APPENDIX A3 – MITIGATION, MONITORING & ADAPTIVE MANAGEMENT PLAN

for

RIO GUAYANILLA, GUAYANILLA, PR
2018 SUPPLEMENTAL APPROPRIATIONS
FLOOD RISK MANAGEMENT STUDY

US Army Corps of Engineers®
Chicago District

Mitigation Plan Summary

The Recommend NED Plan component of the set-back El Faro level would fill/impact about 5.8-acres of mangrove swamp. Based on the findings of the 404(b)(1) analysis and coordination and conservation planning conducted with the USFWS, the secondary growth condition of the black mangrove swamp, the avoidance of impacting 240-acres and the minimization of the El Faro levee size the target for 1:1 in-kind mitigation would be 5.8-acres of mangrove swamp within the project footprint. The 22 January 2020 DCAR confirms that at minimum, 5.8 acres of mangrove swamp would need to be mitigated.

Through this analysis, USACE has ensured that project-caused adverse impacts to significant ecological resources have been avoided or minimized to the extent practicable and that remaining, unavoidable impacts have been compensated to the extent justified. The recommended NED Plan includes sufficient mitigation to ensure that the selected plan will not have more than negligible adverse impacts on ecological resources (Section 906(d), WRDA86).

The affected mangrove swamp as a basin type obtaining its hydrology from extreme high tides, coastal flooding and river flooding. Freshwater input provided by the agricultural drainage canals and overbank flooding by the Rio Guayanilla helps maintain salinity levels. This mangrove basin includes Leather Fern (*Acrostichum* spp) and Cattails (*Typha* spp) along the fringes of the drainage ditches with Red Mangrove (*Rhizophora mangle*), away from the drainage ditch as salinities increase, where species composition changes to Black (*Avicennia nitida*) and White Mangroves (*Laguncularia racemosa*).

An HSI was created using concepts commonly associated with mangrove community ecology and restoration publications that correspond to familiar USACE ecosystem criteria. Variables that comprise this qualitative assessment include: (1) hydrology, (2) geomorphology, (3) hydraulics, (4) connectivity and (5) potential biodiversity. In order to derive a numerical classification to fulfill USACE policy requirements that a quantitative valuation of alternatives be conducted, numerical values on a 0 to 1 scale were assigned to the qualitative values. A 0 to 1 scale was used to normalize the values, which is typically applied by USACE to ensure comparability.

The following goal and objectives were set to guide mitigation measures and alternatives:

- *Target 1 (Goal)* – To replace in-kind 5.8-acres of mangrove swamp.
- *Target 2 (Objective 1) – Reestablish Hydrogeomorphology for Mangrove Swamp Community*
- *Target 3 (Objective 2) – Reestablish Mangrove Swamp Plant Community*

A set of seven (7) measures were utilized to develop four (4) Mitigation Alternative Plans (MAPs). Costs and Net Average Annual Habitat Units were utilized for plan comparison. The cost effectiveness analysis was used to ensure that certain options would be screened out if they produced the same amount or less output at a greater cost than other options with a lesser cost. Four (4) mitigation alternative plans were analyzed for cost effectiveness. Two (2) plans were not cost effective (MAP 2 and MAP 4) and two (2) plans were identified as cost effective and “Best Buys” (MAP 1 and MAP 3).

An incremental cost analysis was performed on the two (2) Best Buy Plans identified from the cost effectiveness analysis. The objective of the incremental cost analysis is to assist in determining whether the additional output provided by each successive plan is worth the additional cost. This incremental cost analysis compares the alternative combinations for ecological restoration (mitigation) that were considered for selecting the recommended mitigation alternative plan. MAP 1 and MAP 3 would both meet planning and mitigation objectives and potentially result in good quality mangrove swamp habitat. MAP 1 has a greater effectiveness than MAP 3 by producing more benefits at a lower cost. To implement MAP 3 over MAP 1, it would cost an additional $13,804 per Habitat Unit.

MAP 1 is currently selected as the recommended mitigation plan simply based on its cost effectiveness and that the USFWS recommended this location for mitigation. This alternative would restore about 6.0-acres of mangrove swamp by manipulating the hydrogeomorphic setting. This type of alternative would replicate how mangrove would look like within a basin, exemplifying a patchwork of open water, mangrove and associated wet community types. Measures utilized to reestablish wetland within this zone include the following: clearing and grubbing, excavation and grading to specified elevations, installation of sediment transport features, no planting of mangrove species (Black and White) and moderate planting of Red Mangrove and conspecifics, invasive species management, and temporary erosion control features. Temporary sediment transportation features would include natural materials such as logs/woody debris, coconut/jute fabrics, brush fascines, etc. placed strategically to a) trap the appropriate amount of sediment for mangrove recruitment and b) disallow complete filling in with sediment.

The mitigation cost for MAP 1 would be $656,000, inclusive of real estate, design, construction, and adaptive management measures. Monitoring would be an additional $58,000 over 5-years and Average Annual O&M costs $500 over 50 years.

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1. Introduction

As discussed in the Integrated Feasibility Report (IFR) and 404(b)(1) Analysis (Appendix A), the proposed El Faro levee alignment would fill/impact approximately 5.8-acres of interior basin mangrove swamp, black mangrove (*Avicennia nitida*) dominant. According to the Puerto Rico Department of Natural and Environmental Resources (PRDNER) botanical surveys in 1988, a greater percentage of the area (Figure 1) was converted from its natural mangrove condition to Cañaveral (sugarcane plantation) (PRDNER 1989) (*Appendix A2 Attachment*). Eventually, the Cañaveral was abandoned and a new plant community established, inclusive of some of the former natural mangrove swamp. This new plant community was noted as dominated by *Avicennia nitida*; for the most part a recovered mangrove swamp, but with altered hydrology, lower species richness and newly introduced invasive species. Various large floods and hurricanes have also influenced this area, in which naturally functioning mangrove swamps are mostly adapted to; however, significant events can change mangrove into different habitat types by changing the geomorphology. Patches of this area have also incurred impacts to hydrology, plant community structure and species composition by the development of El Faro and local practices of harvesting wood from accessible mangrove edges. This mitigation planning effort assessed a limited number of alternatives to ensure that funding allocated for implementation, monitoring and adaptive management is justified to the level necessary to have a net loss of 0-acres of wetland, and that any additional/incidental benefits are captured.

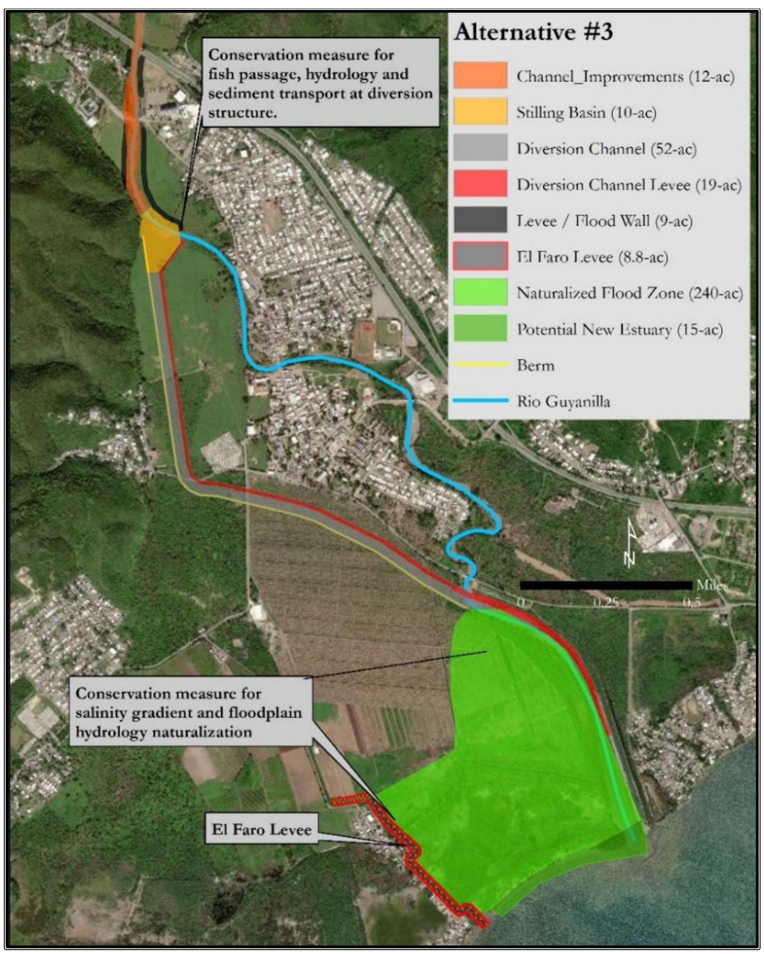

Figure 1: Rio Guayanilla Alternative 3 - El Faro Levee Affected Area

2. Authority and Guidance

The Secretary of the Army is required to include a recommendation with a specific plan to mitigate for damages to ecological resources, including terrestrial and aquatic resources, and fish and wildlife losses created by such project, or determine that the project will have a negligible adverse impact on ecological resources and fish and wildlife without implementing mitigation measures. Mitigation plans for water resource projects shall include a monitoring plan for implementation and ecological success of each mitigation measure; the criteria for ecological success for mitigation; any land and interest in land needed for mitigation; a description of the third party mitigation instrument to be used, if applicable; a description of the types and amount of restoration activities, the physical action to be undertaken to achieve the mitigation objectives within the watershed where such losses occur, and the functions and values that will result from the mitigation plan; and, a contingency plan for corrective action if monitoring demonstrates the mitigation measures are not achieving ecological success. 33 U.S.C. § 2283.

Applicable USACE Guidance

- ER 1105-2-100 (Appendix C) – Planning Guidance Notebook. April 22, 2000.
- Compensatory Mitigation for Losses of Aquatic Resources; Final Rule; Federal Register, Volume 73, No.70, April 10, 2008.
- Implementation Guidance for the Water Resources Development Act of 2007 – Section 2036(c) Wetlands Mitigation. November 6, 2008.
- Implementation Guidance for Section 2036(a) of the Water Resources Development Act of 2007 – Mitigation for Fish & Wildlife and Wetland Losses. August 31, 2009.
- Engineering Technical Letter No. 1110-2-571: Guidelines for Landscape Planting and Vegetation Management at Levees, Floodwalls, Embankment Dams and Appurtenant Structures. April 10, 2009.
- USFWS Draft Fish & Wildlife Coordination Act Report 22 January 2020.

3. Mitigation Determination

The following mitigation planning analysis adheres to the guidelines presented in ER 1105-2-100, Appendix C, Section e., parts 1 through 15 and the amended authority. The typical USACE ER planning process is followed once a determination is made that compensatory mitigation is required for a certain alternative or portion of a project. The study team, inclusive of the USFWS Caribbean Ecological Services Field Office (CESFO), used the following five steps to determine that compensatory mitigation is required to prevent or compensate for resource loss:

a) Avoiding the impact altogether by not taking a certain action or part of an action

Large scale impacts were avoided by not placing a confining berm or levee on the west side of the Río Guayanilla from the southern end of town to the confluence with Guayanilla Bay (Figure 2). This initial measure would have cut off approximately 240-acres of interior basin mangrove swamp and other degraded and abandoned old fields that could be restored ecologically.

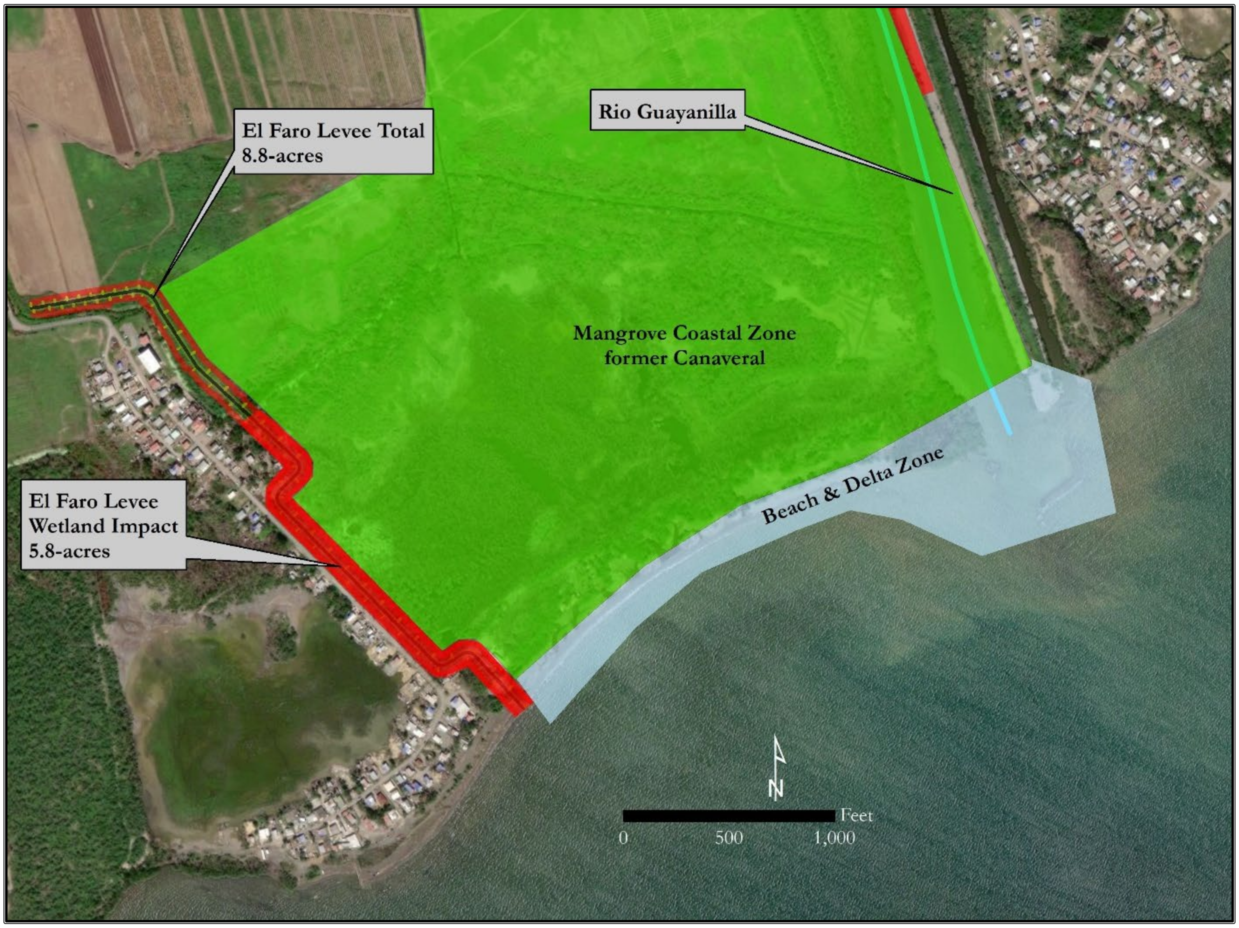

Figure 2: El Faro Levee Footprint & Mangrove Coastal Zone

b) Minimizing impacts by limiting the degree or magnitude of the action and its implementation

Hydrologic and geotechnical analyses of the El Faro area were utilized to minimize the footprint of the levee and set the alignment as close as possible to the existing road. Absence of these analyses would have incurred contingencies that would require a taller, wider and longer levee.

c) Rectifying the impact by repairing, rehabilitating or restoring the affected environment

Consequently, the flooding regime of the affected environment is natural and cannot be repaired, rehabilitated or restored, which requires some type of flood risk reduction measure at El Faro to reduce the risk of incurring flood damages and effects.

d) Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action

The levee construction activities require complete removal of the existing secondary growth Black Mangrove swamp community at the site in order to be functional, so the impact associated with this portion of the project footprint will never be reduced or eliminated over time, nor would the natural flooding regime.

e) Compensating for the impact by replacing or providing substitute resources or environments. "Replacing" means the replacement of fish and wildlife resources in-kind

Based on coordination and conservation planning conducted with the USFWS, the secondary growth condition of the Black Mangrove swamp, the avoidance of impacting 240-acres and the minimization of the El Faro levee size the target for 1:1 in-kind mitigation would be 5.8-acres of Black Mangrove swamp within the project footprint (Figure 2).

f) "Substitute" means the replacement of fish and wildlife resources out-of-kind. Substitute resources, on balance, shall be at least equal in value and significance as the resources lost.

Not considered.

4. Mitigation Planning

4.1 General

Through this analysis, USACE has ensured that project-caused adverse impacts to significant ecological resources have been avoided or minimized to the extent practicable and that remaining, unavoidable impacts have been compensated to the extent justified. The recommended NED Plan includes sufficient mitigation to ensure that the selected plan will not have more than negligible adverse impacts on ecological resources (Section 906(d), WRDA86). These mitigation measures are fully justified, as described in this analysis.

4.2 Justification

Justification of mitigation features recommended for inclusion in this project is based on analyses that demonstrate that the combined monetary and non-monetary values of the last increment of losses prevented, reduced, or replaced is at least equal to the combined monetary and non-monetary costs of the last added increment so as to reasonably maximize overall project benefits. In addition, an incremental cost analysis, to the level of detail appropriate, was used to demonstrate that the most cost effective mitigation plan has been selected.

4.3 Separable Features

Full credit shall be given to the beneficial aspects of an alternative plan, or project, before consideration is given to adding separable mitigation features. The significance of the ecological resources affected by an alternative plan/project, and the significance of adverse impacts to these resources shall be evaluated to determine the need for separable mitigation features. Evaluation of a separable mitigation feature is appropriate when it is determined that the net adverse impacts of an alternative plan/project exceed its net beneficial effects, and/or when the resulting losses include values (monetary and non-monetary) of such significance that specific consideration is justified.

A separable mitigation feature was deemed necessary to reduce the effects of the El Faro levee to negligible in order to have no net loss of wetlands. The historic global/national loss of mangrove habitat also provides significance to the need for replacement in-kind, as well as the goods and services this type of wetland system provide to coastal zones. Puerto Rico has about 15,832 acres of mangrove remaining from an original estimated coverage of 60,045 acres.

4.4 Range of Alternative

To properly evaluate and compare mitigation plans and determine remaining unmitigated losses, if any, this analysis considers a range of alternatives including full compensation of significant ecological resource losses. Appropriate units of measure are used in this evaluation. Examples of units of measure include habitat units, or other habitat quality indicators, numbers of animals, pounds of fish, user-days, etc. The units of measure used in this mitigation plan are habitat units, expressed as Average Annual Habitat Units (AAHUs).

4.5 Land Requirements

USACE has considered the use of both public and private lands and selected the lands that represent the best balance of costs, effectiveness and acceptability consistent with cost guidance. For this analysis, land required for an on-site mitigation project is expected to be in the ownership of the non-Federal sponsor, the PRDNER. Public lands available for mitigation use within the coastal mangrove zone have been valued at approximately $5,000 per acre.

4.6 Special Requirements for Bottomland Hardwoods

The alternative mitigation plans ensure that adverse impacts to bottomland hardwood forests are mitigated in-kind to the extent possible. The intent is that the bottomland hardwood forest as an ecological system be mitigated rather than mitigating for faunal species in an upland hardwood forest habitat type. In this instance "to the extent possible" takes into consideration the availability of manageable units of existing or restorable bottomland hardwood forests and the practicability and feasibility of implementing management measures to accomplish in-kind mitigation. In-kind does not necessarily mean acre-for-acre, but may be restoration or the increased management of bottomland hardwood forests to compensate for the loss of biological productivity (habitat quality).

Mangrove swamp is considered a type of forest and as part of the bottomland hardwood plant community grouping/classification, therefore in-kind mitigation is necessary. The USFWS and USACE agree that 1 to 1 ratio of in-kind mitigation for the 5.8-acres lost is the minimum amount. Mitigation banks do not exist within the Commonwealth of Puerto Rico, so USACE will not satisfy its mitigation requirements through a mitigation bank.

4.7 Incremental Cost Analysis

An incremental cost analysis was performed for all identified mitigation alternative plans. The purpose of incremental cost analysis is to display variation in cost and to identify and describe the least cost plan. The mitigation analysis is presented in an analytical framework commensurate with other project benefits and costs so that rational decisions regarding mitigation can be made. The least cost mitigation plan that provides full mitigation of losses specified in mitigation planning objectives is identified and displayed. The recommended plan, if different, will be compared to it. Planning methods and data were used which yield cost estimate accuracy and reliability commensurate with that of other cost analysis components of the overall study. The rationale and sources of information used in performing incremental cost analysis are included in the discussion below.

4.7.1 Ecosystem Valuation Methodology

The effected mangrove swamp is a basin type, obtaining its hydrology from extreme high tides, coastal flooding and river flooding. Freshwater input provided by the agricultural drainage canals and overbank flooding by the Rio Guayanilla helps maintain salinity levels. This mangrove basin includes Leather Fern (*Acrostichum* spp) and Cattails (*Typha* spp) along the fringes of the drainage ditches with Red Mangroves (*Rhizophora mangle*), away from the drainage ditch as salinities increase, where species composition changes to Black (*Avicennia nitida*) and White Mangroves (*Laguncularia racemosa*).

A species, habitat or community model/index was not available to characterize the type and quality of mangrove habitat impacted by the NED Plan. There are various models under development, where most include complex water quality components and associations and hydrodynamics of sediment transport that would take years to collect data by different types of scientists working together. Therefore, the following provide rational for the use of a simplified Habitat Suitability Index (HSI) specific to the 240 acre mangrove coastal zone at Guayanilla Bay:

- used to assess mitigation plan cost effectiveness, not whether mitigation is required or not
- the wetland being affected is of medium quality and secondary growth
- the wetland incurred impacts from surrounding activities and land uses
- surrounding land use is highly impacted
- relatively minor mitigation costs compared to the NED Plan (<1.0%)
- relatively minor acreage/real estate required (<10-acres)

This HSI was created using concepts commonly associated with mangrove community ecology and restoration publications that correspond to familiar USACE ecosystem criteria. Variables that comprise this qualitative assessment include: (1) hydrology, (2) geomorphology, (3) hydraulics, (4) connectivity and (5) potential biodiversity. In order to derive a numerical classification to fulfill USACE policy requirements that a quantitative valuation of alternatives be conducted, numerical values on a 0 to 1 scale were assigned to the qualitative values. A 0 to 1 scale was used to normalize the values, which is typically applied by USACE to ensure comparability. Table 1 presents the HSI for mitigation plan comparison. Figure 3 provides the general global concept of what optimal hydrogeomorphic parameters are for Black (*Avicennia nitida*) / White Mangrove (*Laguncularia racemosa*), and Red Mangrove (*Rhizophora mangle*) dominated mangrove forest communities.

Table 1: Qualitative Variable & Associated Numerical Values Used for Mitigation Plan Comparison

Variable	Description	Qualitative Habitat Suitability	Numerical Value
(V1) Hydrology$_a$ Waves & Tidal Inundation	Sites that experience a higher frequency of tidal or wave inundation, such as between 60 and 20 times a month.	High	1.0
	Sites that experience a lower frequency of tidal or wave inundation, such as between 20 and 2 times a month.	Moderate	0.6
	Continual inundation (mudflat); No inundation, outside tidal influence zone, or upland.	Low	0.2
(V1) Hydrology$_b$ Freshwater Input	Direct sources of freshwater input apparent, such as river, stream or creek channels; springs; other.	High	1.0
	Indirect sources of freshwater input apparent, such as sites located in large river floodplains or deltas; sites with apparent direct sources that have been cut-off, but repairable.	Moderate	0.6
	Sites that do not receive freshwater inputs or surrounding inputs not available to connect.	Low	0.2
(V2) Geomorphology$_a$ Substrate Depth	Black/White: Those sites that exhibit high tide depths about 12". Red: Those sites that exhibit high tide depths about 27"	High	1.0
	Black/White: Those sites that exhibit high tide depths near extremities, meaning between 0-6" and 15-18". Red: Those sites that exhibit high tide depths between 12-18".	Moderate	0.6
	Black/White: Those sites that exhibit high tide depths less than 0" or greater than 18". Red: Those sites that exhibit high tide depths less than 12" and greater than 8-feet.	Low	0.2
(V2) Geomorphology$_b$ Substrate Slope	Slopes between 0 - 20°	High	1.0
	Slope between 20 - 45°	Moderate	0.6
	Slopes greater than 45°	Low	0.2
(V3) Hydraulics Establishment Hydrodynamics	Sites located in a low energy environment that is always/usually in dynamic-equilibrium.	High	1.0
	Sites that experience moderate geomorphic changing events, particularly during propagule season.	Moderate	0.6
	Sites that experience frequent geomorphic changing events, particularly during propagule season.	Low	0.2

(V4) Connectivity Source Populations	Directly connected to mangrove source population for Red, Black and White species.	High	1.0
	Currently not connected to mangrove source population for Red, Black and White species, but with opportunity for creating a connection.	Moderate	0.6
	Sites that are less than 6 days float time for propagule dispersion and only have a marine connection.	Low	0.2
(V5) Habitat Structure Habitat Diversity	100 - 80% coverage with mangrove trees, with a smaller percentage of intertwined mosaic native plant community and open water.	High	1.0
	Between 80% and 10% mangrove tree coverage, with a greater percentage of intertwined mosaic native plant community and open water, or other plant communities.	Moderate	0.6
	Less than 10% coverage of mangrove trees; agricultural land; barren land.	Low	0.2

The Habitat Suitability Index (HSI) for mangrove habitat is assumed to be an equivalent and additive function of all the variables listed above. The equation to calculate the HSI value is the following:

- $HSI = (V1_a + V1_b + V2_a + V2_b + V3 + V4 + V5) / 7$

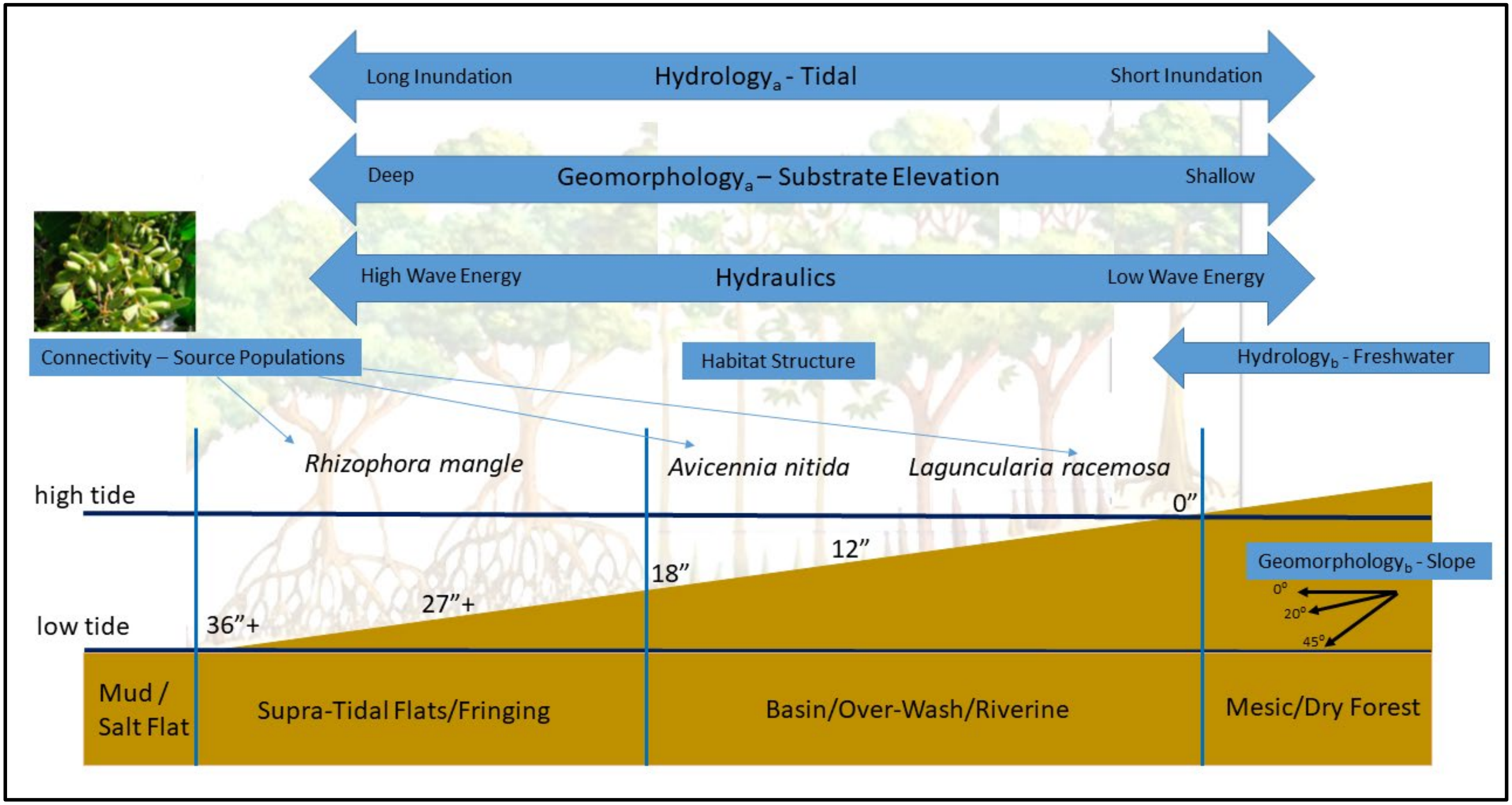

Figure 3: Conceptual Model for Mangrove Coastal Zone at Guayanilla Bay, Puerto Rico

4.7.2 Determine Significant Net Losses

The existing condition habitat suitability for the mangrove swamp wetland that would be filled/impacted by the Recommended Plan are assessed in Table 2:

Table 2: Mangrove HSI Assessment & Values for El Faro Levee Footprint

Variable	Qualitative Value	Numerical Value
Hydrology (V1a)	Moderate	0.60
Hydrology (V1b)	Moderate	0.60
Geomorphology (V2a)	High	1.00
Geomorphology (V2b)	High	1.00
Hydraulics (V3)	High	1.00
Connectivity (V4)	High	1.00
Habitat Structure (V5)	Moderate	0.60
	HSI Value	0.83

Existing Habitat Units (HUs) are calculated by:

- *HSI X Mangrove Wetland Acres = HUs*

Or

- *.83 (HSI) x 5.8 (acres) = 4.8 Habitat Units (HU)*

The existing 5.8-acres of mangrove swamp, or 4.8 habitat units, at a ratio or 1 to 1, would be the basis for loss. The basis for plan formulation of mitigation alternative plans would be Net Average Annual HUs presented in Table 6.

4.7.3 Define Mitigation Planning Objectives

Mangrove Restoration Considerations

Hydrogeomorphic & Biophysical Considerations: Mangroves are lost or degraded in various ways. These may include conversion for other land uses, changes in freshwater supply, loss of sediment, timber harvesting and/or other causes. Based on current literature and reviews of implemented mangrove restoration projects throughout the world, regeneration of a healthy mangrove forest can only happen if the enabling hydrogeomorphic conditions (captured in HSI) for mangrove growth are put back in place; whereas planting only without these land and water considerations typically fail. Research and literature show the effective methods in former aquaculture/agricultural lands are ground-levelling and excavation to resurge hydrology and hydraulics. Examples of this include strategically breaching of pond berms, excavating flats, and restoring old creek systems. Another method that could be applied to the beach/delta zones would be to place permeable structures to dampen wave effects while allowing water through, while trapping necessary sediment. Most instances where hydrogeomorphic restoration occurs, it is done close to existing mangrove stands so natural dispersion and recruitment of mangrove seeds occurs naturally. Some instances are supplemented with plantings if confidence lies with the existing or restored hydrogeomorphology. Finally, mangrove systems are highly dynamic and change all the time resulting from natural processes, therefore it is prudent to place a mangrove restoration within or adjacent to a greater mangrove system while including a diverse list of native conspecific species to fill in the gaps where mangrove trees cannot grow.

Socio-economic Conditions: It is apparent in the Guayanilla mangrove coastal zone that mangrove trees have been physically removed or wet areas filled in by people; this could easily continue to happen. The socio-economic root causes of this could be addressed to prevent mangrove destruction and where possible, economic activities could be developed that sustainably benefit from the restored mangrove values. Land ownership and use rights should be established coupled with local support for recovery and management. Successful projects invest communities, engage local government and ensure that local actions are strengthened by policies and planning. It will be instrumental for the non-Federal sponsor, the PRDNER, and the USFWS-CESFO, to ensure the mitigated and adjacent healthy mangrove swamp are protected and maintained. It would be of high social and ecological benefit for the entire 240-acres of mangrove swamp to be restored and preserved as a whole.

Mitigation Plan Objectives

The existing condition of 5.8 of the 8.8 acres of the El Faro levee footprint is mangrove swamp, dominated by Black, but inclusive of White and Red species. Once constructed, the construction activities and features would have removed 5.8-acres of a 240-acre coastal zone wetland. These impacts are specific to changing the hydrogeomorphology, native plant community and subsequent animal communities of the affected 5.8-acres. This will result in a loss of structural habitat diversity and species richness, as well as commodity and coastal storm services. The following goal and objectives are in response to this condition:

Goal – To replace in-kind 5.8-acres of mangrove swamp.

Objective 1 – Reestablish Hydrogeomorphology for Mangrove Swamp Community

The effects desired by meeting this objective are to recover hydrogeomorphic functions and structure required to establish and sustain Mangrove swamp. The targeted location of these affects would be in the 240-acre coastal zone of the Guayanilla Bay (Figure 2). These affects would be sustained over the life of the project by functioning with natural processes of flood and hurricane; this includes natural shifts in habitat types, and that a resulting habitat change caused by nature is just as important to the system as the restored mangrove plots. Success is measured via the mangrove HSI presented in Section 4.7.1.

Objective 2 – Reestablish Mangrove Swamp Plant Community

The effects desired by meeting this objective are to recover native plant diversity and habitat structure typically provided by a Mangrove swamp community. The targeted location of these affects would be in the 240-acre coastal zone of the Guayanilla Bay (Figure 2). These affects would be sustained over the life of the project by functioning with natural processes of flood and hurricane; this includes natural shifts in habitat types, and that a resulting habitat change caused by nature is just as important to the system as the restored mangrove plots. Success is measured via the mangrove HSI presented in Section 4.7.1.

4.7.4 Potential Mitigation Measures, Alternatives, Cost & Benefits

4.7.4.1 Mitigation Measures

Clearing & grubbing – This measure is required to prepare the site for restoration by removing vegetation and debris from the affected area. This measure would also dispose, compost or recycle all vegetation and foreign debris appropriately according to material characters. Prior to clearing, trees and large shrubs would be flagged and removed separately to be stockpiled on site for use in the hydrogeomorphic portion of the restoration. Once the area is cleared, it can be demarcated (staked/flagged) for additional restoration measures.

Excavation, grading & disposal – This measure would establish the hydrogeomorphic character of the restoration required to support mangrove community. The effective restoration area would be excavated to specified elevations based on surveys and inventory of both ground water and tidal fluctuations during the D&I phase. Average depth of excavation would be about 12-inches, and in certain instances a maximum of about 3-feet. All materials excavated would be reused or properly disposed of in the same upland location as materials generated from the diversion channel excavation. Grading around the fringes to achieve required geomorphology, slopes and elevations for planting would also be part of this measure.

Temporary sediment transport structures – This measure would mimic the effects that mangrove roots have on the transport of sediment, substrates and organic matter. These root systems have been found to establish a dynamic equilibrium of sediment input and output; therefore allowing the hydrogeomorphology to remain relatively constant and seemingly unchanged to the naked eye. Mimicking this processes during the restoration is required for recruitment and establishment of basin and creek type mangrove; Black/White Mangrove.

Temporary sediment and wave beach structures – This measure would intentionally disrupt the dynamic equilibrium of the existing beach at Guayanilla Bay. Strategically driven wood piles and/or placement of large stones to create a response at the bay/beach interface would cause the beach to expand seaward in spit or tombolo formations. These new flat inundated areas created would induce required hydrogeomorphology for fringe type mangrove; Red Mangrove.

Mangrove community plantings (moderate) – Planting mangrove species is currently not anticipated based on the availability of natural connected propagule source populations. This measure would primarily seed and/or plant live plugs of conspecific native salt grasses. There will be areas within the restoration that are transitional in hydrology and will not support mangroves; these areas would be planted with native conspecifics. Plantings would be of low to moderate density based on the long growing season in this sub-tropic zone and the ability for these plants to spread rapidly. There are no readily available native plants for purchase or nurseries to grow native species within the Commonwealth. Seed collection and/or contract-growing methods for species other than the three (3) mangrove species would be needed for the contract. It is anticipated the PRDNER and/or NGOs would provide these services; however this can also be done by contractors.

Invasive species management (clearing & herbicide) –This measure would be to ensure invasive species do not colonize the restoration during construction duration. Vegetation monitoring and subsequent hand removal or spot herbicide treatment of invasive plant species would be conducted to ensure invasive species criteria set forth in the specifications would be met.

Adaptive management – A 3 to 5 year contract would be utilized to ensure recruitment and establishment of the mangrove community is successful. All hydrogeomorphic work would be accomplished within the first several months of the contract. Options would be placed in the contract for future adaptive management measures that could be exercised at any point of the contract duration. These may include but are not limited to changing or adjusting features to achieve the required hydrology and sediment transport; additional plantings of mangrove and other conspecific species. All adaptive management decisions and exercising of contract options would be driven by monitoring.

4.7.4.2 Mitigation Alternative Plans (MAPs)

The preceding measures were combined into Mitigation Alternative Plan (MAPs) (Table 3) and applied to a different location (Figure 4) within the 240-acre coastal mangrove zone.

Table 3: Alternative Plans & Measure Components

Measures	**MAP 1**	**MAP 2**	**MAP 3**	**MAP 4**
Clearing & grubbing	X	X	X	
Excavation, grading & disposal	X	X	X	
Temporary sediment transport structures	X	X	X	
Temporary sediment and wave beach structures				X
Mangrove community plantings (moderate)	X	X	X	X
Invasive species management (clearing & herbicide)	X	X	X	X
Adaptive management	X	X	X	X

<u>MAP 1 – Interior Mangrove Old Basin Modification</u> – This alternative would restore about 6.0-acres of mangrove swamp within the greater mangrove coastal zone (Figure 5) by manipulating the hydrogeomorphic setting. Based on aerial observations and coordination with the local USFWS personnel, this formerly mangrove area was ditched and filled in for agricultural uses. This type of alternative would replicate how mangrove would look like within a basin, exemplifying a patchwork of open water, mangrove and associated wet community types. Measures utilized to reestablish wetland within this zone include the following: clearing and grubbing, excavation and grading to specified elevations, installation of sediment transport features, no planting of mangrove species (Black and White) and moderate planting of conspecifics, invasive species management, and temporary erosion control features. Temporary sediment transportation features would include natural materials such as logs/woody debris, coconut/jute fabrics, brush fascines, etc. placed strategically to a) trap the appropriate amount of sediment for mangrove recruitment and b) disallow complete filling in with sediment.

<u>MAP 2 – Interior Mangrove Old Basin & Creek Modification</u> – This alternative would restore about 6.5-acres of interior basin and freshwater creek mangrove swamp within the greater mangrove coastal zone (Figure 5) by manipulating the hydrogeomorphic setting. Based on aerial observations and coordination with the local USFWS personnel, this area was formerly mangrove and was ditched and filled in for agricultural uses. This type of alternative would replicates how mangrove swamp would look like within a basin that has a freshwater creek flowing into it, exemplifying a patchwork of open water, mangrove and associated wetland types coupled with dendritic side channels a creek would provide. Measures utilized to

reestablish the wetland within this zone include the following: clearing and grubbing, excavation and grading to specified elevations, installation of sediment transport features, no planting of mangrove species (Black and White) and moderate planting of other conspecifics, invasive species management, and temporary erosion control features. Temporary sediment transportation features include natural materials such as logs/woody debris, coconut/jute fabrics, brush fascines, etc. placed strategically to a) trap the appropriate amount of sediment for mangrove recruitment and b) disallow complete filling in with sediment.

<u>MAP 3 – Estuarine Mangrove Old Creek Modification</u> – This alternative would restore about 9.5-acres of tidal creek type mangrove within the greater mangrove coastal zone (Figure 5) by manipulating the hydrogeomorphic setting. Based on aerial observations and coordination with the local USFWS personnel, this area was formerly mangrove swamp and was ditched and filled in for agricultural uses. This type of alternative would replicate how mangrove would look like along an estuarine creek, which would maintain a small open channel and provide various dendritic side channels for increased habitat diversity. Measures utilized to reestablish the wetland within this zone include the following: clearing and grubbing, excavation and grading to specified elevations, installation of sediment transport features, moderate planting of mangrove species (Black and White) and other conspecifics, invasive species management, and temporary erosion control features. Temporary sediment transportation features include natural materials such as logs/woody debris, coconut/jute fabrics, brush fascines, etc. placed strategically to a) trap the appropriate amount of sediment for mangrove recruitment and b) disallow complete filling in with sediment.

<u>MAP 4 –Fringe Mangrove Inducement</u> – This alternative would create 9.3-acres of Red Mangrove fringe along the beach of the greater coastal mangrove zone (Figure 5) by manipulating the hydrogeomorphic setting. The beach is seemingly in dynamic equilibrium based on aerial observations over the past ~20 years and shows signs of natural hydrologic connectivity to the interior swamp via dunal swales and sloughs. To create a large fringing mangrove along the beach, the dynamic equilibrium of the beach would be manipulated by placing wave attenuating and sediment (sand) trapping structures at strategic points along the beach and within littoral drift zone. Measures utilized to reestablish wetland within this zone include the following: placement of wood pile structures to dampen wave attack and trap sediment while allowing water to flow freely; invasive species management and adaptive management options to adjust wood pile structures to increase effectiveness during construction. The wood pile structures would be constructed to be temporary/sacrificial, as mangroves would eventually take over the functionality of tempering surf zone energies. Minimal Red Mangrove planting would occur due to the dynamic nature of this type (fringe) of mangrove; moderated planting of conspecifics including dune grasses would be to help stabilize non-mangrove patches.

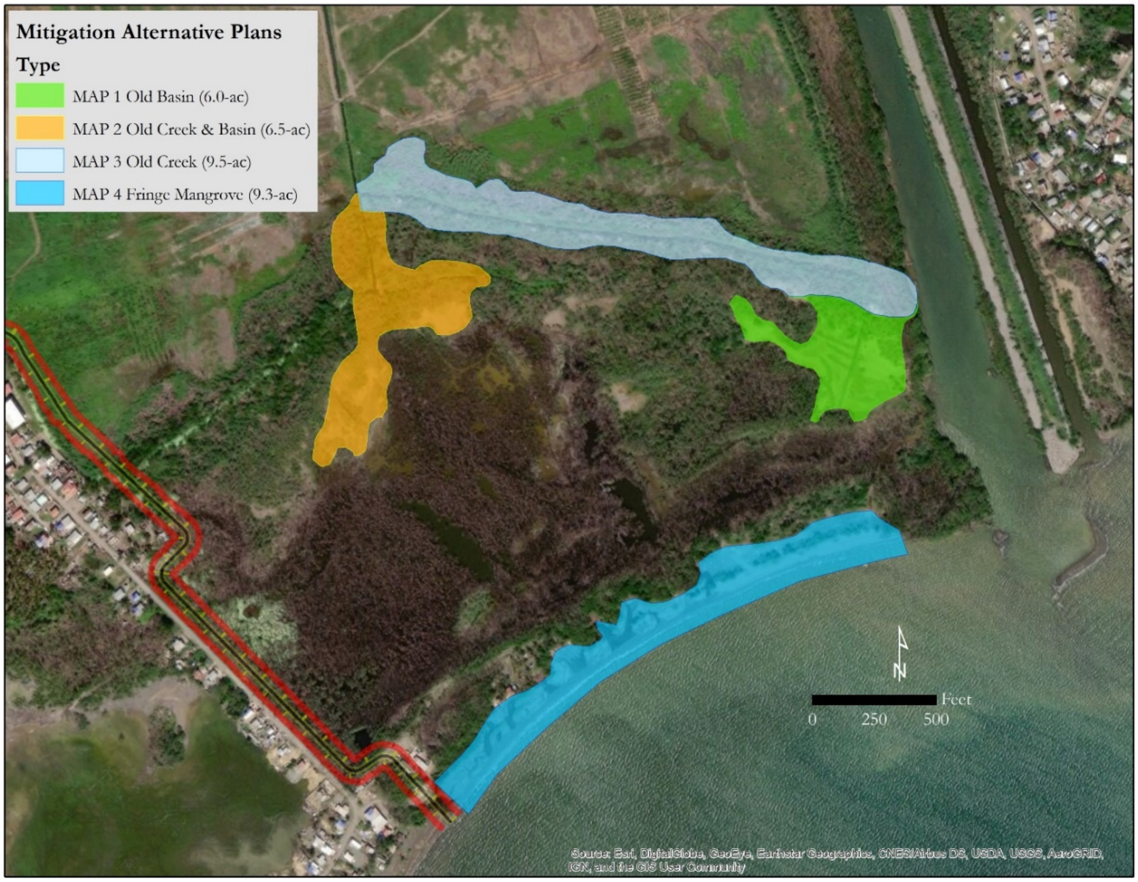

Figure 4: Mitigation Alternative Plan Location & Aerial Extent

4.7.4.3 Benefits of Alternative Plans

The HSI presented in Section 4.7.1 was utilized to provide numerical values to the changes in mangrove habitat quality for the purposes of evaluating mitigation alternative plans against one another. Habitat suitability values for the Future Without (FWOP) and Future With Project (FWP) conditions are presented in Table 4 and Table 5, respectively.

Table 4: Future Without Project Average Annual Mangrove HSI Values

Variable	El Faro Site	MAP 1	MAP 2	MAP 3	MAP 4
Hydrology (V1a)	0.6	0.0	0.0	0.0	1.0
Hydrology (V1b)	0.6	0.6	0.6	0.6	0.6
Geomorphology (V2a)	1.0	0.0	0.0	0.0	0.2
Geomorphology (V2b)	1.0	0.6	0.6	0.6	0.6
Hydraulics (V3)	1.0	0.2	0.4	0.4	0.2
Connectivity (V4)	1.0	0.6	0.6	1.0	1.0
Habitat Structure (V5)	0.6	0.2	0.2	0.2	0.6
HSI Values	0.83	0.31	0.34	0.40	0.60

Table 5: Future With Project Average Annual Mangrove HSI Values

Variable	El Faro Site	MAP 1	MAP 2	MAP 3	MAP 4
Hydrology (V1a)	0.0	1.0	1.0	1.0	1.0
Hydrology (V1b)	0.0	1.0	1.0	1.0	1.0
Geomorphology (V2a)	0.0	1.0	1.0	1.0	0.6
Geomorphology (V2b)	0.0	1.0	1.0	1.0	0.6
Hydraulics (V3)	0.0	1.0	1.0	0.6	0.6
Connectivity (V4)	0.0	1.0	1.0	1.0	0.6
Habitat Structure (V5)	0.2	0.6	0.6	0.6	0.6
HSI Values	0.03	0.94	0.94	0.89	0.71

The total HSI Values and acres show that any of the plans would provide sufficient acres and habitat units to mitigate for the project impacts. To determine the most cost efficient of these plans, Net Average Annual Habitat Units (NAAHUs) (Table 6) were utilized in the CE/ICA analysis to evaluate the alternatives amongst themselves.

Table 6: Net Average Annual Habitat Units (NAAHUs) per Mitigation Alternative Plan

MAP	Alternative	FWOP HSI	FWP HSI	NAA HSI	Acres	NAAHUs
0	No Action on Mitigation	0.83	0.03	-0.80	5.8	-4.6
1	Interior Mangrove Old Basin Modification	0.31	0.94	0.63	6.0	3.8
2	Interior Mangrove Old Basin & Creek Modification	0.34	0.94	0.60	6.5	3.9
3	Estuarine Mangrove Old Creek Modification	0.40	0.89	0.49	9.5	4.6
4	Fringe Mangrove Inducement	0.60	0.71	0.11	9.3	1.1

4.7.4.4 Costs of Alternative Plans

Plan formulation level cost estimates were prepared for each measure (Table 7). These cost estimates do not represent Total Project Cost (TPC) estimates, but rather individual restoration measures that are the building blocks of a complete plan. These plan formulation level cost estimates were developed by Cost Engineering using data from current similar construction contracts, cost data and publications, and informal discussions with vendors. Costs include construction, staging, access, haul road construction, preliminary real estate estimates, adaptive management, monitoring and operations and maintenance. A preliminary real estate estimate for plan formulation purposes was provided by per acre Real Estate. The measures were used to provide a monetary basis for the assessment of project alternatives.

Annualizing costs is a method whereby the project costs are discounted to a base year then amortized over the period of analysis. The base year for this project was determined to be the year in which the first phase of the project is to be completed (calendar year 2026). Costs that occur prior to this year need to be compounded to the base year, while those occurring after the base year need to be discounted to the base year. The period of analysis for this project is 50 years. The present value method was used to discount future costs to the base year. Costs are compounded or converted to present value for the base year then amortized over the 50-year period of analysis to determine the average annual cost. The discount rate was determined by the appropriate Economic Guidance Memorandum Economic Guidance Memorandum 15-01, Federal Interest Rates for Corps of Engineers Projects, which is 2.75%. The construction period is 3-

years. Calculation of the measures Average Annual Cost (AA Cost) was completed via the Certified IWR Planning Suite Annualization Calculator (Table 8).

Table 7: Mitigation Measure Costs

Measures	Cost/Unit	Unit	MAP 1	MAP 2	MAP 3	MAP 4
Clearing & grubbing	$ 22,000	ac	$132,000	$143,000	$209,000	$ 66,000
Excavation, grading & disposal	$ 38,000	ac	$228,000	$247,000	$361,000	na
Temporary sediment transport structures	$ 4,000	ea	$ 28,000	$ 28,000	$ 48,000	na
Temporary sediment and wave beach structures	$ 46,000	ea	na	na	na	$ 552,000
Mangrove community plantings (moderate)	$ 20,000	ac	$ 30,000	$ 40,000	$ 50,000	$ 160,000
Invasive species management (clearing & herbicide)	$ 6,000	ac	$ 36,000	$ 39,000	$ 57,000	$ 55,800
Adaptive management	$ 17,000	ac	$ 51,000	$ 51,000	$ 85,000	$ 255,000
Construction Sub-Total			**$505,000**	**$548,000**	**$810,000**	**$1,088,800**

Table 8: Mitigation Alternative Plan Costs

#	MAP	Acres	Real Estate	Eng. & Design	Construction	Total Cost	AA Cost
0	No Action	0	$ -	$ -	$ -	$ -	$ -
1	Interior Mangrove Old Basin	6.0	$ 34,500	$ 125,000	$ 505,000	$ 664,500	$24,805
2	Interior Mangrove Old Basin & Creek	6.5	$ 37,300	$ 125,000	$ 548,000	$ 710,300	$26,518
3	Estuarine Mangrove Old Creek	9.5	$ 54,600	$ 150,000	$ 810,000	$1,014,600	$37,889
4	Fringe Mangrove Inducement	9.3	$ 53,500	$ 200,000	$ 1,088,800	$1,342,300	$50,133

4.7.5 Cost Effectiveness and Incremental Costs

Cost effectiveness and incremental cost analysis (CE/ICA) are two distinct analyses that must be conducted to evaluate the effects of alternative plans according to USACE policy. First, it must be shown through cost effectiveness analysis that a restoration plan's output cannot be produced more cost effectively by another alternative. *Cost effective* means that, for a given level of non-monetary output, no other plan costs less and no other plan yields more output at a lower cost.

Incremental cost analysis means that the subset of cost effective plans are examined sequentially to ascertain which plans are most efficient in the production of environmental benefits. Those most efficient plans are called "best buys." As a group of measures, they provide the greatest increase in output for the least increases in cost. They have the lowest incremental costs per unit of output. In most analyses, there will be a series of best buy plans, in which the relationship between the quantity of outputs and the unit cost is evident. As the scale of best buy plans increases (in terms of output produced), average costs per unit of output and incremental costs per unit of output will increase as well. The incremental analysis by itself will not point to the selection of any single plan. The results of the incremental analysis must be synthesized with other decision-making criteria.

4.7.6 Cost Effectiveness

The cost effectiveness analysis was used to ensure that certain options would be screened out if they produced the same amount or less output at a greater cost than other options with a lesser cost. Four (4) mitigation alternative plans were analyzed for cost effectiveness. Of these, two (2) cost effective combinations were identified (Table 9 & Figure 5); also the same plans were identified as "Best Buys"

(MAP 1 and MAP 3). The No Action plan is always deemed cost effective. Two (2) mitigation alternative plans were screened out as non-cost effective (MAP 2 and MAP 4).

Table 9: Cost Effectiveness Analysis Results

MAP	AA Cost	NAAHUs	Cost Effectiveness
MAP 4	$ 50,133	1.1	Non-Cost Effective
MAP 2	$ 26,518	3.9	Cost Effective
No Action Plan	$ -	0	Best Buy
MAP 1	$ 24,805	3.8	Best Buy
MAP 3	$ 37,889	4.6	Best Buy

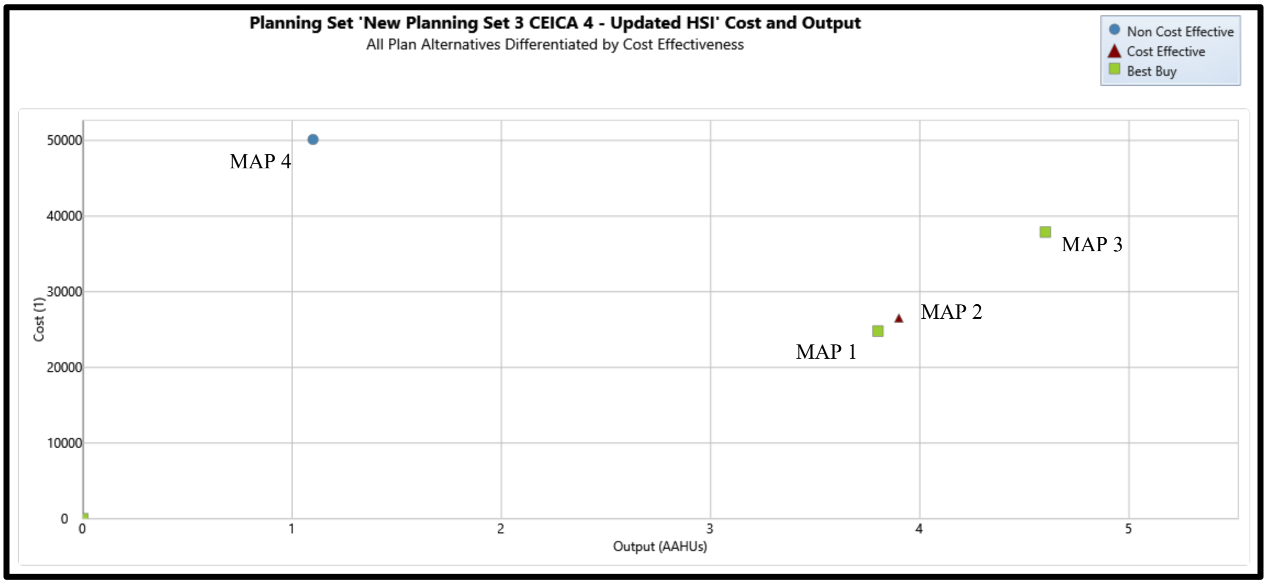

Figure 5: Mitigation Plans Differentiated by Cost Effectiveness

4.7.7 Incremental Cost Analysis

An incremental cost analysis was performed on the two (2) Best Buy Plans identified from the cost effectiveness analysis. The objective of the incremental cost analysis is to assist in determining whether the additional output provided by each successive plan is worth the additional cost. This incremental cost analysis (Table 10 & Figure 6) compares the alternative combinations for ecological restoration that were considered for selecting the recommended mitigation alternative plan.

Table 10: Incremental Cost Analysis of Two Best Buy Plans

#	MAP	NAAHU	AA Cost	AA Cost / HU	Inc. Cost	Inc. HU	Inc. Cost / HU
0	No Action	0	$ -				
1	Interior Mangrove Old Basin	3.8	$ 24,805	$ 6,528	$ 24,805	3.8	$ 6,528
3	Estuarine Mangrove Old Creek	4.6	$ 37,889	$ 8,237	$ 13,084	0.8	$ 16,355

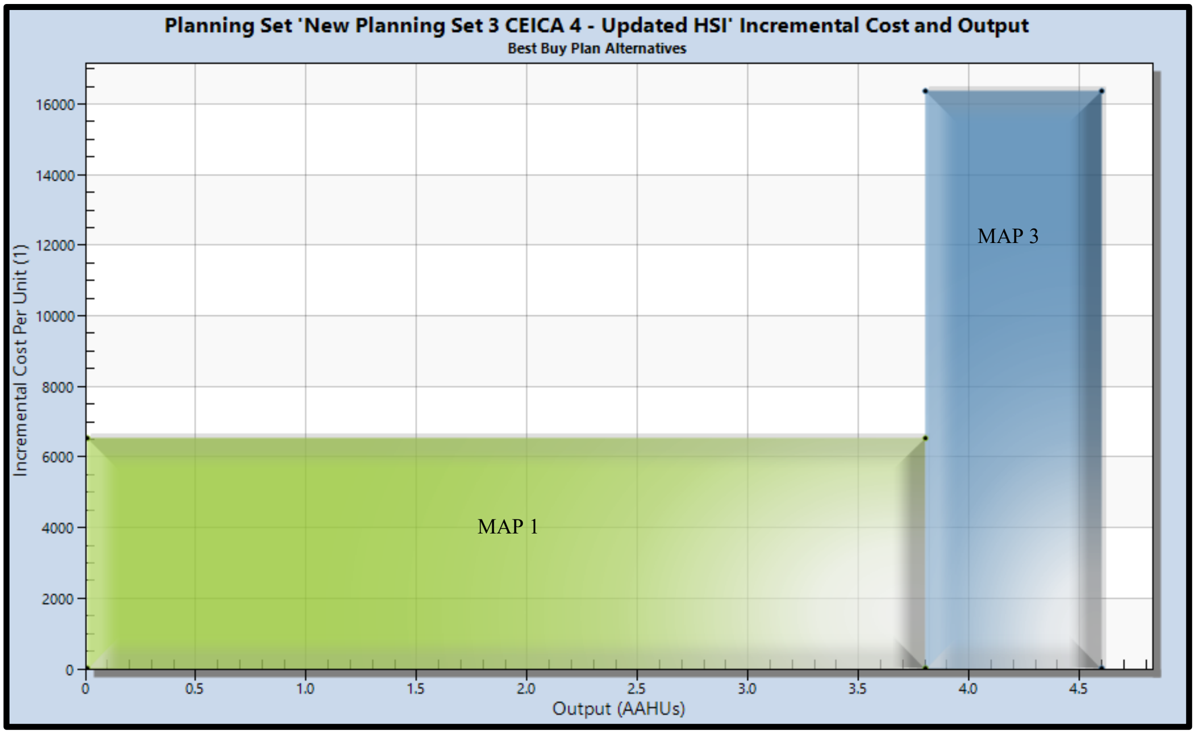

Figure 6: Incremental Cost Analysis for the Two Best Buy Plans

5. Recommended Mitigation, Monitoring & Adaptive Management Plan

MAP 1 (Figure 7) is currently selected as the recommended mitigation plan simply based on its cost effectiveness and that the USFWS recommended this location for mitigation.

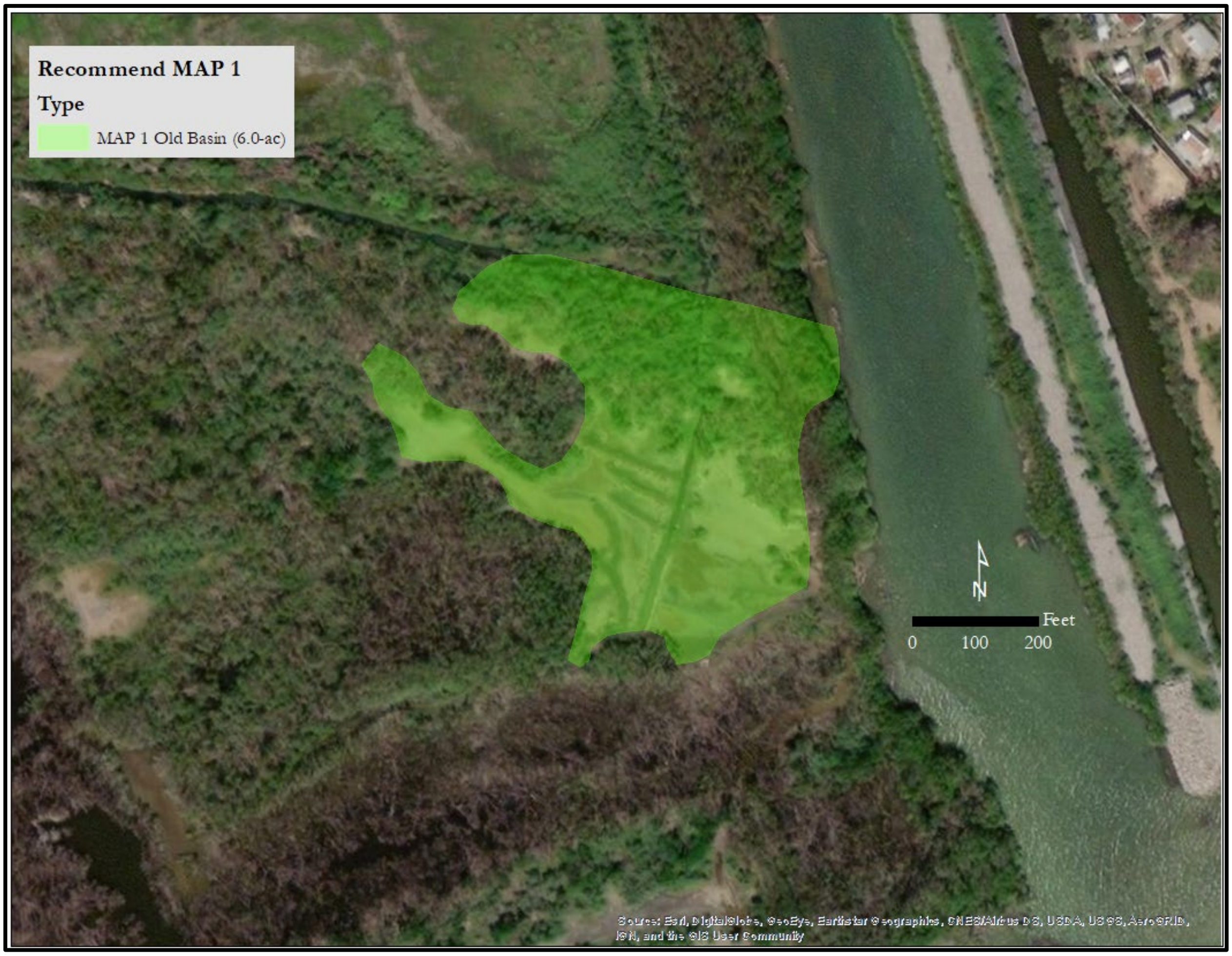

Figure 7: Recommended Mitigation Plan Alternative 1 Old Basin

5.1 Design Analyses

Various assessments would be completed to gain information for the mitigation design. The types of assessments to be carried out are detailed in Lewis III et al 2014. Hydrology of both the freshwater inputs and tidal frequency and inundation depths would be characterized. Observation and simple measurements of erosion and sedimentation would also be assessed. Existing substrate elevations, slopes and types would be determined. Detailed vegetation inventory and map would be created to characterize the existing buffering mangrove community. These assessments would be developed and completed with assistance and guidance from the USFWS-CESFO. These assessments would be presented and document in a General Design Memorandum (GDM).

5.2 Plans & Specifications

A contract set of plans and specification would be developed separate from the FRM contract(s). This set would be developed with assistance and guidance from the USFWS-CESFO. Technical specifications would generally include site preparation, earthwork and grading, native plant propagation, native plant community establishment, hydrogeomorphic features, adaptive management options, and success criteria.

5.3 Monitoring & Adaptive Management

The monitoring and adaptive management plan focuses on success of native plant community establishment, which is the ultimate goal for wetland mitigation/restoration. Should the native plant community targeted for restoration show signs of failure, degradation or other, the following monitoring components would reveal problems and adequately address them during the construction phase with adaptive management options as described in the measures section.

Component 1 – Plant Community Establishment

This component would specifically monitor coverage, species richness and relative abundance of native plant species within the mangrove swamp community mitigation work limits. Plant communities would be monitored for species richness, % coverage of native, % coverage of invasive species, and tree and shrub health. It would take incidental records of all other organisms observed i.e. reptiles, amphibians, mammals. This monitoring component would drive the need to engage the structural monitoring component and would take place twice a year, every year for 5-years.

Component 2 – Hydrogeomorphic Functionality

This component covers the structural sustainability of the implemented hydrogeomorphic features. It is a qualitative assessment of whether each feature is retaining its physical character and project purpose. The most important information derived from this component would be to determine if adaptive management measures are needed or not. Assessments would be conducted by walking through the project and visually assessing each of the components or project features. This is intended to be fairly quick and to notice problems before they require complete overhauls that may adversely impact other project features.

Component 3 – Planning Goal & Objectives

This component is to ensure mitigation planning criteria are being met for required acres and quality.

- *Target 1 (Goal)* – To replace in-kind 5.8-acres of mangrove swamp.
- *Target 2 (Objective 1) – Reestablish Hydrogeomorphology for Mangrove Swamp Community*
- *Target 3 (Objective 2) – Reestablish Mangrove Swamp Plant Community*

These objectives would be assessed the same way as the FWOP and FWP project benefits were modeled as described in the Main Report, Section 4.7.1 – Ecosystem Valuation Methodology. If the following specific targets are not achieved, the responsible site stewards would need to implement necessary measures to bring the quality of the habitat types up to the functional levels set by the construction period.

Monitoring Costs & Schedule

It was determined that 5-years of monitoring is sufficient for the proposed mangrove restoration due to the rapid growth and establishment of this community type within the Sub-Tropical growing season zone.

Table 11: Schedule of Monitoring Costs

Tasks	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Component 1	$ 5,000	$ 5,000	$ 5,000	$ 5,000	$ 5,000	$ 25,000
Component 2	$ 2,500	$ 2,500	$ 2,500	$ 2,500	$ 2,500	$ 12,500
Component 3	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 5,000
Reports	$ 1,500	$ 1,500	$ 1,500	$ 1,500	$ 10,000	$ 16,000
Total	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 18,500	$ 58,500

Monitoring Responsibilities

The PRDNER will be responsible for implementing all three Monitoring Components as described above. Coordination with USFWS and other agencies and organizations to discuss future monitoring responsibilities is planned.

Adaptive Management

Adaptive management measures are not the same as typical operation and maintenance activities described in the following section. These measures are technically response actions to changes that adversely affect how the system was predicted to respond. In so being adaptive, there are no absolute measures that can be defined prior to issue arising. The primary concerns for this project are restoration and establishment of native plant communities. Types of adaptive managements below are brief and will be further detailed once a complete set of plans and specifications are drafted. This is necessary since the adaptive management measures will need to be based upon contracting bid items, final feature designs and predicted adverse responses.

A 3 to 5 year contract would be utilized to ensure recruitment and establishment of the mangrove community is successful. All hydrogeomorphic work would be accomplished within the first several months of the contract. Options would be placed in the contract for adaptive management measures that could be exercised at any point of the contract duration. These may include but are not limited to changing or adjusting features to achieve the required hydrology and sediment transport; additional plantings of mangrove and other conspecific species. All adaptive management decisions and exercising of contract options would be driven by monitoring.

Warranties

The contract set of plans and specifications would include warranty clauses for native plants that would make the contractor responsible for growing/collecting the correct species and genotypes and replacing native plants lost due to predation or other factors that are deemed controllable by the contractor.

5.4 Timing of Implementation

For all water resources development projects on which construction has not commenced as of November 17, 1986, authorized ecological resource mitigation features, including the acquisition of lands or interest in lands to mitigate losses to ecological resources. Mitigation measures will generally be scheduled for accomplishment concurrently with other project features in the most efficient way. Circumstances warranting the accomplishment of mitigation as the first or last elements of project construction will require prior approval by HQUSACE.

5.5 Allocation and Apportionment of Mitigation Costs

Ecological resources mitigation costs incurred after November17, 1986 are allocated among the authorized purposes which caused the requirement for mitigation, and are cost shared to the same extent as project costs allocated to these purposes.

Allocation: The impact analysis identifies the project purposes which cause losses to be mitigated. If practicable, the analysis identifies the extent of losses separable or specific to each purpose. Mitigation costs not associated with specific purposes will be included with other joint project costs.

Apportionment: Once the proportionate amounts of losses and corresponding amounts of mitigation and costs are assigned to the appropriate purposes, joint costs of mitigation should be allocated among the causative purposes on the same basis as other joint costs.

5.6 Mitigation Cost Sharing

(a) LERRD. Non-Federal interests will to provide lands, easements, rights-of-way, relocations and disposal areas (LERRD) where this is a requirement of the purpose that necessitates the mitigation except where otherwise agreed for the Corps to accomplish with non-Federal funds. As Title I of Public Law 99-662 contains a generic requirement that non-Federal interests provide LERRD, all future mitigation features will require non-Federal interests to provide LERRD, if required, unless the project authorization after 17 November 1986 provides differently for mitigation.

(b) Construction. Construction costs for mitigation will be treated the same as other project construction costs for cost sharing purposes.

(c) OMRR&R. Non-Federal interests will be responsible for all costs of operation, maintenance, repair, rehabilitation, and replacement of mitigation features except for:

(d) Exception. No cost sharing will be imposed without the consent of the non-Federal interests where contracts have previously been signed for repayment of costs or until such contracts are complied with or renegotiated.

5.7 Preconstruction Environmental Protection and Mitigation Fund

This fund was established by Section 908 of WRDA '86. Implementation of the fund has not been sought since timing of implementation of mitigation features will assure that mitigation features will be available to mitigate for unavoidable adverse project impacts as they occur.

5.8 OMRR&R of Mitigation Features

Federal Responsibility: Execution and performance of Operation, Maintenance, Repair, Replacement, and Rehabilitation (OMRR&R) of ecological mitigation features of a project is a Corps responsibility whenever the project authorization, or recommendation for authorization, provides for the Corps to operate, maintain, repair, rehabilitate or replace other project features. The manner in which the District Commander exercises this authority and responsibility will vary widely, depending on the location of the fish and wildlife mitigation features and the type of ecological management and administration required. Plans recommended for authorization in this category will identify the Corps OMRR&R responsibility. OMRR&R of ecological resource features included in an alternative plan to mitigate losses associated with an existing Federal program (e.g., National Migratory Bird Management Program) will be the responsibility of the Federal agency that administers that program.

Non-Federal Responsibility: OMRR&R of fish and wildlife mitigation features is a non-Federal responsibility whenever the project authorization or recommendation for authorization provides for non-Federal interests to operate and maintain other project features, and in some cases where there is a Federal OMRR&R responsibility but no Federal (Corps) presence, e.g., no Corps project management office located on site. Assignment of such responsibility will be a part of the items of local cooperation for the project, to be fulfilled by either a local sponsor or another agency which will provide the necessary assurances to the Corps.

The O&M costs of the project are estimated to an average annual cost of about $500 over 50 years. A detailed O&M Manual containing all the duties will be provided to the non-Federal sponsor after construction is closed out. The O&M for Chicago District ecosystem projects are practical and minimal due to initial project design efforts and design targets for sustainability, where O&M costs are predicted to drop as the communities naturalize and come to equilibrium. Mostly if not all of the O&M activities are no different than the specific activities that take place during construction, but to a lesser degree. The O&M described here is not the same as the Adaptive Management measures described in the mitigation alternative plan section.

<u>Invasive Plant Species Control</u> – This maintenance activity is probably the most important to conduct. Preventing the establishment of invasive species and weedy vegetation prevents the need for large scale herbicide or physical eradication and replanting efforts. An annual maintenance plan would be drafted in conjunction with input from the entity responsible for O&M, taking into account the types of invasive and non-native species to be treated and the acreage of the treatment area. Problematic areas would include barren patches after large storm events. Precautions should be taken to ensure that any long term herbicide application is appropriately dispensed to remove non-native plants and invasive species while avoiding native plant communities; however, timely inspections and implementation of O&M measures should preclude the need.

Native Plant Community Maintenance – It will be required to maintain the species richness, abundance and structure of the restored mangrove swamp community. It will be important to continue to protect plant communities from external changes by man's daily activities, whether single incidents or chronic stressors. These can cause native plant communities to experience significant species richness declines even to the point of becoming barren. The best operational measure to quickly identify and rectify external stressors is vigilance. Routine inspections by site stewards are imperative to notice adverse change quickly. The long term monitoring and O&M plan provided after construction would help guide observation, monitoring and O&M activities.

5.9 Total Mitigation Costs

The mitigation cost would be $656,000, inclusive of real estate, design, construction, and adaptive management measures. Monitoring would be $58,000 and Average Annual O&M costs $500 over 50 years.

6. References

Banus, Mario D. & Seppo E. Kolehmainen. The Rooting and Early Growth of Red Mangrove Seedlings from Thermally Stressed Trees. Puerto Rico Nuclear Center, College Station.

Golley, Frank, Howard T. Odum and Ronald F. Wilson. 1962. The Structure and Metabolism of Puerto Rican Mangrove Forest in May. *Ecology* Col 43, No. 1 pp. 9-19.

Lewis III, Roy R & Ben Brown. 2014. Ecological Mangrove Rehabilitation: A Field Manual for Practitioners.

Lugo, Ariel E. & Samuel C. Snedaker. 1974. The Ecology of Mangroves. Annual Review of Systematics. Vol. 5 (1974), pp. 39-64.

Mangrove Restoration, To Plant or Not To Plant.

Puerto Rico Department of Natural and Environmental Resources. 1989. Environmental Impact Statement for Flood Control on the Rio Guayanilla. Vegetation Survey and Map.

University of Puerto Rico. 2001. Guide to identify common wetlands plants in the Caribbean Area: Puerto Rico and the U.S. Virgin Islands/ in cooperation with Commonwealth Department of Natural and Environmental Resources. 1st ed.

Vega-Rodriguez, Maria. 2008. Estimating Primary Productivity of Red Mangroves in Southwestern Puerto Rico from Remote Sensing and Field Measurements. University of Puerto Rico.

Worthington, Thomas & Mark Spalding. Mangrove Restoration Potential: A global map highlighting a critical opportunity. The Nature Conservancy.

DEPARTMENT OF THE ARMY
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CEMVD-PDP 28 February 2020

MEMORANDUM FOR Commander, Chicago District, U.S. Army Corps of Engineers (Attn: Ms. Sue Davis, CELRC-PMD-PB)

SUBJECT: Single Use Approval – Mangrove Mitigation Habitat Suitability Index (HSI) Model

1. References:
   a. Engineer Circular 1105-2-412: Assuring Quality of Planning Models, 31 Mar 2011.

   b. Planning Bulletin 2013-02, Assuring Quality of Planning Models (EC 1105-2-412), 31 Mar 2013.

   c. Memorandum to Directors of National Planning Centers of Expertise – Subject: Modification of the Model Certification Process and Delegation of Model Approval for Use, 04 Dec 2017.

   d. Memorandum to Director of the National Ecosystem Restoration Planning Center of Expertise - SUBJECT: Recommend Single Use Approval of the Mangrove Mitigation Habitat Suitability Index (HSI) Model, 24 Feb 2020.

2. An independent review managed by the National Ecosystem Restoration Planning Center of Expertise evaluated the subject model. The model was found to be technically sound, computationally correct, usable for Civil Works planning, and policy compliant using appropriate functional assessment procedures.

3. The Mangrove Mitigation HSI model is approved for single use in the Rio Guayanilla Flood Risk Management Study. The model meets the criteria contained in References 1.a. and 1.b. There are no unresolved issues.

Gary L. Young
Chief, MVD Planning and Policy and
Director, National Ecosystem Restoration
Planning Center of Expertise

CF
CEMVD-PDP (Lawton, Mallard, Mickal)
CEMVP-PD-F (Richards)
CELRD-PDS-P (Clay, Sadri, Jarboe, Linkowski)
CELRC-PMD-PB (Davis)
CELRC-PM-PL-E (Veraldi)
CELRC-PM (Zuercher)
CESAJ-PD (Summa)
CESAJ-PD-PW (Keefe)
CESAJ-PD-E (Dunn)
CEMVP-PD-F (Keenan)

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS, MISSISSIPPI VALLEY DIVISION
P.O. BOX 80
VICKSBURG, MISSISSIPPI 39181-0080

CEMVD-PDP 24 February 2020

MEMORANDUM FOR CEMVD-PDP (Young)

SUBJECT: Recommend Single Use Approval of the Mangrove Mitigation Habitat Suitability Index (HSI) Model

1. References:

   a. Engineer Circular 1105-2-412: Assuring Quality of Planning Models, 31 Mar 2011.

   b. US Army Corps of Engineers. Assuring Quality of Planning Models - Model Certification/Approval Process: Standard Operating Procedures, Feb 2012.

   c. Memorandum to Directors of National Planning Centers of Expertise – Subject: Modification of the Model Certification Process and Delegation of Model Approval for Use, 04 Dec 2017.

   d. Memorandum from the Director of Civil Works to MSC Commanders – Subject: Delegation of Model Certification, 11 May 2018.

   e. Model Documentation, Mangrove HSI Model, 18 Feb 2020 (Encl 1).

   f. Comment Response Record, Mangrove HSI Model, 18 Feb 2020 (Encl 2).

2. The National Ecosystem Restoration Planning Center of Expertise (ECO-PCX) evaluated the Mangrove Mitigation HSI Model following references 1.a. and 1.b. Based on the results, the ECO-PCX recommends single use approval of the model in the Rio Guayanilla Flood Risk Management Study. In accordance with reference 1.c., please review this recommendation and provide your concurrence or, if appropriate, additional directions to the team.

3. The Chicago District developed the model to represent key mangrove habitat variables required to establish and sustain mangrove forest community. The purpose of the model is to help both quantify conditions required for establishing and sustaining mangrove forest community and evaluate the effectiveness of potential mitigation actions to improve or restore this specific type of wetland.

   The mangrove index consists of HSI categories for the habitat variables hydrology, geomorphology, hydraulics, connectivity and habitat structure. These represent key variables in determining required hydrogeomorphic setting and connectivity for mangrove to be present. HSI categories are based on available literature and concepts of restoring hydrogeomorphic settings for plant communities. HSI categories determined by corresponding data to compute a total HSI score that ranges between 0.0 (not present or complete lack of habitat) to 1.0 (optimal habitat conditions). The index can be used to better understand mangrove potential and quality under existing conditions, future without project conditions and future with project conditions. Habitat quality generated from the model would be multiplied by an aerial measurement of acres to compute a “habitat unit” for comparison. Microsoft Excel, IWR Planning Suite and/or other methods could be used to calculate Average Annual Habitat Units.

4. The ECO-PCX conducted an intermediate review of the HSI variables and documentation in accordance with the requirements of EC 1105-2-412. Review of the model and documentation was performed during Agency Technical Review by Mr. Mike Greer (USACE Great Lakes and Rivers Division Regional Technical Specialist), personnel from the U.S. Fish and Wildlife Service (USFWS Caribbean Field Office), and the ECO-PCX. The reviewers were provided a review charge and guiding review questions via email. The review included evaluation of the methodology used to determine the ecological variables, quality index scoring methods, and the aggregation equation used to quantify final quality scores.

5. The review resulted in four medium significance comments regarding the technical quality and completeness of the model documentation. The following summarizes each comment and resolution.

   - Scoring methodology – guidance for scoring particular variables was vague and subjective. It was difficult for users to differentiate between the value categories. As a result, the model and documentation were updated to substantiate and add clarity to the value breakpoints and to expand the guidance on the scoring methodology.

   - Fidelity of the quality categories – the original model included multiple scoring categories in 0.2 increments. However, the scoring methodology was not sensitive enough to differentiate at that level of fidelity. The model was revised to reduce the number of categories to be commensurate with the expected level of detail necessary for adequate evaluation.

   - Connectivity variable – while the variable is important, the documentation didn’t adequately describe the evaluation procedure. The documentation was updated to include rationale for scoring this variable and input requirements.

   - Hydrology variable – this variable only addressed water inundation, and not waves or freshwater inputs. Because all the variables are critical to mangrove health and habitat quality the variables were addressed through a 2-part procedure. Tidal and wave inundation was split from freshwater inputs, and both included in the overall modeling methodology. Documentation was reorganized and clarified to provide the rationale for the purpose of the variables, input requirements, and the process for scoring the category.

6. The Mangrove Mitigation HSI Model has sufficient technical quality. The model was developed through appropriate use of conceptualization, quantification, evaluation, and application concepts. As a result, the model represents the current best, most practical approach to estimating quality of basin type mangrove communities in southwestern Puerto Rico. It was assembled with assistance and guidance from Chicago District planning and engineering, Jacksonville District, and USFWS; with facilitation from experts in model development at the ECO-PCX and USACE Buffalo District. The model was constructed based on the best available scientific literature and from field observations within the defined geographic extent. This model represents the most reasonable approach to quantifying habitat quality for the mangrove habitat in question.

7. The Mangrove Mitigation HSI Model has sufficient system quality. The model parameters, equations, and aggregation methodology are all well-documented and technically adequate. The model does not include a spreadsheet or application software, but the straightforward nature of the equations would allow for model building in the IWR Planning Suite II (certified for National Use), via simple spreadsheet, or by hand. The ECO-PCX does not have concerns related to use of these methods. District Quality Control and Agency Technical Review should ensure results presented in reports are accurate.

8. The Mangrove Mitigation HSI Model has sufficient usability. Model results are useful in project evaluation. A stand-alone user guide is not necessary. The model documentation includes guidance for scoring, variable interpretation, and input requirements. The model is transparent and calculations can be easily verified.

9. The Mangrove Mitigation HSI Model is consistent with USACE policies and accepted procedures for conducting functional assessments. The model does not incorporate, facilitate, or encourage the use of non-ecosystem parameters or values. The functional approach to assessing quality of mangrove habitat aligns with our mitigation planning policies and procedures.

10. The ECO-PCX finds the Mangrove Mitigation HSI Model has sufficient technical quality, system quality, is usable, and is policy compliant. The ECO-PCX team recommends approval of the model for mitigation planning purposes in the Rio Guayanilla Flood Risk Management Study.

Gregory Miller

Encls (3)

Gregory Miller
Operating Director
National Ecosystem Restoration
Planning Center of Expertise

CF
CEMVD-PDP (Lawton, Mallard)
CEMVP-PD-F (Richards)
CELRD-PDS-P (Clay, Sadri, Jarboe, Linkowski)
CELRC-PMD-PB (Davis)
CELRC-PM-PL-E (Veraldi)
CELRC-PM (Zuercher)
CESAJ-PD (Summa)
CESAJ-PD-PW (Keefe)
CESAJ-PD-E (Dunn)
CEMVP-PD-F (Keenan)

ENCLOSURE 1

HABITAT SUITABILITY INDEX FOR MANGROVE MITIGATION EVALUATION

at

RIO GUAYANILLA, GUAYANILLA, PR

2018 SUPPLEMENTAL APPROPRIATIONS

FLOOD RISK MANAGEMENT STUDY

US Army Corps of Engineers
Chicago District

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1. Background

As discussed in the Integrated Feasibility Report (IFR) and 404(b)(1) Analysis (Appendix A), the proposed El Faro levee alignment would fill/impact approximately 5.8-acres of interior basin mangrove swamp, Black Mangrove (*Avicennia nitida*) dominant. According to the Puerto Rico Department of Natural and Environmental Resources (PRDNER) botanical surveys in 1988, a greater percentage of the area (Figure 1) was converted from its natural mangrove condition to Cañaveral (sugarcane plantation) (PRDNER 1989) (*Appendix A2 Attachment*). Eventually, the Cañaveral was abandoned and a new plant community established, inclusive of some of the former natural mangrove swamp. This new plant community was noted as dominated by *Avicennia nitida*; for the most part a recovered mangrove swamp, but with altered hydrology, lower species richness and newly introduced invasive species. Various large floods and hurricanes have also influenced this area, in which naturally functioning mangrove swamps are mostly adapted to; however, significant events can change mangrove into different habitat types by changing the geomorphology. Patches of this area have also incurred impacts to hydrology, plant community structure and species composition by the development of El Faro and local practices of harvesting wood from accessible mangrove edges. The mitigation planning effort assessed a limited number of alternatives to ensure that funding allocated for implementation, monitoring and adaptive management is justified to the level necessary to have a net loss of 0-acres of wetland, and that any additional/incidental benefits are captured.

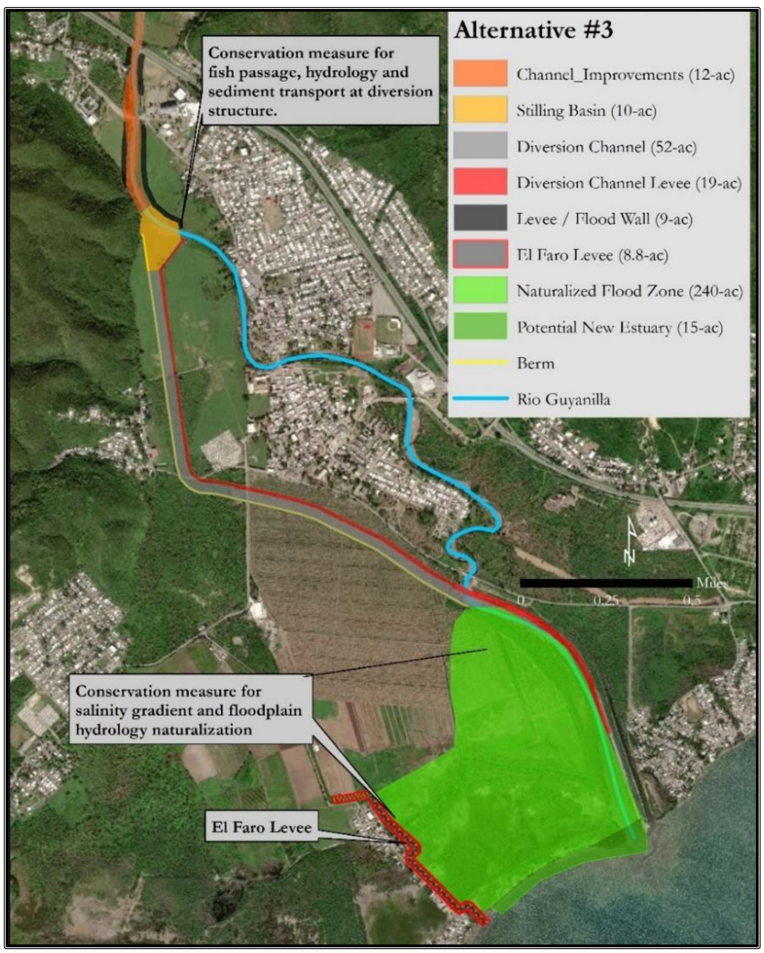

Figure 1: Rio Guayanilla Alternative 3 - El Faro Levee Affected Area

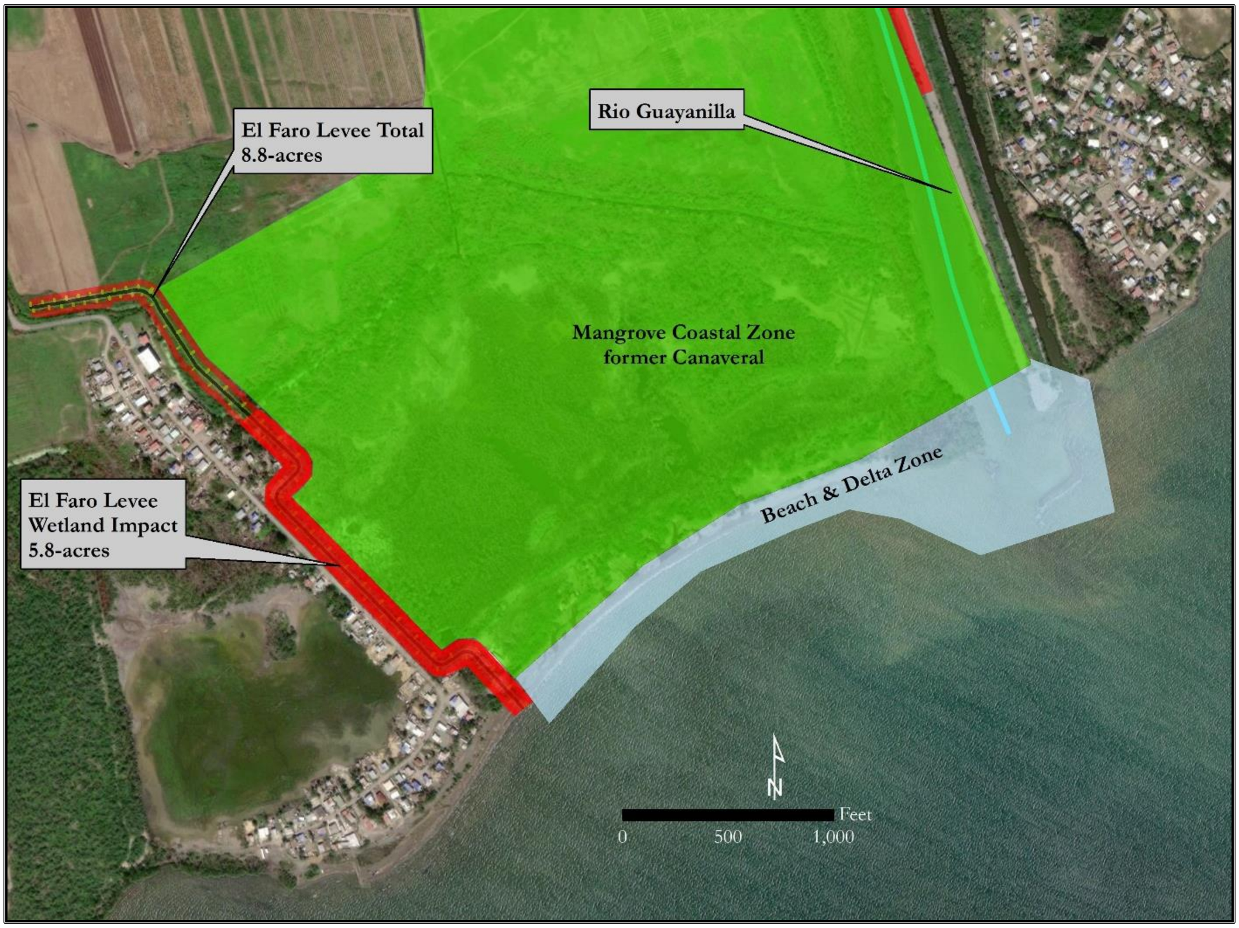

Figure 2: El Faro Levee Footprint & Mangrove Coastal Zone

Problem Statement

A species, habitat or community model/index was not available to characterize the type and quality of mangrove habitat impacted by the NED/Recommended Plan. There are various models under development, where most include complex water quality components and associations and hydrodynamics of sediment transport that would take years to collect data by different types of scientists working together. Individual species models were also investigated, however there were no single species models particular to Caribbean or mangrove habitat. Therefore, the following provide rational for the use of a novel, simplified Habitat Suitability Index (HSI) specific to the 240 acre mangrove coastal zone at Guayanilla Bay:

- used to assess mitigation plan cost effectiveness, not whether mitigation is required or not
- the wetland being affected is of medium quality and secondary growth
- the wetland incurred impacts from surrounding activities and land uses
- surrounding land use is highly impacted
- relatively minor mitigation costs compared to the NED Plan (<1.0%)
- relatively minor acreage/real estate required (<10-acres)

Model Purpose

Due to the lack of existing models, the Chicago District made the decision to develop a new Habitat Suitability Index (HSI) that would adequately represent key mangrove habitat variables required to establish and sustain mangrove forest community. The proposed mangrove HSI is intended to help both quantify conditions required for establishing and sustaining mangrove forest community and evaluate the effectiveness of potential mitigation actions to improve or restore this specific type of wetland. The model also could be used to evaluate other potential areas for mangrove restoration.

Model Summary

This mangrove index consists of HSI categories for the habitat variables hydrology, geomorphology, hydraulics, connectivity and habitat structure. These represent key variables in determining required hydrogeomorphic setting and connectivity for mangrove to be present. HSI categories are based on available literature and concepts of restoring hydrogeomorphic settings for plant communities. HSI categories determined by corresponding data to compute a total HSI score that ranges between 0.0 (not present or complete lack of habitat) to 1.0 (optimal habitat conditions). The index can be used to better understand mangrove potential and quality under existing conditions, future without project conditions and future with project conditions. Habitat quality generated from the model would be multiplied by an aerial measurement of acres to compute a "habitat unit" for comparison. Microsoft Excel, IWR Planning Suite and/or other methods could be used to calculate Average Annual Habitat Units.

This report is intended to provide documentation of the model's technical details, use and relevant information for USACE model certification (EC 1105-2-412, PB 2013-02). Because of its basic nature, this report includes necessary information to also serve as the user's guide for the model.

2. Model Development

Conceptual Model

Conceptual ecological models are required for all USACE ecosystem restoration projects due to their utility to increase understanding, identify potential alternatives and facilitate team dialog (Fischenich 2008, USACE 2011). Conceptual models also inform the development of quantitative ecological models (Grant and Swannack 2008, Swannack et al 2012). As such, a conceptual model was first developed to serve as the foundation of understanding for the key hydrogeomorphic variables that drive mangrove establishment and sustainability; and to serve as the foundation for overall index development.

Index development was conducted by the Chicago District USACE with technical advice provided by the USFWS-CESFO. USACE areas of expertise included hydrogeomorphology, fluviogeomorphic processes, coastal and tidal processes, hydrology and hydraulics. USFWS provided mangrove plant community and wetland expertise. Figure 3 shows the geomorphic types of mangrove communities for Southwestern Puerto Rico (Vega-Rodriguez 2008).

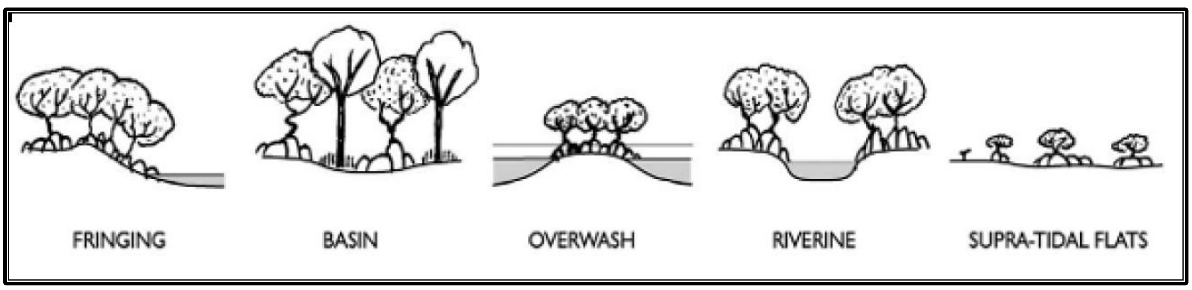

Figure 3: Mangrove Geomorphic Types Found in Southwest Puerto Rico

Figure 4 provides the concept of what optimal hydrogeomorphic parameters are for Black (*Avicennia nitida*) / White Mangrove (*Laguncularia racemosa*), and Red Mangrove (*Rhizophora mangle*) dominated mangrove forest communities at Guayanilla Bay, Puerto Rico.

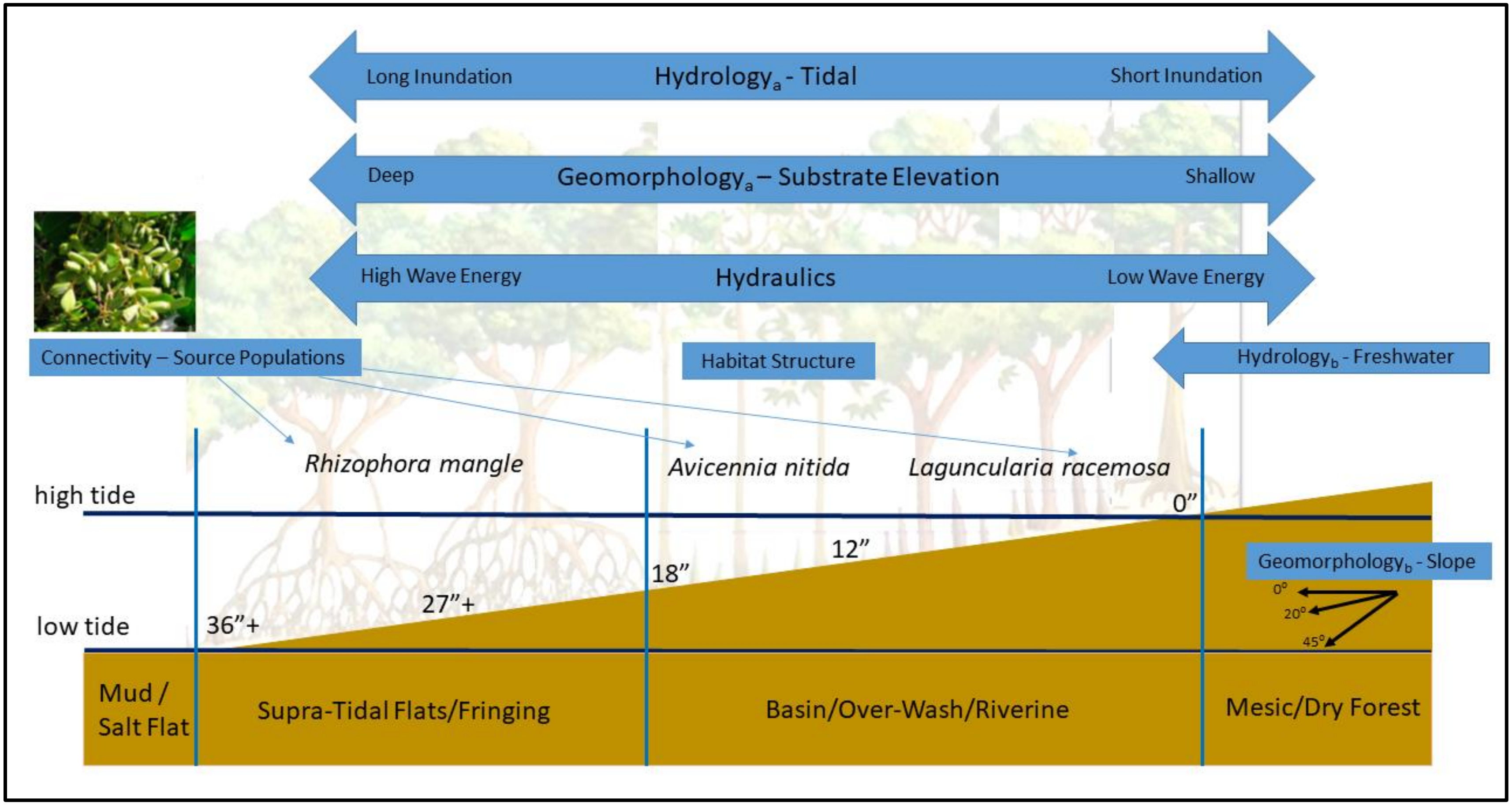

Figure 4: Conceptual Model for Mangrove Coastal Zone at Guayanilla Bay, Puerto Rico.

Habitat Suitability Index

This HSI was created using concepts commonly associated with mangrove community ecology and restoration publications (R.R. Lewis, C. Snedaker), that correspond to familiar USACE ecosystem criteria. Variables that comprise this qualitative assessment include: (V1) hydrology, (V2) geomorphology, (V3) hydraulics, (V4) connectivity and (V5) habitat structure. In order to derive a numerical classification to fulfill USACE policy requirements that a quantitative valuation of alternatives be conducted, qualitative descriptions were assigned quantitative values. A 0 to 1 scale was used to normalize the values, which is typically applied by USACE to ensure comparability.

Quantitative index variables were developed from the conceptual model. The following variables were selected for the quantitative model. Each variable had a corresponding Habitat Suitability Index-type category developed to describe general habitat quality across the range of conditions for that variable. The following variables/concept are highly important for mangrove community to be present at a site and to be sustainable. Tables 1 through 7 present the HSI for mitigation plan comparison at Guayanilla, Puerto Rico.

(V1) Hydrology$_a$ – Tidal Inundation & Periodicity – There are a range of tolerances to tidal inundation between different plant species along an inundation gradient. Species richness is typically correlated with inundation frequencies and durations. The interior basin at Guayanilla is dominated by Black Mangrove, which this community prefers daily tidal shifts.

Table 1: Metric Descriptors & Scoring for V1 Hydrology$_a$

Variable	Description	Qualitative Habitat Suitability	Numerical Value
(V1) Hydrology$_a$ Waves & Tidal Inundation	Sites that experience a higher frequency of tidal or wave inundation, such as between 60 and 20 times a month.	High	1.0
	Sites that experience a lower frequency of tidal or wave inundation, such as between 20 and 2 times a month.	Moderate	0.6
	Continual inundation (mudflat); No inundation, outside tidal influence zone, or upland.	Low	0.2

(V1) Hydrology$_b$ – Freshwater Inputs – Mangroves require a freshwater supply/input. These are typically in the form of streams, creeks, rivers and their associated zone of flood influence. Freshwater inputs, especially to basin, riverine and over-wash types, are required to keep salinity gradients optimal.

Table 2: Metric Descriptors & Scoring for V1 Hydrology$_b$

Variable	Description	Qualitative Habitat Suitability	Numerical Value
(V1) Hydrology$_b$ Freshwater Input	Direct sources of freshwater input apparent, such as river, stream or creek channels; springs; other.	High	1.0
	Indirect sources of freshwater input apparent, such as sites located in large river floodplains or deltas; sites with apparent direct sources that have been cut-off, but repairable.	Moderate	0.6
	Sites that do not receive freshwater inputs or surrounding inputs not available to connect.	Low	0.2

(V2) Geomorphology$_a$ – Depth to Substrate – Substrate depths and slopes are physical parameters that need to be in a certain morphology for a mangrove to exist at a particular site. Optimal depths for the targeted black mangrove basin type community to exist would be between 0 and 15" deep for a low and high tidal fluctuation cycle, respectively.

Table 3: Metric Descriptors & Scoring for V2 Geomorphology$_a$

Variable	Description	Qualitative Habitat Suitability	Numerical Value
(V2) Geomorphology$_a$ Substrate Depth	Black/White: Those sites that exhibit high tide depths about 12". Red: Those sites that exhibit high tide depths about 27"	High	1.0
	Black/White: Those sites that exhibit high tide depths near extremities, meaning between 0-6" and 15-18". Red: Those sites that exhibit high tide depths between 12-18".	Moderate	0.6
	Black/White: Those sites that exhibit high tide depths less than 0" or greater than 18". Red: Those sites that exhibit high tide depths less than 12" and greater than 8-feet.	Low	0.2

(V2) Geomorphology$_b$ – Slope – Optimal slopes for interior basin mangrove establishment are flat to a slight pitch. A low value would be a site with substrates pitched at 45+ degrees.

Table 4: Metric Descriptors & Scoring for V2 Geomorphology$_b$

Variable	Description	Qualitative Habitat Suitability	Numerical Value
(V2) Geomorphology$_b$ Substrate Slope	Slopes between 0 - 20°	High	1.0
	Slope between 20 - 45°	Moderate	0.6
	Slopes greater than 45°	Low	0.2

(V3) Hydraulics – Establishment Hydrodynamics –Mangroves are generally found in sheltered, low-energy environments such as estuaries, sheltered coasts, bays and/or behind barrier islands and beaches. These environments do not generally experience large waves or strong currents, except during extreme events. Together, waves and currents can be defined as hydrodynamics. Hydrodynamics are an important control on mangrove establishment and distribution. To resist being dislodged by currents and waves, a mangrove seedling must grow roots to anchor sufficiently into the soil. An optimal site would be those that are in a low energy environment that is always/usually in dynamic-equilibrium. Less than optimal would be those sites that experience frequent geomorphic changing events, particularly during propagule season; i.e. disturbed frequently by waves; riverine scour.

Table 5: Metric Descriptors & Scoring for V3 Hydraulics

Variable	Description	Qualitative Habitat Suitability	Numerical Value
(V3) Hydraulics Establishment Hydrodynamics	Sites located in a low energy environment that are always/usually in dynamic-equilibrium.	High	1.0
	Sites that experience moderate geomorphic changing events, but not particularly during propagule season.	Moderate	0.6
	Sites that experience frequent geomorphic changing events, particularly during propagule season.	Low	0.2

(V4) Connectivity – Nexus to Source Populations – Surface water connectivity for propagule dispersal. Hydrochory is the term used for propagule dispersal by tidal action. The Black Mangrove is exemplary of this being a pioneer mangrove species. This parameter is highly important for mangroves to sustain themselves and to recover after natural disturbance events such as hurricanes and tsunamis. There must be enough propagules available in the local area and they must be able to disperse to the restoration site. Optimal conditions would be those sites that have mangroves adjacent or surrounding them; and are surface water connected permanently. A suboptimal conditions would be those sites that are over 6 days float time for propagule dispersion and only have a marine connection.

Table 6: Metric Descriptors & Scoring for V4 Connectivity

Variable	Description	Qualitative Habitat Suitability	Numerical Value
(V4) Connectivity Source Populations	Directly connected to mangrove source population for Red, Black and White species.	High	1.0
	Currently not connected to mangrove source population for Red, Black and White species, but with opportunity for creating a connection.	Moderate	0.6
	Sites that are less than 6 days float time for propagule dispersion and only have a marine connection.	Low	0.2

(V5) Habitat Structure – Diversity of Plant & Animal Habitats – Mangrove wetlands provide breeding, nesting and feeding habitat for millions of waterfowl, birds, fish and other wildlife world-wide. Mangrove are an integral part of the life cycle for many marine organisms; they are the nursery and spawning grounds for about 39 commercially valuable fish and invertebrate species (TNC). Golley et al (1960) found an average of 67 animals (fish, crustacean, insects) / meter square plot of healthy mangrove community in Magueyes Island Puerto Rico. Mangrove communities can provide valuable food, timber and storm protection functions for humans as well.

Table 7: Metric Descriptors & Scoring for V5 Habitat Structure

Variable	Description	Qualitative Habitat Suitability	Numerical Value
(V5) Habitat Structure Habitat Diversity	100 - 80% coverage with mangrove trees, with a smaller percentage of intertwined mosaic native plant community and open water.	High	1.0
	Between 80% and 10% mangrove tree coverage, with a greater percentage of intertwined mosaic native plant community and open water, or other plant communities.	Moderate	0.6
	Less than 10% coverage of mangrove trees; agricultural land; barren land.	Low	0.2

Summation of Habitat Conditions

The Habitat Suitability Index (HSI) for mangrove habitat is assumed to be an equivalent and additive function of all the variables listed above. The equation to calculate the HSI value is the following:

- $HSI = (V1_a + V1_b + V2_a + V2_b + V3 + V4 + V5) / 7$

3. Modeling Application

Geographic Extent

The model was developed from global literature and restoration methods of mangrove hydrogeomorphology and field observations focused on the 240 acre mangrove coastal zone at Guayanilla, Puerto Rico. The mainstay of this HSI are abiotic hydrogeomorphic conditions, or metrics based on physics and landform; therefore, the use of the model beyond this geographic extent could be done as long as the additions of confounding biological variables were avoided.

Geographic Scale

This model is best applied to assessing mangrove habitat conditions at any scale, but gains more meaning the larger the site becomes. Similarly, the user will need to account for variability of any individual variable within the unit size. The unit size is not specified and is up to the user to identify the appropriate unit scale for their evaluation. It's likely that multiple unit or block areas may be selected to evaluate habitat within any given area.

Model Inputs

Much like traditional HSI models, input data for each variable could come from a variety of sources. A consistent methodology would be to apply the methods in the EMR Field Manual for Practitioners; however, likely sources include the following:

(V1) $Hydrology_a$ – physically counting and recording lengths of hydroperiod over a months' time; existing data and studies; local scientific knowledge base (i.e. USFWS, USGS, Natural Resource Departments, etc.)

(V1) $Hydrology_b$ – Google Earth; GIS platforms.

(V2) $Geomorphology_a$ – physically measuring substrate elevations; topographic/bathymetric survey; GIS platforms; Mircostation

(V2) $Geomorphology_b$ – Google Earth; physically measuring substrate elevations; topographic/bathymetric survey; GIS platforms; Microstation

(V3) Hydraulics – site observation; Google Earth; riverine models i.e. HEC-RAS; coastal models; GIS platforms

(V4) Connectivity – site observation; Google Earth; topographic/bathymetric survey; GIS platforms

(V5) Habitat Structure – site observation; remote sensing; Google Earth; GIS platforms; local scientific knowledge base

Important Considerations

Hydrogeomorphic & Biophysical Considerations – Mangroves are lost or degraded in various ways. These may include conversion for other land uses, changes in freshwater supply, loss of sediment, timber harvesting and/or other causes. Based on current literature and reviews of implemented mangrove restoration projects throughout the world, regeneration of a healthy mangrove forest can only happen if the enabling hydrogeomorphic conditions (captured in HSI) for mangrove growth are put back in place; whereas planting only without these land and water considerations typically fail. Research and literature show the effective methods in former aquaculture/agricultural lands are ground-levelling and excavation to resurge hydrology and hydraulics. Examples of this include strategically breaching of pond berms, excavating flats, and restoring old creek systems. Another method that could be applied to the beach/delta zones would be to place permeable structures to dampen wave effects while allowing water through, while trapping necessary sediment. Most instances where hydrogeomorphic restoration occurs, it is done close to existing mangrove stands so natural dispersion and recruitment of mangrove seeds occurs naturally. Some instances are supplemented with plantings if confidence lies with the existing or restored hydrogeomorphology. Finally, mangrove systems are highly dynamic and change all the time resulting from natural processes, therefore it is prudent to place a mangrove restoration within or adjacent to a greater mangrove system while including a diverse list of native conspecific species to fill in the gaps where mangrove trees cannot grow.

Socio-economic Conditions – It is apparent in the Guayanilla mangrove coastal zone that mangrove trees have been physically removed or wet areas filled in by people; this could easily continue to happen. The socio-economic root causes of this could be addressed to prevent mangrove destruction and where possible, economic activities could be developed that sustainably benefit from the restored mangrove values. Land ownership and use rights should be established coupled with local support for recovery and management. Successful projects invest communities, engage local government and ensure that local actions are strengthened by policies and planning.

Model Limitations

Output of the model should not be interpreted as an absolute quantification of habitat or biodiversity quality for any given area. Rather, it provides insight into the mangrove hydrogeomorphic setting that translates into bio-physical habitat. It provides a relative index of habitat quality and conditions, particularly to how specific physical habitat quality may change as a result of excavation/grading, installing sediment transport structures and naturally recruiting individual mangrove trees. This model is intended as a planning tool to guide alternative plan selection and design criteria for implementation.

Hydrogeomorphic Type – This model is currently specific to basin, over-wash and riverine hydrogeomorphic type mangrove forested swamp communities. Modifications could be easily made to suit other hydrogeomorphic types.

Preliminary Model Testing

Field testing of the model has not been completed. Several iterations of model usage were performed specifically for compensatory mitigation at Guayanilla. Results were as expected. Review by USFWS-CESFO did not indicate inappropriate use or complications with use or application of this HSI. This HSI was developed for a one-time use at Guayanilla, Puerto Rico for compensatory mitigation alternatives at the El Faro levee site. However, in the absence of an approved/certified USACE tool for assessing mangrove quality during the planning phase, an adaptive management approach could be employed to refine the model should future USACE needs arises, which could include additional testing. Any potential model modifications would undergo required review and approval.

Model Technical Quality

The model represents the current best, most practical approach to estimating quality of basin type mangrove community in southwestern Puerto Rico. It was assembled with assistance and guidance from USACE Chicago District planning and engineering, USACE Jacksonville District and USFWS-CESFO; with facilitation from experts in model development at the EcoPCX and Agency Technical Review provided by USACE Buffalo District. The model was constructed based on the best available scientific literature and from field observations within the geographic extent the model would be applied to. It should be reiterated that this model addresses fairly specific basin, out-wash and/or riverine hydrogeomorphic mangrove types. While available information is limited at best, this model represents the most reasonable approach to quantifying habitat quality for the mangrove habitat in question.

Model System Quality & Usability

This quantitative HSI or model is a simplistic mathematical equation that can be carried out in Microsoft Excel or by hand.

Intended Model Usage

This HSI or model is intended for use by the USACE as a part of plan formulation evaluation for Ecosystem Restoration (ER) and compensatory mitigation. Currently, this model is more specific to interior basin, over-wash and riverine hydrogeomorphic types of mangrove forested swamp community within the Caribbean, but more specifically to the Island of Puerto Rico. Future modifications to this HSI to develop modules per basin type and geographic area per USACE need is recommended.

4. References

Banus, Mario D. & Seppo E. Kolehmainen. The Rooting and Early Growth of Red Mangrove Seedlings from Thermally Stressed Trees. Puerto Rico Nuclear Center, College Station.

Golley, Frank, Howard T. Odum and Ronald F. Wilson. 1962. The Structure and Metabolism of Puerto Rican Mangrove Forest in May. *Ecology* Col 43, No. 1 pp. 9-19.

Lewis III, Roy R & Ben Brown. 2014. Ecological Mangrove Rehabilitation: A Field Manual for Practitioners.

Lugo, Ariel E. & Samuel C. Snedaker. 1974. The Ecology of Mangroves. Annual Review of Systematics. Vol. 5 (1974), pp. 39-64.

Mangrove Restoration, To Plant or Not To Plant.

Puerto Rico Department of Natural and Environmental Resources. 1989. Environmental Impact Statement for Flood Control on the Rio Guayanilla. Vegetation Survey and Map.

University of Puerto Rico. 2001. Guide to identify common wetlands plants in the Caribbean Area: Puerto Rico and the U.S. Virgin Islands/ in cooperation with Commonwealth Department of Natural and Environmental Resources. 1st ed.

Vega-Rodriguez, Maria. 2008. Estimating Primary Productivity of Red Mangroves in Southwestern Puerto Rico from Remote Sensing and Field Measurements. University of Puerto Rico.

Worthington, Thomas & Mark Spalding. Mangrove Restoration Potential: A global map highlighting a critical opportunity. The Nature Conservancy.

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Comment Report: Comments Authored by Michael Greer
Project: FRM Feasibility **Review**: Final Feasibility Report ATR (*00002*)
(sorted by Discipline , ID)

Displaying 6 comments for the criteria specified in this report.

Id	Discipline	Section/Figure	Page Number	Line Number
8383691	Environmental	Mitigation Plan	n/a	n/a

Comment Classification: **Unclassified\\For Official Use Only (U\\FOUO)**

a. Statement of the Concern: Mitigation plan has been updated.
b. Basis of the concern: ER 1105-2-100, Appendix C-4 and C-6
c. Significance of Concern: NA
d. Suggested Action: No issues identified in the revised mitigation plan in terms of content, formulation and the recommendation. Revised plan provided on 30 JAN 20.

Submitted By: Michael Greer (716-879-4229). Submitted On: Feb 05 2020

1-0 Evaluation **Concurred**
Concur.

Submitted By: Frank Veraldi (312-846-5589) Submitted On: Feb 18 2020

1-1 Backcheck Recommendation **Close Comment**
Closed without comment.

Submitted By: Michael Greer (716-879-4229) Submitted On: Feb 19 2020.

Current Comment Status: **Comment Closed**

Id	Discipline	Section/Figure	Page Number	Line Number
8383700	Environmental	Mangrove HSI Model	n/a	n/a

Comment Classification: **Unclassified\\For Official Use Only (U\\FOUO)**

a. Statement of the Concern: Model is being reviewed for one time use.
b. Basis of the concern: Professional judgment
c. Significance of Concern: NA
d. Suggested Action: Variables selected appear to be appropriate, make sure there is good rationale for them in the model documentation.

Submitted By: Michael Greer (716-879-4229). Submitted On: Feb 05 2020

1-0 Evaluation **Concurred**
Concur. Rationale provided in HSI Documentation, see attached.

Submitted By: Frank Veraldi (312-846-5589) Submitted On: Feb 18 2020 (Attachment: RG_MangroveHSIDocumentation_2020_02_18.docx)

1-1 Backcheck Recommendation **Close Comment**
Closed without comment.

Submitted By: Michael Greer (716-879-4229) Submitted On: Feb 19 2020.

Current Comment Status: **Comment Closed**

Id	Discipline	Section/Figure	Page Number	Line Number
8383701	Environmental	Mangrove HSI Model	n/a	n/a

Comment Classification: **Unclassified\\For Official Use Only (U\\FOUO)**

a. Statement of the Concern: Model is being reviewed for one time use.
b. Basis of the concern: Professional judgment
c. Significance of Concern: Moderate
d. Suggested Action: The metric description which essentially provides guidance for scoring is somewhat vague and subjective. There isn't enough detail to reasonably differentiate between all 4 values (qualitative or numerical) for each variable. I recommend clear descriptions and break points for each value. Should provide details that can reasonably be assessed by people using or reviewing the model.

Submitted By: Michael Greer (716-879-4229). Submitted On: Feb 05 2020

1-0 Evaluation **Concurred**
Concur. All recommendations accepted. Reorganization and addition of backup information was provided to substantiate and add clarity to HSI variables. HSI Documentation uploaded to comment 8383700.

Submitted By: Frank Veraldi (312-846-5589) Submitted On: Feb 18 2020

1-1 Backcheck Recommendation **Close Comment**
Closed without comment.

Submitted By: Michael Greer (716-879-4229) Submitted On: Feb 19 2020.

Current Comment Status: **Comment Closed**

Id	Discipline	Section/Figure	Page Number	Line Number
8383707	Environmental	Mangrove HSI Model	n/a	n/a

Comment Classification: **Unclassified\\For Official Use Only (U\\FOUO)**

a. Statement of the Concern: Model is being reviewed for one time use.
b. Basis of the concern: Professional judgment
c. Significance of Concern: Moderate
d. Suggested Action: Related to the previous comment. You might consider only using 3 scoring categories as I'm not sure we can reasonably differentiate in .2 increments using these metric descriptions/definitions. Methodology might not be that sensitive.

Submitted By: Michael Greer (716-879-4229). Submitted On: Feb 05 2020

1-0 Evaluation **Concurred**
Concur. Variables reduced to 3 categories from 5 to provide clarity, technical rationale and sensitivity. HSI Documentation uploaded to comment 8383700.

Submitted By: Frank Veraldi (312-846-5589) Submitted On: Feb 18 2020

1-1 Backcheck Recommendation **Close Comment**
Closed without comment.

Submitted By: Michael Greer (716-879-4229) Submitted On: Feb 19 2020.

Current Comment Status: **Comment Closed**

Id	Discipline	Section/Figure	Page Number	Line Number
8383716	Environmental	Mangrove HSI Model	n/a	n/a

Comment Classification: **Unclassified\\For Official Use Only (U\\FOUO)**

a. Statement of the Concern: Model is being reviewed for one time use.
b. Basis of the concern: Professional judgment
c. Significance of Concern: Moderate
d. Suggested Action: Connectivity, I understand the importance of the metric but I'm not sure how it is reasonably evaluated.

Submitted By: Michael Greer (716-879-4229). Submitted On: Feb 05 2020

1-0 Evaluation **Concurred**
Concur. Information on connectivity variable inputs provided in HSI Documentation uploaded to comment 8383700.

Submitted By: Frank Veraldi (312-846-5589) Submitted On: Feb 18 2020

1-1 Backcheck Recommendation **Close Comment**
Closed without comment.

Submitted By: Michael Greer (716-879-4229) Submitted On: Feb 19 2020.

Current Comment Status: **Comment Closed**

Id	Discipline	Section/Figure	Page Number	Line Number
8383734	Environmental	Mangrove HSI Model	n/a	n/a

Comment Classification: **Unclassified\\For Official Use Only (U\\FOUO)**

a. Statement of the Concern: Model is being reviewed for one time use.
b. Basis of the concern: Professional judgment
c. Significance of Concern: Moderate
d. Suggested Action: Hydrology variable only addresses inundation; waves and fresh water are not addressed. Remove waves and fresh water inputs in description.

Submitted By: Michael Greer (716-879-4229). Submitted On: Feb 05 2020

1-0 Evaluation **Concurred**
the hydrology variable was modified into 2 parts, Tidal/Wave Inundation and Freshwater Inputs. Both of these components are critical to mangrove hydrology. Both variable components were further reorganized with additional information to guide data inputs and categorization. HSI Documentation uploaded to comment 8383700.

Submitted By: Frank Veraldi (312-846-5589) Submitted On: Feb 18 2020

1-1 Backcheck Recommendation **Close Comment**
Closed without comment.

Submitted By: Michael Greer (716-879-4229) Submitted On: Feb 19 2020.

Current Comment Status: **Comment Closed**

Report Complete