal in its capacity to provide sufficient dike fill material for dike construction from borrow sources located within the footprint of the upland cells of the project footprint. This marginal status can be improved by either obtaining borrow material from outside of the site footprint or building wetland cells over borrow areas. Those alternatives requiring borrow areas for dike construction outside of the alignments footprint would have additional impacts to bottom fish habitat and were deemed unsuitable for further consideration. Those alternatives that would also require building wetland cells over borrow areas within the footprint were considered unfeasible to construct due to compaction necessary to fill deep borrow areas, which would not be a suitable foundation for wetland cells. It was decided that additional engineering investigations and analyses be performed to optimize the recommended alignment with regard to borrow material siting, and to support the development of a more detailed design of the various alignment features.

4.1.2 Additional Investigations and Design. The recommended additional engineering tasks for the recommended plan included:

- Perform additional subsurface investigations and laboratory testing for the selected alignment. These investigations would provide information on the foundation

conditions that would affect dike and access channel alignment selection and would provide better definition of borrow resources.
- Perform settlement and slope stability analyses on the proposed dike sections to ensure appropriate costs are covered for overbuilding or material removal and replacement in reaches with very poor foundation conditions.
- Incorporate coastal and hydraulic engineering considerations into design of such features as the dike section, stone armor protection, internal tidal gut and wetland channel systems.
- Provide updated cost estimate based on recommended plan.
- Obtain bathymetric surveys of the preliminary alignment, access channel, wetland and internal borrow area.

4.2 Preliminary Alignment. Based on previous analysis and engineering judgment, the James Island Modified Alignment 5 was developed. See Figure 6 for the alignment footprint. Preliminary subsurface information indicated that the primary source of borrow sand was along the northern half of the proposed footprint. Therefore, the upland portion of the alignment was located on the northern part of the alignment in contrast to the arrangements developed earlier. Because of the exposure of the project to high wave energy to the west and south, it was considered unlikely that wetland cells would be opened directly on the west side to the Bay. Therefore, the preliminary site layout included a tidal gut feature that was intended to supply water needed for tidal flushing of wetland cells. Preliminary dike sections were based on the dike sections of the existing Poplar Island project where the top elevation of the armored dike section was approximately +10.5 ft MLLW. These sections were used for the initial slope stability and settlement analyses and the preliminary quantity calculations. Stone armor sizes were also assumed to be the same as the existing Poplar Island armor stone.

4.3 Site Investigations.

4.3.1 Reconnaissance Study Subsurface Investigations. During November 2001, twenty-two (22) borings were drilled to depths of 30 to 70 feet and samples were obtained to investigate alternative alignments associated with the reconnaissance studies for James Island. Laboratory testing included grain size analyses for basic soil classification, and tests to determine shear strength and compressibility characteristics of the fine-grained (clay and silt) soils. Field testing included cone penetrometer and vane shear tests at several locations. The grain size analyses on sandy soils provided information about the location, quantity, and quality of potential borrow materials for dike construction. Logs for all of the borings and results of laboratory testing are presented in the Geotechnical Reconnaissance Study for James Island, Chesapeake Bay, Maryland, dated August 2002. The report was prepared by E2CR, Inc., for Gahagan and Bryant Associates, Inc. under contract to the Maryland Port Administration.

4.3.2 Feasibility Study Subsurface Investigations. The current feasibility study considered the potential for creating an island in a manner similar to the schemes presented in the reconnaissance study. During Summer 2004, sixty-one (61) borings were completed to investigate subsurface conditions along the proposed dike alignments, proposed channel alignments, and in the potential borrow areas. The borings were typically drilled to a depth of 25-40 feet from the mudline. Eight undisturbed samples (Shelby Tubes) of soft clay and silt were obtained and laboratory testing included consolidated-undrained triaxial shear testing, unconfined compression testing, and consolidation testing of selected samples. Logs of the completed borings and results of laboratory testing are presented in Attachment E – *Subsurface Investigations and Laboratory Testing.*

4.3.3 Surveys. For the initial phase of the feasibility study, survey information for areas in the vicinity of James Island was obtained from NOAA Electronic Navigational Chart (ENC) files. ENC files are databases which contain information found on NOAA's paper nautical charts in a vector-based format, and are available for download from NOAA at http://nauticalcharts.noaa.gov/mcd/enc/download.htm.

Features such as soundings, depth contours, navigation restrictions, and shorelines were extracted from ENC files US5MD16M (nautical chart 12266) and US5MD21M (nautical chart 12264) in order to develop digital mapping products for the James Island site. All features contained in the ENC files have geographic coordinates (latitude and longitude) that reference the World Geodetic System of 1984 (WGS84), and depth-related information in meters referencing MLLW. Pertinent features from the ENC files were imported into GIS software and reprojected into the Maryland State Plane Coordinate System, North American Datum of 1983 (NAD83) (feet). Depth information was converted from meters to feet. The converted soundings and depth contours were then used to create a triangulated irregular network (TIN) surface model for the area around James Island. Soundings and depth contours derived from the ENC files are presented in Figure 7.

Since the information contained in the ENC files was collected between 1940 and 1969, it was determined that the shoreline features depicting the extent of the island remnants collectively known as James Island were grossly inaccurate. Post, Buckley, Schuh, & Jernigan, Inc. (PBS&J) was contracted to provide updated imagery and shoreline information for James Island. PBS&J utilized color aerial photography obtained in October 2004 to develop the high tide shoreline and black and white aerial photography obtained in November 2004 to develop the low tide shoreline for James Island. As part of the aerial mapping contract, PBS&J also established three permanent survey control points on James Island. All survey information provided by PBS&J was referenced to the Maryland State Plane Coordinate System, NAD83 (feet).

Since there are no tidal benchmarks in the vicinity of James Island and no published relationship between NAVD88 and local MLLW at James Island, Offshore & Coastal Technologies, Inc. (OCTI) was contracted to establish local MLLW for the current tidal epoch at James Island. As part of this contract, OCTI determined the relationship between MLLW and NAVD88 at James Island and established MLLW elevations for the three PBS&J survey control points on James Island. The results of the tidal study are presented in Attachment J.

Subsurface investigations conducted during the feasibility study revealed significant differences between the depths contained in the ENC files and actual depths observed in the vicinity of James Island. As a result of these discrepancies, PBS&J was contracted to conduct a reconnaissance-level hydrographic survey in the vicinity of the preliminary alignment (shown in Figure 6) and the proposed access channel. Ocean Surveys, Inc. (OSI) was subcontracted by PBS&J to conduct the survey. The horizontal datum for this survey was the Maryland State Plane Coordinate System, NAD83 (feet), and all bathymetric data were referenced to the North American Vertical Datum of 1988 (NAVD88). All bathymetric data were converted to MLLW for the 1983-2001 Tidal Epoch at James Island, based on the datum relationship developed by OCTI. The bathymetry was used to create a TIN surface model of the survey area. Depth contours derived from the TIN surface model and soundings are presented in Figure 8.

4.4 Borrow Area Evaluation.

4.4.1 Borrow Area Limits. Based on the geotechnical investigations to date, the main area of suitable sand for dike construction found within the project footprint are in the northern portion of the site. The sand deposit ranges from 5 feet to greater than 25 feet in thickness, and is underlain by a clay stratum. The thickest deposit, between 15 and 25 feet in thickness, is located within the north-central to northeast portion of the proposed footprint. The deposit diminishes in thickness as it extends to the south where it is less than 7 feet thick and thins out altogether in some zones.

4.4.2 Borrow Excavations. To the maximum extent practicable, borrow materials will be obtained from within the proposed upland cells of the project, and from the required access channel and turning basin excavations. During the construction of the current Poplar Island Project, most of the required borrow materials were obtained from locations within wetland cells 3, 4, and 5. The deep depressions left in those cells significantly increased the thickness of dredged material required for wetland development and resulted in a wide variation in dredged material thickness required within the cells. The consequent large settlements and large differential settlements due to the long-term consolidation of the dredged material will make it very difficult to achieve the extremely narrow range of target elevations (between El. +1.2 and 1.8 ft MLLW) required for low marsh wetland habitat. Therefore, borrow sites will be excluded from wetland cells to the maximum extent possible. If unavoidable, borrow excavations will be completed to a uniform depth across the entire wetland cell and the total excavation depth will be minimized. However, such wetland borrow excavations would only be considered if all potential upland and access channel borrow sources have been exhausted.

4.4.3 Borrow Quantity. Given that the proposed site will contain approximately 2070 acres of upland and wetland habitat, not more than 932 acres (45%) of that area will consist of upland habitat. After reducing the potential borrow area for the dike footprint and an appropriate setback of 100 feet from the toe of the dike, the remaining area would yield an estimated 14.45 mcy of sand for construction of the project without having to dredge through clay or silt layers. That quantity coupled with an estimated 1.48 mcy from the access channel is approximately 1.86 times the estimated quantity of sand needed for dike construction and is considered marginally sufficient to satisfy the project needs. See Figure 9 for the surficial sand depth at the project site.

As stated previously, it has been considered preferable to identify borrow sources containing approximately twice the dike volume to account for a reduction due to the loss of fines in dredging, inefficiencies in dredging, and overall uncertainties that exist due to the relatively wide spacing of the borings performed to date. The borrow available-to-borrow required ratio for the Poplar Island project was 1.5. There have been some difficulties in obtaining adequate sand quantities for the various requirements on that project. Therefore it was considered prudent to raise the ratio to provide a better factor of safety. The desired ratio selected was 2.0, but with the current information, that ratio has been unachievable within the upland areas and the access channel. However, by dredging through a 2-5-ft thick silt and clay layer in the southwestern and central portion of the upland area, 2.5 to 3.5 million additional cubic yards of borrow sand is expected to be available. This would push the borrow available-to-required ratio above 2.0. If required to be dredged, the silt/clay cover material would be spoiled within an area of the upland cells.

4.4.4 Borrow Material Quality. The complete results of the laboratory testing are presented in Attachment E – *Subsurface Investigations and Laboratory Testing.* A total of 196 gradation tests were performed on samples from the borings performed during the feasibility study. While not all of the sands tested will end up within the borrow limits, the tests are indicative of the quality of the materials that will be used for dike construction. The sands tested contain an average of approximately 16% fines. The actual fines content ranged from a low of 0% to a high approaching 45% fines. The majority of the samples tested contained less than 25% fines, with many having less than 15% fines. Therefore, the sand deposits found within the project site are good sources of materials with respect to quality of material for dike construction.

The quality of the borrow material for dike construction is primarily defined by the percentage of fines (percentage by weight passing a standard No. 200 sieve) within the material. Fines are the silt and clay size portion of the borrow materials. A significant portion of these fine materials, and some of the fine sand fraction will be washed away when the sand is dredged for use in dike construction. While that loss of fines improves the engineering properties of the sand, it reduces the quantity available for construction. It is generally estimated that 15 to 25 percent of the quantity excavated by dredging will be lost. As the percentage of fines at the borrow source increases, the percentage lost in the dredging process also increases. Since this deposit has a relatively low average fines content, the percentage lost can be expected to remain near the low end of the typical 15 to 25 percent range.

A lower fines content at the borrow source will result in a lower fines content in the sand placed in the dike section. It is desirable to maintain the fines content in the dike fill below 30% to assure that the material properties are dominated by the sand fraction rather than the weaker and less permeable clay and silt materials. Because of the low average fines content in this deposit, the resulting fill properties can be expected to be good with limited pockets of marginal material.

4.5 James Island Selected Alignment. The subsurface exploration and borrow analysis generally confirmed the results of previous investigations with regard to borrow material issues. There were minor adjustments made to the limits of the borrow areas and the estimated borrow quantities, however, they did not require any significant changes to the dike alignment. However, further investigations and testing for the northeast section of alignment caused the dikes to be realigned to attempt to avoid some reaches of very deep, very soft clay deposits. Settlement and slope stability analyses were performed for various reaches of the project based upon drilling and testing information. These analyses showed the need to remove and replace an excessive amount of material from the existing bay foundation in order for the proposed dike to be constructed successfully. The results of these analyses are presented in Attachment D-*Slope Stability and Settlement Analysis*. The estimated volume of material removal and replacement was in excess of 350,000 cy. Therefore, a shift was made to the project alignment in order to avoid the worst known portion of the alignment. See Figure 10 for the selected alignment at James Island.

4.5.1 Layout. The alignment encompasses approximately 2070 acres to the west and north of the existing James Island remnants. The upland cells are located on the northern portion of the site overlaying the primary borrow sources, with the wetlands located in the southern portion of the site. The site has been configured to provide 45% upland habitat, and 55% wetland habitat with the potential for leaving a portion of the uplands available for conversion to wetlands if the estimated amount of borrow material is recovered from within the uplands footprint. The water depths in the upland portion of the site average 9.4 feet at MLLW, with the range of depths from 6.8-13.0 ft MLLW. The water depths in the wetlands portion of the site average 7.8 ft MLLW, with the range of depths from 4.1-11.7 ft MLLW.

A tidal gut passes through the center of the wetland areas. The preliminary tidal gut is approximately 150 feet wide and enters at the northeast and southeast portions of the wetland area. The tidal gut feature will keep the western section of the wetland cells from being opened to the Bay on the western side. Each wetland cell will either be opened to tidal flow from the tidal gut or from the much lower energy of the Bay on the east side of the alignment. Locating the tidal gut entrance on the east side of the project protects the primary tidal gut and interior wetland cells from the harsh northwesterly and southerly wave exposure. The historical James Island shoreline maps show two tidal guts on the eastern side of the island that were similarly sheltered from the extreme wave exposure. Detailed hydraulic modeling could result in refinements of the tidal gut size and alignment as needed to accomplish the required tidal exchange with the wetland habitat. Although the tidal gut is not connected to the Bay on the west side, if further analysis recommends opening the gut to the west, design features will need to be included to protect the area from erosion.

Parallel sand dikes will be constructed to define the tidal gut during the initial construction of the project. Under normal tidal conditions, the anticipated velocities in the channel are expected to be very low. The sides of the tidal gut sand dikes will be constructed with materials that will be resistant to erosion by current velocities associated with normal tides. This may be accomplished by using clay from required excavations, or by using a geosynthetic matting material with vegetation planted to stabilize the sand surfaces. However, during extreme storm events, current velocities through the tidal gut would be higher. Additional hydraulic analysis of extreme storm events during the next design phase will determine whether additional measures are needed to prevent erosion of the tidal gut during storm events.

4.5.2 Proposed Dike Section Optimization. The sand perimeter dike will be protected by a stone toe dike and revetment consisting of several layers of armor, underlayer, and bedding stone. A life-cycle analysis of the stone protection structures was performed by the Corps of Engineers Engineering Research Development Center (ERDC) to establish the optimum design features for the structure including crest elevation, armor stone size, and side slopes. The life-cycle analysis accounts for progressive damage due to a series of successive storms that may occur between maintenance cycles over the life of the structure. This approach was initially intended to be applied to establish optimum design features that balance initial cost with expected future maintenance in order to reduce the overall costs of the structure. However, there were significant concerns over the possible impacts of sediments that could be released if a large breach in the dike could not be repaired in a timely manner. A decision was made to design the stone protection to minimize the potential for large breaches and associated repairs.

The life-cycle analysis of potential breaches considered two modes of failure: damage to the crest due to overtopping and displacement of stone along the slope due to armor instability. The preliminary results of the overtopping analysis indicated that a structure at +10 ft MLLW along the southern, western, and northern exposures, and +8 ft MLLW along the eastern exposure, would have an insignificant risk of overtopping over the life of the project. The preliminary results of the armor stability analysis indicate that armor and toe stone sized for a 50-year return interval would have an insignificant risk of a breach due to armor instability over the life of the project. Based on the life-cycle analysis, the preliminary stone size recommended for the northerly, westerly, and southerly exposures is 2500 lbs for armor stone and 3500 lbs for toe stone. The preliminary stone size recommended for the easterly exposures is 250 lbs for armor stone and 1000 lbs for toe stone. A side slope of 1V:3H was considered to be optimum from a constructability perspective. A detailed description of the life-cycle analysis for James Island is provided in Attachment I – *Life-Cycle Analysis of Mid Bay and Poplar Island Projects*.

4.5.3 Foundation Issues. As previously discussed, the subsurface exploration has further confirmed the presence of a deep deposit of very soft silt and clay along the northeast portion of the original selected alignment. The dike alignment has been shifted to avoid the worst known portion of the deposit in order to minimize the removal and replacement requirements. It is likely that not all of the very soft materials can be fully avoided, so based on the current alignment and subsurface data, it is estimated that approximately 50,000 cy of foundation material will need to be removed and replaced to facilitate dike construction. This unsuitable material will be contained within the upland footprint. Final subsurface investigations will provide the data needed to more precisely define the removal quantities or determine if total avoidance can be achieved.

Settlement analyses for portions of the remainder of the dike alignment show a potential for some long-term settlement of portions of the wetland perimeter dike. For quantity estimates, the perimeter dike from station 320+00 to 355+00, from 385+00 to 452+35, and from 0+00 to 15+00 will be estimated to be overbuilt by 6 inches to account for the predicted long-term settlement. The remainder of the alignment foundation consists primarily of sand deposits, or sand overlying stiffer clays that should be able to support the dike without concern for slope stability or excessive settlement.

4.5.4 Borrow Issues. The borrow area analysis indicates that there is marginally sufficient material to support construction of the dikes for a project consisting of 45 percent uplands. The borrow available to borrow required ratio is 1.86, which is lower than the desired ratio of 2.0. This includes the assumption of not dredging through any clay or silt layers to get to deeper sand deposits. As discussed in section 4.4.3, an additional amount of borrow sand is available in the southwest portion of the upland cell beneath a 2-5-ft thick layer of clay and silt. The additional amount is estimated at approximately 2.5-3.5 mcy, which would push the borrow available-to-required ratio above 2.0. During the next design phase, the additional borrow exploration will give a much clearer indication of available borrow material within the footprint of the uplands. If a shortfall of borrow material is realized after further exploration and analysis, several options can be undertaken. First, the access channel can be widened. This could increase the quantity of sand borrow depending on the width of widening and the availability of sand within the widened channel footprint. If additional borrow material is still required, several wetland cells can be designated as borrow areas. Depth of borrowing will be tightly controlled to ensure that the wetland depths are kept as shallow as possible. Additionally, uniform borrowing will be required. The entire wetland cell will be required to be dredged to the same elevation. This will ensure that differential settlement will be minimized. The additional development time for these wetlands would need to be factored in when deciding borrow quantities and locations. There is a sand deposit within the northeastern portion of the wetlands which would most likely be able to accommodate any borrow requirements.

4.5.5 Upland Grading Issues. Once the optimum surface elevations have been achieved by hydraulic placement and several years of crust development, drainage, and monitoring indicate that settlement has been largely completed, the upland will be graded to achieve the desired topography. If small ponds are desired, they will be sited at locations that tend to settle (based on monitoring results). Final upland surfaces will be graded so that surface runoff will generally be directed toward wetlands where possible. Achieving that runoff collection is expected to require several feet of elevation differential on the upland surface, and development of a system of shallow swales that will conduct water to the southern side of the upland area. Collected runoff will then be transmitted from the +20 ft MLLW elevation to the +2.5 ft MLLW high marsh elevation over a distance of approximately 100 feet, and dispersed uniformly into the wetland areas. The exact methods of transporting flow across the 100-foot transition zone and the means of dispersing the flow into the wetlands will be subject to extensive additional engineering analysis. It may be necessary to excavate portions of the southern containment dike below elevation +20 ft MLLW and stabilize the dredged materials exposed within the excavation limits. Draining the northern portion of the uplands to the wetlands may be very difficult to accomplish. This will need to be explored much further in the next design phase.

4.6 Detailed Placement Analysis.

4.6.1 Scope of Placement Analysis. Detailed dredged material placement analyses were performed for varying upland/wetland ratios for the selected alignment. Initially, the additional capacity provided by the excavation of the borrow material within the uplands was not accounted for. However, some placement analyses were included to account for the benefit of the additional capacity from the borrow excavation. These were as follows:

1. 50% wetlands with uplands to +20 ft MLLW
2. 55% wetlands with uplands to +20 ft MLLW
3. 55% wetlands with uplands to +20 ft MLLW and borrow excavation included
4. 60% wetlands with uplands to +20 ft MLLW
5. 60% wetlands with uplands to +25 ft MLLW
6. 60% wetlands with uplands to +30 ft MLLW
7. 60% wetlands with uplands to +20 ft MLLW and borrow excavation included

The analyses shown with uplands at a greater final elevation than +20 ft MLLW are for illustrative purposes only. It was determined throughout the plan formulation process that the upland elevation would be no higher than approximately +20 ft MLLW, with containment dikes being built temporarily to about +25 ft MLLW. Final elevations may vary slightly to permit proper grading, drainage and development of the upland. The analysis was performed in compliance with the detailed criteria presented in Attachment C – *Placement Analysis.*

4.6.2 Results of Analysis. The detailed results of the placement analyses are presented in Attachment C – *Placement Analysis.* A summary of the results are presented below in Table 4-1. The analyses show that a 45%/55% upland to wetland ratio is achievable for the selected alignment with the uplands built to elevation +20 ft MLLW. They also show that if the estimated amount of borrow material is recovered from within the uplands footprint, that a 40%/60% ratio is achievable.

4.6.3 Timing Analysis to Optimize Recommended Plan at James. Due to the recently approved Poplar Island Environmental Restoration Project GRR (31 March 2007), the impact of concurrent dredged material placement operations at Poplar Island and James Island was conducted. The purpose of this analysis was to optimize placement at both sites and ensure that benefits claimed for the Poplar Island projects were not impacted negatively as a result of James Island coming on line.

The scenarios being evaluated have James Island accepting dredged material in 2014, 2018, or 2023, with dike construction 4 years in advance of those years (see Attachment 1 for placement scenarios). This results in overlapping operations at both Poplar and Midbay for four years for the 2014 and 2023 scenario, and only one year for the 2018 scenario. Overfilling is reduced by 17% at Poplar Island for the 2014 and 2023 scenario, but is reduced by 34% for the 2018 scenario. The different start dates at James also affect the operational life of the Poplar Island projects. The 2014 scenario extends the operational life of Poplar Island by 4 years, to 2029, while the 2018 scenario extends the operational life by one year to 2027. The 2023 scenario does not change the operational life at Poplar Island as presented in the Poplar Island Expansion GRR. These results were used to develop the implementation plan in Section 7 of the main report, which has placement beginning in 2018. Justification for selecting this scenario is provided in section 4.7.5 of the main report.

Table 4-1. Placement Summary for James Island Recommended Plan.

MID-BAY PLACEMENT SUMMARY											
Total Area (acres)	Alternative		Wetland Area (acres)	Capacity (mcy)	Capacity Ratio Up/Wet	Last Year @ 3.2 mcy	Years of Cell Overload	No. Wetland Cells per Year	Last Wetland Placement	Last Upland Placement
2070	Alignment 5 - James 50%Upland-**50%Wetland**		1035	84.6	76%	Year 26	0	2	Year 19	Year 27
2070	Alignment 5 - James 45%Upland-**55%Wetland**		1139	78.8	73.30%	Year 24	0	2	Year 20	Year 25
2070	Alignment 5 - James 45%Upland-**55%Wetland w/ Borrow Excavation**		1139	95.7	78.00%	Year 29	0	2	Year 20	Year 30
2070	Alignment 5 - James 40%Upland-**60%Wetland**		1242	67.3	**72.70%**	Year 20	0	2	**Year 23**	**Year 21**
2070	Alignment 5 - James 40%Upland-**60%Wetland w/ Borrow Excavation**		1242	89.4	74.20%	Year 27	0	2	Year 21	Year 28
2070	Alignment 5 - James 40%Upland-**60%Wetland-+25 MLLW Uplands**		1242	76.0	**75.80%**	Year 23	0	2	**Year 23**	**Year 24**
2070	Alignment 5 - James 40%Upland-**60%Wetland-+30 MLLW Uplands**		1242	84.7	78.30%	Year 26	0	2	Year 23	Year 27

4.7 Recommended Alternative. Selection of a final scheme for creation of the dredged material disposal site offshore of James Island includes consideration of environmental, cultural, real estate, public involvement, funding, and other factors in addition to engineering considerations. The following discussion focuses primarily on engineering considerations as developed within the generally established environmental and cultural limitations.

4.7.1 Preferred Engineering Alternative. From the perspective of efficient placement and high probability of success in wetland development, the recommended alternative would consist of a 2070 acre project site having 932 acres for upland placement and 1138 acres for wetland development (45% uplands/55% wetlands). This alternative would provide between 78 and 95 million cubic yards of dredged material placement capacity, depending upon borrow excavation within the island footprint. Upland placement capacity would last at least two full years beyond anticipated wetland placement. This alternative could be configured to accommodate approximately 100 acres initially designated as upland habitat to be shifted to wetland habitat thereby increasing the total site proportions to nearly 60 percent wetlands. This decision would be made during construction as part of the adaptive management process.

4.7.2 Proposed Dike Section. The dike section for the proposed project will be similar to the section for the existing Poplar Island project. The sand portion of the dike will be constructed using sand obtained from borrow sites located below water within the proposed upland cells and from the access channel. The access channel is aligned northwest to southeast and will be approximately 12,720 feet long and 400 feet wide with 3:1 side slopes. The sand dike will be protected by a stone toe dike and revetment consisting of several layers of armor, underlayer, and bedding stone. A geotextile will be placed on the sand surface of the external slope of the dike beneath the stone toe dike and revetment to act as a filter to retain the sand. A 6-inch layer of bedding material, a gravel-sized crushed stone material, will be placed on the geotextile to protect it during armor stone placement. For the Poplar Island project, it was necessary to specify a woven mono-filament geotextile to provide the required combination of tightly controlled filter capability while achieving the highest possible tensile and puncture strength needed to resist damage during placement of overlying armor stone layers.

The total length of the perimeter dike is estimated at 45,235 LF as measured along the perimeter road. The length of the main separator dike between the uplands and wetlands is estimated to be 6235 LF. The upland perimeter dike and separator dike will be constructed to approximately elevation + 20.0 MLLW (Temporarily to +25.0 MLLW). The entire perimeter dike will be protected by a toe dike. Two sections of toe dike have been proposed. The toe dike for the dike sections with southern, western, and northern exposure will consist of a core of quarry run stone, with two layers of 3500 pound armor stone above the core. The toe dike for the dike sections with eastern exposure will consist of a core of quarry run stone, with two layers of 1000 pound armor stone above the core. The top elevation of the toe dikes will be at +1 ft MLLW for all dike sections. The upland perimeter dike is currently estimated to run from station 0+00 to station 207+16. The wetland perimeter dike is estimated to run from station 207+16 to station 452+35.

The external surfaces of lower portion of the upland perimeter dike and all of the wetland perimeter dike will be protected with several layers of armor stone obtained from commercial sources. Generally, the section will consist of two layers of armor stone placed on two layers of underlayer having a mean weight of about 250 pounds. Preliminary hydraulic analysis indicates that the mean armor stone size on the southern, western, and northern exposures will be approximately 2500 pounds. The eastern exposure will be more lightly armored with 500 pound stone. The 500 pound stone will be placed on two layers of 50 pound stone. A 6-inch bedding layer will be placed in all dike sections. The crest of the armored dike sections will be set at elevation +10 ft MLLW from station 0+00 to station 125+00 and from station 300+00 to station 452+35, with external armored slopes at 3 horizontal to 1 vertical (3H:1V), and internal sand slopes constructed to 2.5H:1V. The crest of the armored dike sections will be set at elevation +8 ft MLLW from approximately station 125+00 to station 300+00, with external armored slopes at 3H:1V and internal sand slopes at 2.5H:1V. Slopes of the upland dike sections above the armor will not require stone armor, but may receive lighter slope protection in the form of a reinforced vegetative matting. Further analyses will be required to finalize the slope protection features. A 6235 LF separator dike is located between the upland cells and the wetland cells. Additionally, it is estimated that the upland area will be divided into 4 cells. The cross-dikes required to divide these cells will be built to about elevation +25 ft MLLW, with 2.5H:1V sideslopes and a top width of 20 feet. The wetland area will also be subdivided. It is estimated that approximately 27 wetland cells will be created. The dividing cross-dikes will be built to about +6 ft MLLW with a top width of 15 feet. See Figures 11-14 for the proposed dike sections.

In light of the potential impacts of relative sea level rise on the project, consideration will be given to modifying the dimensions of the perimeter dike during the detailed design phase. By increasing the initial width of the perimeter dike, future dike raisings could occur with little to no effect on project operations. Increasing the initial height of the perimeter dike would accommodate rising sea levels during the life of the project.

4.7.3 Tidal Gut. The proposed alternative includes a tidal gut passing along all of the wetland cells with an opening at both the northeastern and southeastern end of the wetland area footprint. The tidal gut is currently assumed to be 150 feet wide and will not be connected to the Bay on the western side of the proposed island. The final dimensions and alignment of the tidal gut will be determined following detailed hydraulic modeling in the next design phase. Constructing unarmored containment dikes along both sides of the proposed alignment will create the tidal gut. These dikes will be composed primarily of sand with appropriate surface stabilization to minimize erosion and deposition that could affect the hydraulic efficiency of the gut during dredged material placement. The containment dikes can be removed after development and stabilization of the wetlands, or can be left in place as desired. Further hydrodynamic analysis will be required to determine if the entrances to the tidal gut from the bay will require a limited reach of stone armor. During the dike construction and wetland development phases of the project, culvert structures or bridges spanning the entrances/exits of the proposed tidal gut will be required to allow access along the project's perimeter dike.

4.7.4 Dredged Material and Barge Offloading Facilities. Offloading of dredged materials and equipment/materials from barges will initially occur inside the upland area at the south-central portion of the area. In order to site the access channel through a sand deposit to maximize borrow materials, the channel is located along the western side of upland cells and is aligned northwest to southeast. The access channel will be approximately 12,720 feet long and 400 feet wide with 3:1 side slopes. A sheetpile bulkhead will most likely be required along the crossdike adjacent to the turning basin. This will allow for barges to offload equipment and materials easily. This location is the most central location to the entire site within the upland area. Thus, the overall length of dredged material pumping to the wetland cells and the other upland cells will be minimized. Once the other upland cells are filled, the unloading cell will need to be closed. To provide for that, an unloading facility/bulkhead/turning basin will need to be provided on the outside of the upland cell. Wave protection structures such as jetties, breakwaters, and/or sheetpile walls will be provided to allow for protection of the offloading facilities during periods of high wave conditions. A sheetpile bulkhead will be provided along the dike to allow for equipment offloading.

4.7.5 Island Facilities. To adequately operate and maintain the project site, various facilities are required for the project. Office space in the form of an operations building or trailer complex will be required. It is likely that the office space will be located on the separator dike between the uplands and wetlands, due to its central location. A personnel pier is proposed to be constructed on the east side of the project to provide access for work crews. It will most likely be located near the separator dike as well. The east side of the project will be more protected and therefore is the best location for the pier. A fuel farm will be required to supply the various vehicles and generators which will be operating on-site. Power and telephone service from the mainland will likely be required as well. Additionally, a land base will be required on the mainland, most likely at the Marina along Slaughter Creek.

5. CONSTRUCTION OF RECOMMENDED PLAN AT JAMES ISLAND

5.1 General. In general, construction procedures are assumed to be similar to those used on the Poplar Island project where the sand portion of the dikes was built using mechanical methods. It is likely that hydraulic dike construction will not be allowed due to the higher material losses associated with that method. Current estimates indicate that there is not enough of a sand borrow surplus to risk hydraulic placement. Construction quality sand from the borrow areas and access channel will be hydraulically dredged into a stockpile(s). From the stockpile area(s), the material will be mechanically moved into final place in the perimeter or cross dikes. The armor stone, underlayer stone, and bedding/core stone will be barged in from commercial sources. Initial construction of the stone toe dikes will be accomplished by barge, however, it is assumed that all subsequent stone placement will be from the sand dike surface. Settlement monitoring may be required in reaches having soft foundation conditions to allow for accurate quantity measurements.

5.2 Construction Sequence. The project has been developed with the assumption that funding will be provided to build the project in one phase. However, if funding does become a limitation, the project will have to be built in phases. Poplar Island was built in two phases at the request of the non-Federal sponsor.

5.2.1 Single-Phase Construction. The project will be built most effectively, efficiently, and economically if construction is performed in a single phase. It is assumed that the access channel dredging would be accomplished first. The contractor would begin by hydraulically pumping the borrow material from the channel dredging into a stockpile. See Figure 15 for a construction sequence illustration. The first item constructed will be the toe dike section. The toe dike will be constructed from a barge in open water. A geotextile fabric will be placed on the existing foundation on top of which appropriate sized stone will then be placed and shaped to provide the required section. A portion of the geotextile beneath the toe dike stone will be pulled up along the inboard side of the dike to prevent migration of sand through the toe dike from the main dike.

As construction of the toe dike advances, the main dike section construction can begin. The construction of the main dike will be accomplished by conventional means by land. The sand dike will be pushed out from the sand stockpile area. As the sand dike advances, trucks will be loaded with the stockpiled sand by excavators. The sand will then be dumped and pushed out with bulldozers until the dike section is above the water surface. At this point, the dike slopes will start to be shaped. As the sand advances vertically, a geotextile will be placed along the exterior sand slope. This will provide some erosion protection during the time of highest exposure during construction and will provide a filter between the sand and the bedding stone. A 6-inch thick bedding layer will be placed on the geotextile, mainly for cushioning purposes. After the bedding stone is placed, the first and second layers of the underlayer stone will be placed. Careful placement to reduce the potential for geotextile damage will be required. Once the underlayer stone is in place, the armor stone layers can be placed. They must be placed individually to ensure the proper interlocking with the adjacent stone, as well as proper orientation of each stone. During the entire construction process, the toe dike section will need to stay ahead of the sand placement in order to provide the needed protection against large amounts of sand erosion.

Once a large enough area in the uplands has been constructed to provide adequate protection, dredging of the borrow material from within the uplands can begin. This material will be hydraulically dredged and pumped into a large stockpile. The proposed stockpile area will be midway along the separator dike in the uplands area. This sand will then be mechanically moved from the stockpile to be placed as the dike construction progresses. Depending on time requirements for dredged material inflow into the site, an upland cell could be closed off initially while construction progressed over the remainder of the site.

Where required, spillway structures will be constructed for the purpose of decanting water from upland and wetland cells after dredge material inflows. They will most likely be a telescoping weir (T-Weir) structure or stoplog type structure, with either welded high density polyethylene (HDPE) pipe or concrete pipe as the outlet. Corrugated metal pipe will not be used due to the potential for damage to the joints during installation leading to a piping failure through the dike embankment. Currently it is estimated that 19 spillway structures will be required throughout the upland and wetland cells. Each of the four upland cells is expected to need an outlet directly to the Bay. Spillway structures for the wetland cells will either empty into the Bay directly or into the tidal gut. Discharging into the tidal gut will need to be assessed more thoroughly in the next design phase in order to address the water quality issues that may occur. It should be noted that the purpose of the spillway structures is not to facilitate tidal exchange between the wetland cells and the Bay. Separate tidal inlet structures will be constructed as required to allow tidal flow in and out of the wetland cells.

It is assumed that a temporary docking facility/pier will be used during construction for purposes of providing personnel access to the island. A permanent personnel pier will also be constructed as part of the project. It will be located on the east side of the project, most likely near the upland/wetland dividing dike. This could be constructed any time after the dike construction is finished in that reach. Additional facilities required will be a fuel farm, office space (trailers or buildings), power, and telephone service.

5.2.2 Multi-Phase Construction. If required due to funding constraints, construction of the James Island project may be built in several phases. However, a number of environmental and engineering issues will need to be considered. Keeping each phase at 45% upland/55% wetland will be difficult. Unlike Poplar Island, the project is not divided in half longitudinally for the upland/wetland delineation. Therefore, with the current configuration it will be difficult to stage the construction laterally and maintain the final upland/wetland ratio throughout. Additionally, partial construction of the wetlands may be very difficult due to the prominent tidal gut feature.

Project phasing will also need to consider protection of the existing James Island remnants. If the full island footprint isn’t constructed initially, the James Island remnants will remain exposed to continued erosion. A temporary form of erosion protection such as geotextile tubes or stone breakwaters may be required to protect the remnants until the full project footprint has been constructed.

One phasing option would be to vertically phase the construction. This would involve constructing all the perimeter dikes and the interior cross-dikes up to elevations +8 ft MLLW or +10 ft MLLW, depending on the location of the cross-dike. Later, the upland cell dikes would be raised to their full height of approximately elevation +25 ft MLLW. This phasing would require the initial upland perimeter and cross-dikes to be built wide enough to accommodate the future raising. Also, the borrow materials in the upland cells to be filled initially would need to be dredged and stockpiled during the initial phase. One or two upland cells could be designated as stockpile areas. All of the project infrastructure would also need to be constructed during the first phase, including the offloading facilities, personnel pier, office space, power, and telephone.

Since phasing would be required due to funding constraints, and vertical phasing would require a large amount of funding for the initial construction phase, this is an unlikely scenario. A more likely scenario would be to laterally phase the construction. In other words, build a portion of the overall footprint in each phase. The phasing scheme would be very dependant on the number of phases required. The access channel would be constructed first, with the dredged sand being used as borrow for dike construction. The initial phase would require some amount of uplands to be constructed, dependant on the capacity requirements at the time of construction in addition to the projected timeframe until future phases could be constructed. The entire borrow deposit within the footprint of the uplands built in the first phase would need to be dredged and stockpiled during the first phase. Most of the borrow would likely be used for construction of the dikes, but any additional borrow would also need to be dredged in order to allow inflows into the upland cell(s). If more borrow was required than what was acquired from within the access channel and the initial uplands, then borrow outside the first phase footprint (but within the overall final project footprint) would be required. As stated previously, assuring any upland/wetland ratio would be difficult due to the island layout. More likely an attempt to provide the most economical and efficient phasing would be recommended, while ensuring adequate environmental restoration occurs during each phase. Additionally, as discussed previously, some temporary protection of the existing island remnants would likely be required if adequate protection wasn't provided by the initial construction phases.

5.2.3 Wetland Construction/Development. Regardless of the construction phasing, wetland construction will be undertaken after the appropriate wetland perimeter dikes and interior dikes are constructed for a given wetland section. At this point, wetland construction is expected to be performed in a similar manner to the construction of Cell 3D at Poplar Island. This would involve dividing the overall wetland area into smaller cells, approximately 40 acres in nominal area. See Figure 16 for the Cell 3D layout at Poplar Island.

Each cell would then be developed by a combination of hydraulic dredged material inflows and surface dewatering/crust development. During the first inflows into a wetland cell, up to 70% of the total expected dredged material volume will be inflowed into the cells. Then, 70% of the remaining dredged material volume will be added in the next inflow, continuing on this cycle until the last inflow is less than 20,000 cy. The remaining volume required would be placed at this time.

After each inflow event, an aggressive dewatering/crust development process will need to be undertaken. These methods may be similar to those used at Poplar, such as perimeter trenches and pumping, but also a lesson learned approach. Once a stable surface and an elevation was achieved which is close to the target elevation (+1.5 ft MLLW at Poplar Island), mechanical excavation of the channel features and grading of the site to provide the required topography for the different plant types would begin. This excavation and grading process will allow for channels of varying widths and alignments to be cut, as well as desired elevation variations in the marsh areas to be created. Equipment used for the cell 3D grading and channel excavation included low ground pressure excavators, dozers, and tracked dump trucks. This equipment had no difficulties operating on the crust surface. Depending on the material balance for the site, additional material may need to be mechanically placed into the cell during this process or some material may have to be removed. Once the final grades are met, a tidal inlet structure will be installed at the site to connect the wetland channel to the tidal gut or the Bay as required. After sufficient tidal flushing occurs, planting of the low-marsh and high-marsh plants will proceed. Alternate methods of wetland cell development are currently being considered at Poplar Island as well, and if they prove successful, they could also be employed at James Island.

During the detailed design phase for each of the wetland cells, engineers and scientists will develop grading and planting plans that will attempt to accommodate expected changes in sea level. One such method would be to grade the marsh plain so that final elevations are at the higher end of the low-marsh and high-marsh planting zones. This would allow for moderate increases in relative sea level with little to no change in the ratio of low-marsh to high-marsh. Another possible design strategy would be to initially develop the marsh with a significantly higher percentage of high-marsh, thereby allowing the marsh to naturally progress toward the desired low-marsh/high-marsh ratio with rising sea levels over the life of the project.

5.2.4 Upland Cell Construction/Development. As previously stated, the upland area will be divided into cells for dredged material placement and cell development. The cross-dikes required for cell division will be constructed to approximately elevation +25 ft MLLW. They will be comprised mainly of sand on 2.5H:1V sideslopes. Further analyses will be performed to determine the best solutions for erosion control. Until the dredged material is filled above the Bay water level, the cells will contain open water. There is a high potential for erosion caused by wave action within the cells to occur. This has occurred in Cell 6 at Poplar Island. Some geotextile tubes may be required as breakwaters within the cells. Additionally, surface treatments of erosion-resistant geosynthetics or clays may also be employed.

Once the cells have been divided, the southwestern upland cell will require the access channel to be dredged and a turning basin with an offloading bulkhead to be constructed. This cell will serve as the primary dredged material and equipment offloading area throughout most of the life of the project. This area will be the most centrally located and protected area available for offloading on the site. The other three upland cells will be filled according to a general schedule that will keep each inflow lift thickness under 3 feet. This will allow for an aggressive crust management effort to be employed efficiently and will increase the overall site capacity over time. After each lift is placed, trenches will be excavated through the dredged material and a dewatering effort will ensue. Currently at Poplar Island, the drainage trenches/desiccation zone extends about 18 inches below the surface. Therefore, a larger lift would not allow as high a percentage of the lift to be drained and overconsolidated, which would result in a slower and lesser amount of lift consolidation. This would eventually lead to a loss in some capacity. If the cell is overloaded repeatedly, the lost capacity could become substantial.

The ultimate goal for each upland cell is to provide for as much dredged material placement capacity as possible and allow the cell to be developed into an upland habitat after the capacity has been exhausted. The final elevation of the upland cells will be approximately +20 ft MLLW. Once this elevation has been achieved, each cell will be taken off-line and upland development will commence. This will include providing drainage features to handle surface drainage from storm events, as well as preventing concentrated areas of open water or erosion from runoff. It will be difficult to keep any drainage features functioning as designed due to the likelihood of continued settlement for years after the final inflow into the cell. This settlement will be greatest at the center of each cell. Therefore, it may be desirable to overbuild the center portion of the cell to account for this. During the next design phase, lessons learned from any upland grading at Poplar Island will be incorporated into the upland cell development for James Island.

6. DEVELOPMENT OF RECOMMENDED ALTERNATIVE: BARREN ISLAND

6.1 Introduction.

6.1.1 Results of Plan Formulation. As a result of the plan formulation process, an area along the west side of the existing remnant islands at Barren Island was selected for an environmental restoration project. Basically, Alignment D was converted to a single line of protection. There is already a limited project constructed along part of the island with wetlands added by maintenance dredged material placement from the Honga River channel. This project area extends south along an existing sand bar, which was the location of the original Barren Island shoreline before it eroded. The stated purpose of the environmental restoration at Barren Island was to protect the existing shoreline at Barren Island, provide protection to the submerged aquatic vegetation (SAV) areas on the east side of the island, and to create wetlands using maintenance dredged material from local channels where possible. The existing Barren Island site has many more environmental benefits than the existing James Island site. This led the plan formulation process to focus on creating the dredged material placement at James Island, while focus on protecting the existing environmental resources at Barren Island, with some additional wetland creation. The restoration would consist of a continuous stone nearshore sill along the existing island shoreline to elevation +4 ft MLLW, with a continuous stone breakwater to +6 ft MLLW south of the island to the end of the project. The existing stone sill along the northwest portion of the island would be modified to elevation +4 ft MLLW to increase the protection provided to the island. Also, a restoration scheme involving a stone sill or breakwater will be considered on the northern exposure of the island, which may also provide an area for dredged material placement and wetland creation. See the attached Figure 19 for more detailed project delineation.

6.1.2 Additional Investigations and Design. The recommended additional engineering tasks included:

- Perform additional subsurface investigations and laboratory testing for the selected alignment. These investigations will provide information on the foundation conditions that could affect the breakwater design sections.
- Perform settlement and slope stability analyses on the proposed breakwater sections to ensure appropriate costs are covered for overbuilding or material removal and replacement in reaches with very poor foundation conditions.
- Incorporate coastal and hydraulic engineering considerations into design of the project features.
- Provide updated cost estimate based on recommended plan.
- Obtain limited bathymetric surveys along the alignment and wetlands areas.

6.2 Site Investigations.

6.2.1 Reconnaissance Study Subsurface Investigations. During September and October 2001, eighteen (18) borings were drilled to depths of 35 to 70 feet and samples were obtained to investigate alternative alignments associated with the reconnaissance studies for Barren Island. Laboratory testing included grain size analyses for basic soil classification, and tests to determine shear strength and compressibility characteristics of the fine-grained soils. The grain size analyses on sandy soils provided information about the location, quantity, and quality of potential borrow materials for dike construction. Logs for all of the borings and results of the laboratory testing are presented in the Geotechnical Reconnaissance Study for Barren Island, Chesapeake Bay, Maryland, dated

February 2002. The report was prepared by E2CR, Inc., for Roy F. Weston, Inc. under contract to the Maryland Port Administration.

6.2.2 Feasibility Study Surface Investigations. During May 2004, twenty-seven (27) borings were completed at Barren Island to investigate subsurface conditions along the proposed dike alignments for the island alternatives and in the potential borrow areas. Testing consisted of grain size analyses, Atterberg Limits, and water contents for material classification. Strength data was estimated based on blow counts from drilling and pocket penetrometer tests of some of the samples. No borings were performed along the proposed alignment of the recommended plan due to the late development of the plan. The available borings for Alignment D were considered to be close enough to use for the feasibility evaluation of the plan. Logs of the completed borings and results of laboratory testing are presented in Attachment E – *Subsurface Investigations and Laboratory Testing.*

6.2.3 Surveys. For the initial phase of the feasibility study, survey information for areas in the vicinity of Barren Island was obtained from a NOAA ENC file. Features such as soundings, depth contours, navigation restrictions, and shorelines were extracted from ENC file US5MD21M (nautical chart 12264) in order to develop digital mapping products for the Barren Island site. All features contained in the ENC file have geographic coordinates (latitude and longitude) that reference the WGS84, and depth-related information in meters referencing MLLW. Pertinent features from the ENC file were imported into GIS software and reprojected into the Maryland State Plane Coordinate System, NAD83 (feet). Depth information was converted from meters to feet. The converted soundings and depth contours were then used to create a TIN surface model for the area around Barren Island. Soundings and depth contours derived from the ENC files are presented in Figure 17.

Since the information contained in the ENC file was collected between 1940 and 1969, it was determined that the shoreline features depicting the extent of the island remnants collectively known as Barren Island were grossly inaccurate. PBS&J was contracted to provide updated imagery and shoreline information for Barren Island. PBS&J utilized color aerial photography obtained in October 2004 to develop the high tide shoreline and black and white aerial photography obtained in November 2004 to develop the low tide shoreline for Barren Island. As part of the aerial mapping contract, PBS&J also established one permanent survey control point on Barren Island. All survey information provided by PBS&J was referenced to the Maryland State Plane Coordinate System, NAD83 (feet).

Since subsurface investigations conducted during the feasibility study revealed significant differences between the depths contained in the ENC files and actual depths observed in the vicinity of James Island, similar discrepancies were assumed to exist in the vicinity of Barren Island. PBS&J was contracted to conduct a reconnaissance-level hydrographic survey along the alignment of the recommended plan for Barren Island. OSI was subcontracted by PBS&J to conduct the survey. The horizontal datum for this survey was the Maryland State Plane Coordinate System, NAD83 (feet), and all bathymetric data were referenced to MLLW for the 1983-2001 Tidal Epoch at Barren Island, as determined by the National Ocean Service (NOS). See Attachment K for information on the tidal benchmarks established by NOS at Barren Island. The bathymetry was used to create a TIN surface model of the survey area. Depth contours derived from the TIN surface model and soundings are presented in Figure 18.

6.3 Barren Island Recommended Plan. The subsurface exploration was based on the previous island alternatives and performed farther offshore than the alignment of the recommended plan. To provide an assessment of potential foundation conditions along the proposed plan alignment, results of the closest borings were used in a general assessment. These borings were G-2, G-3, G-4, G-15, G-104, G-111, G-115, G-116, and G-123. No detailed analyses were performed for the proposed section, rather engineering judgment was used based on the boring information to assess potential settlement or stability issues. The initial structure extended to the south and east along the sand spit and encompassed all recent remnants of Barren Island. This length of this alignment was scaled back due to concerns about increasing current velocities between the structure and the existing mainland. The potential for increased sedimentation in areas which were more sheltered also contributed to the decision to reduce the structure length.

6.3.1 Layout. See Figure 19 for the proposed alignment. The western project alignment is approximately 13,550 LF in length. The northern project option is approximately 3840 LF in length. Each alignment is laterally located just off-shore in relatively shallow water (est. 3-4 feet of depth at MLLW). The northern portion of the western alignment consists of adding one layer of armor stone to the existing project. This will raise the top of the structure from the existing elevation +2 ft MLLW to +4 ft MLLW. The new continuous breakwater/sill option along the western shoreline will be built to +4 ft MLLW. The breakwater section that continues south of the existing island will be built to +6 ft MLLW. This is mainly due to guidance from the US Coast Guard with respect to navigation hazards. Since this portion of the project will be located essentially in open water, the structure needs to be built high enough to be visible to boaters during higher water conditions. The northern protection option will also consist of a stone breakwater/sill to elevation +4 ft MLLW. Wetland creation behind the northern protection and much of the western protection is also recommended. It is envisioned that dredged material from the maintenance of the local channels will be used to fill behind these portions of the structures. The existing project already has already incorporated wetland creation between the structure and the existing shoreline. Containment on the eastern side of the proposed wetland area will also be required just south of the existing island. This containment will likely consist of a stone sill to approximately elevation +4 ft MLLW. The south breakwater will be constructed in order to provide a more favorable environment for the large SAV beds located to the east of Barren Island. The wave reduction provided by the breakwater will create and/or retain favorable conditions for SAV growth. Detailed hydraulic modeling will still need to be performed and could result in refinements of the structure lengths, heights, and locations. The additional modeling will also consider whether the breakwater structure to the south of the existing island can be segmented.

6.3.2 Coastal Hydraulics Issues. An analysis of the waves and water levels at Barren Island was performed by ERDC to establish the range of conditions to which the proposed structure would be subjected over the life of the project. A life-cycle analysis of the stone protection structures was applied to optimize design features for the project including crest elevation, armor stone size, and side slopes. Both structural stability and functional performance of the breakwater/sill were considered.

The functional performance of the breakwaters was evaluated in terms of the ability to reduce wave heights to levels tolerable for SAV. An overtopping analysis was performed to determine the crest elevation for the breakwater structure required to reduce wave heights to levels tolerable by SAV. Crest heights of 2-, 4-, 6-, and 8-feet were evaluated. Available literature on SAV indicates that the tolerable wave height for SAV ranges from 0-2 meters with an average of 1 meter. The preliminary results for the overtopping analysis indicate that a crest height of +4 ft MLLW would provide SAV protection to the limiting tolerable wave height of 1 m for just over a 30-year return period storm event. A structure of +6 ft MLLW would reduce waves to tolerable levels for up to a 50-year return period event. These preliminary results are based solely on an overtopping analysis, which is considered to be the predominant factor affecting the transmitted wave for submerged structures. Future design efforts will also need to consider wave transmission through the structure and any gaps in proposed segmented structures, diffraction through the gap between the mainland and the proposed alignment, and local waves generated on the eastern side of the project.

The preliminary results of the armor stability analysis indicate that armor and toe stone sized for a 50-year return interval would be stable over the life of the project. The preliminary armor stone size recommended was 1300 lbs for the stone sill along the northern portion of the westerly alignment and 1000 lbs for the breakwater along the southern portion of the westerly alignment. However, due to uncertainty in the water depths along the sand spit which could affect wave heights, it was decided to use a conservative 1300 lb armor stone for the entire project . A side slope of 1V:1.5H was considered to be optimum. Details on the wave and water level analysis and the lifecycle analysis of functional performance and structural stability for the Barren Island project are provided in Attachment I – *Life-Cycle Analysis of Mid Bay and Poplar Island Projects*.

6.3.3 Foundation Issues. As previously discussed, the subsurface exploration was performed farther offshore than the proposed project alignment. Therefore, the boring results have been extrapolated as sensibly as possible. Most of the borings that are located nearest the proposed alignment contain layers of soft clay that vary in thickness from 2 feet to 10 feet. Based on this information, a 6 inch overbuild will be estimated to account for long-term consolidation settlement that may occur. Although some very soft silt and clay deposits do exist at the surface, at this time, it is not estimated that a large amount of foundation removal and replacement will be required. The structure heights and sizes are not very large in comparison to the James Island dikes. By comparing the conditions at Barren to a similar subsurface profile of JB-217, the corresponding estimated settlement will be less than 6 inches. Therefore, it is considered adequate to estimate 6 inches of overbuild over the entire structure length to account for potential foundation problems. Certainly, a much more intensive and thorough geotechnical analysis will be required in the next design phase to confirm these assumptions.

6.3.4 Borrow Issues. Currently, no borrow material is expected to be required for use at the Barren Island site. The breakwaters/sills will be constructed from armor stone and crushed stone that will be barged in from offsite. All wetland fills are assumed to be provided by future local channel maintenance operations at this time. Therefore, no sand borrow will need to be dredged from outside the footprint of the proposed project. The only reason sand would be required is for any foundation removal and replacement operations. However, at this time the assumption is that no removal and replacement effort is necessary.

6.3.5 Proposed Breakwater/Sill Section. Three different sections are proposed for use on the project. They are identified as 1)Modification of existing sill, 2)Near-shore sill, and 3)South Breakwater. See Figures 20-22 for the typical sections. The section for the modification of existing sill consists of adding two layers of 1300 lb. armor stone to the sill section currently in place and adding two stones at the bayside toe of the structure. The top width will be 6 feet, and the top elevation will be +4 ft MLLW. The total length of this modification is estimated at 4,900 LF.

The near-shore sill has a top elevation of +4 ft MLLW, a top width of 6 feet, and consists of core stone layer covered by 2 layers of 130 lb. underlayer stone and 2 layers of 1300 lb. armor stone. A geotextile/sand filter section will be required on the eastern side of the section in order to prevent the eventual backfill material from migrating through the stone section. The filter will be provided at the time of backfilling. The total length of the near-shore sill is 3,840 LF along the north side of the island, and 4,620 LF along the west side of the island. The containment sill has not been designed at this point, but will likely be the same section as the near-shore sill. The estimated length of the containment sill is 1,300 LF.

The south breakwater section has a top elevation of +6 ft MLLW, a top width of 6 feet, and consists of a core stone section covered by 2 layers of 130 lb. intermediate stone, and 2 layers of 1300 lb. armor stone. The estimated length of the breakwater section is 8,200 LF.

In light of the potential impacts of relative sea level rise on the project, consideration will be given to increasing the top elevations of all of the structures discussed in this section. Any changes in structure elevations would occur during the detailed design phase of the project.

6.3.6 Proposed Wetland Creation. As described previously, portions of the recommended project will be backfilled between the created structure and the existing island in order to create wetlands along the shoreline of the island. It is proposed to use dredged material from the local channel maintenance projects to supply the backfill for the wetland creation. The wetlands will need to be created in several increments, as the quantity of maintenance dredged material will likely not be enough to create the wetlands all at once. Planting of the wetlands will commence after each backfilled portion or cell is filled and consolidated to the required elevations. See Section 5.2.3 of this appendix for a discussion of wetland design and relative sea level rise.

7. CONSTRUCTION OF RECOMMENDED PLAN AT BARREN ISLAND

7.1 General. In general, construction procedures are assumed to be similar to those used on the existing Barren Island project. Most of the construction will be performed from barges with cranes or excavators being used for stone placement. Due to the shallow depths along the selected alignment, it is anticipated that the larger stone barges will anchor off-shore in deeper water, while the contractor uses smaller barges to access the work locations. This "light-loading" method has proven effective for the existing project at Barren Island. While efficiency is somewhat sacrificed by using this method, large environmental effects that would occur due to dredging to allow near-shore barge access will be avoided.

7.2 Construction Sequence. The project has been developed with the assumption that the project will be built in two main phases, with the wetland creation occurring over time during the various dredging cycles. However, if possible, a project built in a single phase will be the most efficient, and cost-effective, and will provide the most environmental benefits by protecting the various areas soonest.

7.2.1 Single-Phase Construction. As stated above, the project will be built most effectively, efficiently, and economically if construction is performed in a single phase. Depending on the contractor's preference, the first item constructed will either be the northern near-shore sill or the modifications to the existing sill. Construction of the northern near-shore sill will begin by installation of the foundation geotextile. Following that, the contractor will begin by placing the core stone section. As the core stone construction progresses along the alignment, the contractor may bring another small barge to begin placing the intermediate stone. After the intermediate stone is placed, the armor stone layers will be placed. This process will continue down the alignment in this order. It is most likely that the contractor will start at the northwest end and progress to the south and east from there.

The construction of the existing sill modifications will then begin. The contractor will place the armor stone from a barge. The contractor will start at the bottom of the section and work up to the crest. As the contractor moves down the alignment, he will likely add the toe stone. This will allow him to get as close to the existing structure as possible while placing the armor stone.

After the existing sill modifications are finished, the contractor will start on the construction of the near-shore sill section that is attached to the existing structure. Construction will occur in the same manner as for the northern near-shore sill. The contractor will most likely progress from the north to the south of the project. The contractor will likely build the east side containment sill at the point.

After the full length of the near-shore sill is built, the construction of the breakwater section will begin. The contractor will likely place the geotextile and the toe stones initially to secure the geotextile. Core stone will then be placed, followed by the intermediate stone and the armor stone, just as with the near-shore sill section. Once again, the contractor will likely construct from the north to the south during this work.

7.2.2 Multi-Phase Construction. It is likely that this project will be built in two main phases, to be followed as required by backfilling and wetland planting. The reasons for building in multiple phases may include lack of full project funding, or desire to obtain more detailed information for the final design of the breakwater section.

This project would likely be phased by building the near-shore sill sections on the north and west sides in addition to the modifications to the existing sill. The east side containment sill could be built at this point or held until later. However, before any dredged material backfill was placed south of the existing island, the containment sill would need to be in place.

The second phase of the project would likely involve the construction of the south breakwater section. This portion of the project is separate in both section and purpose. The near-shore sills provide erosion protection to the island in addition to allowing for wetland creation. The south breakwater section's main purpose is to provide a reduction in the wave environment for the SAV area located to the east of Barren Island. By holding off on construction of the breakwater section, more detailed engineering analyses can be performed to determine the optimum size and length of the breakwater project. Additionally, the decision on whether to make the breakwater continuous or segmented can be more accurately made with more analysis. The risk of waiting to build the breakwater is the additional time that the SAV area is exposed to a high energy environment. If the SAV area is degraded or lost, creation of the breakwater may not be beneficial, and many of the environmental benefits of the project will be lost.

7.2.3. Wetland Construction. Wetland creation can begin once the required stone sill containment sections are constructed. The size and timing of each wetland creation event will depend upon the local maintenance channel dredging. During the backfilling operation, some containment such as sand dikes may be required on the southern extent of each pumping operations to keep the dredged material from spreading out too far and not allowing any wetland development to occur at that time. The inflow amount of each event should be estimated. Using that estimate, an appropriate acreage can be estimated for wetland creation from that event. Once the event acreage is determined, the "secondary" containment structure can be put into place. This will be less critical if the dredged material is predominantly sand, due to its tendency to settle out close to the inflow point. The containment of the inflow event will be much more critical if the dredged material contains a lot of fines (silts and clays).

8. FUTURE DESIGN EFFORT

8.1 General. If the feasibility study is approved, the next design phase will be the preconstruction engineering and design (PED) phase. The result of this effort will be the creation of construction plans and specifications for the proposed projects. The schedule for this phase will depend upon approvals and funding.

8.2 Geotechnical Engineering Design Effort. The first step in the PED effort will be to obtain additional subsurface information for each project. This will require a very large and intensive drilling and testing effort. For James Island, a final boring spacing of between 300 to 500 feet along the dike alignments is desired. The dike foundation conditions need to be thoroughly characterized in order to minimize potential construction issues involving poor foundation conditions. In addition, a more thorough investigation will be required for the proposed borrow areas within the upland cells and the access channel. The testing program for James Island will consist of material gradations, Atterberg limits, consolidation tests, unconfined compression tests, and triaxial shear tests. Additional tests may be required depending on what the investigations reveal.

For Barren Island, a final spacing of 200-300 feet will be desired. The foundation conditions will need to be thoroughly characterized as well in order to properly design the sills/breakwaters for both stability and settlement purposes. The testing program will generally be the same as for James Island, although on a much smaller scale. Triaxial shear tests may or may not be required depending on foundation conditions.

Geotechnical design will consist of performance borrow material analysis, developing the dike/sill/breakwater sections in conjunction with H&H and Civil Sections, performing slope stability and settlement analyses, developing a workable construction sequence (specifically for the wetlands), performing foundation design for appropriate structures (bridges/culverts across tidal gut, bulkhead, fuel farm, piers, weirs, etc.) in coordination with Structural Section, and further developing the overall site layout. Once the design effort is completed, full plans and specifications will be required. The geotechnical specifications will include all earthwork, dike construction, road construction, stone specifications, geotextile, concrete, and foundation specifications.

8.3 Civil Engineering Design Effort. The initial civil engineering PED task will be to acquire more detailed surveys of both projects. For James Island, the survey will encompass the access channel and dike alignments and the interior of the diked areas. The new survey will be used to refine the alignment in conjunction with the additional boring information and updated geotechnical and hydrodynamic analyses. In addition, this data will be used to refine the quantity estimates for dike construction and serve as a baseline for the borrow sites within the project footprint. A digital terrain model will be created of this surface and actual air space volumes for dredge placement will be updated. This model will again be updated during construction after borrow has been excavated and post-dredging surveys conducted.

Additional surveys will also be required at Barren Island to refine the alignment and quantities. Any changes due to updated geotechnical or hydrodynamic analyses will be incorporated.

Detailed alignments, sections and details will be developed for all the project features, including dikes, spillways, piers, operations facilities, etc. Location and design of these features will be closely coordinated with the Foundations & Dams and Structural & Site

Development Sections. Additional tasks will be the development of the contract plans and specifications for project construction. Civil specifications include all seeding, planting, erosion and sediment control and measurement and payment.

8.4 Hydraulics and Hydrology Design Effort. An initial PED task will involve updating the wave and hydrodynamic modeling for James and Barren Island to reflect recent nearshore survey data, as well as updated project alignments. The updated wave and hydrodynamic models will be applied to alternative breakwater configurations at Barren Island to establish the optimum lengths, heights, and locations that reduce waves to tolerable levels for SAV while minimizing impacts on sedimentation. The additional wave and hydrodynamic analyses will also consider whether the breakwater structure to the south of the existing island can be segmented.

The life-cycle analysis for the stone protection structures will be updated for both projects to refine the crest elevation and armor stone size. A more thorough analysis of the constructability and stability of the toe dike will also be performed. Detailed design of stone revetment, breakwater, and sill features will be developed for both projects in conjunction with Foundations & Dams and Civil Engineering Sections. For Barren Island, further analyses and possible physical model testing of the structural stability and functional design parameters for submerged structures, including wave transmission and overtopping, will be necessary to optimize design.

Detailed hydrodynamic modeling of James Island will determine final dimensions and alignment of the primary tidal gut and wetland cell channels as needed to accomplish the required tidal exchange with the wetland habitat. The hydrodynamic models will be applied for extreme storm events, in addition to typical conditions, to determine whether additional measures are needed to prevent erosion of the tidal gut at James Island and for use in assessing the potential long term project impacts of both projects on sedimentation and erosion. A more thorough analysis of sediment transport in the vicinity of both projects will be accomplished to verify projected impacts and to refine design features such as tidal guts at James or segmented breakwaters at Barren Island. The possibility of discharging into the tidal gut at James Island will need to be assessed more thoroughly in order to assess the water quality issues that may occur. Additional field data collection of tide elevations, currents, wave heights may be conducted to improve verification of the modeling efforts.

In addition to the other modeling discussed in this section, potential impacts resulting from relative sea level rise will be examined during the PED phase. Using predictive models, hydraulic engineers will determine the required dike, sill, and breakwater heights and armor stone sizes.

8.5 Structural Engineering Design Effort. Structural engineering effort will be required for final design of some of the features proposed. These include the bridges or culverts that will span the main tidal gut, the sheetpile bulkhead proposed for the unloading area, the personnel pier and any additional piers, the fuel farm structures, required weirs, and any permanent buildings that may be proposed.

8.6 Electrical/Mechanical Engineering Design Effort. Since electric power and telephone services will be required during construction and operation of the site, the availability of services will be investigated during PED. Coordination with the local utilities will be required to determine the availability of sufficient power. Power demand will be assessed and conduits, electric panels and distribution lines will be designed. Mechanical Section will have input to any gated structures at the spillways. In addition, if operations buildings are proposed, both disciplines will be required for electrical and mechanical design of the buildings, including preparation of plans and specifications for construction.

8.7 Architectural Design Effort. Any operations buildings will require architectural design effort, including preparation of plans and specifications for construction.

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