Draft

Appendix A
Habitat Analysis and Mitigation Plan

Sabine Pass to Galveston Bay

Port Arthur and Vicinity

PAV03B and PAV03C

August 2022

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1 Introduction

This appendix provides documentation of the habitat evaluation and quantification process that was conducted to evaluate the benefits of various habitat types for the Sabine to Galveston (S2G) Port Arthur and Vicinity (PAV) Contracts 3B and 3C, also known as PAV03B and PAV03C. Quantification is needed in the project planning process to evaluate benefits or impacts of project features because traditional benefit/cost evaluation is not applicable when valuing habitat.

1.1 Project Description

The Galveston District is currently in the Preconstruction, Engineering, and Design (PED) Phase for two contracts. One contract, PAV03B, will have direct impacts to coastal prairie pondshore and cattail-inundated emergent wetlands. Both habitat types were evaluated as palustrine emergent wetlands through the implementation of levee and floodwall coastal storm risk management features. The other contract, PAV03C, would have direct permanent impacts to cattail-inundated wetlands, evaluated as palustrine emergent wetlands, through implementation of utility pipe relocation and construction staging. Additional information regarding PAV03B and PAV03C can be found in Section 1.6 of the Draft Supplemental Environmental Assessment (SEA).

1.2 Project Area

The project area for the purposes of habitat impact analysis includes wetland areas that would be directly impacted by construction of PAV03B and PAV03C (Figure 1 and Figure 2). See Attachment A for photos associated with both project areas. The project areas associated with both contracts are located within the city limits of Port Arthur, TX. Due to their position, the habitats are highly disturbed and expected to degrade into the 50-year future due to continued population growth and urbanization. Additional information regarding the project areas for PAV03B and PAV03C can be found in Section 1.6 of the Draft SEA.

Figure 1. Palustrine Emergent Wetlands within the Alignment of PAV03B

Figure 2. Palustrine Emergent Wetlands within PAV03C

1.2.1 Ecology of the Project Areas

1.2.1.1 PAV03B

Approximately 4 acres of the project area for PAV03B is considered disturbed coastal prairie and another 2 acres are considered wooded coastal prairie. Another site within the proposed levee alignment is considered cattail wetland (*Typha spp*.). These sites are heavily degraded. Habitat within the PAV03B project area on both sides of the railroad supports highly degraded low-quality coastal prairie consisting of hackberry (*Celtis occidentalis*), dewberry (*Rubus spp*.), poison ivy (*Toxicodendron radicans*), live oak (*Quercus virgininia*), green ash (*Fraxinus pennsylvanica*), and black willow.

The project area is split into two sections: west of the railroad and east of the railroad. The project area west of the railroad has dry and shrubby wetland vegetation. Here the depth of habitat is shallow (<one inch) after precipitation events, otherwise it is dry. The soils west of the railroad are suitable for wetland vegetation, and are dominated by deep-rooted sedge (*Cyperus entrerianus*), Chinese tallowtree (*Triadica sebifera*), bushy bluestem (*Andropogon glomeratus*), dewberry (*Rubus spp*.) and rattlebox (*Ludwigia alternifolia).* This area does not support rooted vascular plants (submerged aquatic vegetation [SAV]).

The project area east of the railroad is also considered palustrine emergent wetland habitat. There is a drainage ditch that supports emergent wetland habitat such as cattail (*Typhus spp*.), deep-rooted sedge, black needle rush (*Juncus roemerianus*), and Chinese tallowtree. There is some standing water within the drainage ditch, but towards the southern section of this action area it becomes dry. Although the area is dry it does accommodate wetland vegetation such as soft-stem bulrush (*Schoenoplectus tabernaemontani*), deep-rooted sedge, black willow (*Salix nigra*), and rattlebox.

Approximately 1.5 acres of highly disturbed non-native invasive grassland will also be impacted by construction. The non-native invasive grassland was not evaluated for impacts and will not be mitigated.

For the purposes of mitigation, all sites associated with PAV03B are considered palustrine emergent wetland upon completion of applicable habitat analyses

1.2.1.2 PAV03C

The soils within this project area for utility pipe relocation and construction staging are partially suitable for wetland vegetation and are dominated by cattail. This area does not support rooted vascular plants (submerged aquatic vegetation [SAV]).

This project area is highly disturbed and consists of vegetation such as small diameter hackberry and dewberry outside of the palustrine wetland site that will not be evaluated or mitigated due to their current condition.

2 Habitat Classification

This study applies the Wetlands Value Assessment (WVA) Coastal Marsh (Version [V] 2.0) model to calculate impacts and develop mitigation for the Recommended Plan (U.S. Fish and Wildlife Service [USFWS] 2002). The WVA methodology is similar to the USFWS Habitat Evaluation Procedures (HEP) in that habitat quality and quantity are measured for baseline conditions and predicted for Future Without-Project (FWOP) conditions and Future With-Project (FWP) conditions. Instead of the species-based approach of HEP, the WVA models use an assemblage of variables considered important to the suitability of a given habitat type for supporting a diversity of fish and wildlife species. As with HEP, the WVA allows a numeric comparison of each future condition and provides a combined quantitative and qualitative estimate of project-related impacts on fish and wildlife resources.

The WVA models operate under the assumption that optimal conditions for fish and wildlife habitat within a given coastal wetland type can be characterized, and that existing or predicted conditions can be compared to that optimum to provide an index of habitat quality. Habitat quality is estimated and expressed through the use of a mathematical model developed specifically for each habitat type. The model consists of 1) a list of variables that are considered important in characterizing fish and wildlife habitat; 2) a Suitability Index graph for each variable, which defines the assumed relationship between habitat quality (Suitability Indices) and different variable values; and 3) a mathematical formula that combines the Suitability Indices for each variable into a single value for wetland habitat quality, termed the Habitat Suitability Index (HSI).

The habitat variable-habitat suitability relationships within the WVA model have not been verified by field experiments or validated through a rigorous scientific process. However, the variables were originally derived from HEP suitability indices taken from species models for species found in that habitat type. An independent external peer review of the WVA Models has been conducted by the U.S. Army Corps of Engineers (USACE) Ecosystem Planning Center of Expertise (ECO-PCX) (Battelle, 2010). The reviewers agreed that the concept and application of the models are sound for planning efforts. The models seem to sufficiently capture the habitats being modeled and do not have any irreparable deficiencies.

2.1 Habitat Classification

The Texas Parks and Wildlife Department (TPWD) Ecological Mapping Systems (Elliott et al., 2009-2014) habitat classification was used as baseline data to define the existing habitat of the study area.

2.1.1 Ecological Mapping Systems

The TPWD, in cooperation with private, state, and federal partners, produced a 398-class, 10-meter spatial resolution land classification map for Texas (Elliott et al. 2009-2014). This was accomplished by attributing land cover and abiotic variables to 10-meter resolution image objects generated from National Agriculture Imagery Program photographs.

The project mapped multiple vegetation types that are components of the more broadly defined ecological systems, which are called "Mapped Vegetation Types." The mapping subunits typically represent the various land covers (e.g. broadleaf evergreen forest, deciduous forest, evergreen Shrubland, grassland, etc.) that constitute the full range of variation within an ecological system, depending on land use history or successional state.

Three date mosaics of Landsat Thematic Mapper Satellite Imagery, combined with ancillary data, such as slope, aspect, landscape position, solar insolation, percent canopy cover from National Landcover Dataset (NLCD), percent impervious surface from NLCD, and agricultural areas as defined by the most recent version of the National Agricultural Statistics Service cropland data layer, were used to classify land cover. A decision tree classification process was used to assign pixels to land cover classes using the statistical relationship between field collected data, satellite imagery, and the ancillary data of a given area. All decision tree classifications were run using a 30-meter spatial resolution, which is the native spatial resolution of the Landsat Thematic Mapper imagery. The 30-meter spatial resolution was then re-sampled to a 10-meter spatial resolution.

After the 10-meter spatial resolution image objects were developed, abiotic environmental data were generated and attributed to the image objects, in addition to the land cover data. Abiotic environmental data included: soil data (ecological site type, soil texture, and flooding frequency) provided by the Natural Resource Conservation Service (NRCS) Soil Geographic Database (SSURGO); stream buffers based on the National Hydrologic Dataset (30-meter corridor); 10-meter digital elevation models (DEM)-derived variables (percent slope, land position, and solar insolation); and additional data from geology layers that aided in classification specific to that vegetation type. The different combinations of land cover with different soils, slopes, hydrology, or ecoregions were assigned to different final mapped vegetation types. In total 398 land cover types were mapped in Texas.

2.2 Model Selection

An interagency team consisting of USACE, USFWS, and TPWD identified the applicable WVA model to be used for this project, which is the WVA Coastal Marsh (Version [V] 2.0) model. The WVA model is approved for regional or nationwide use in accordance with documented geographic range, best practices, and its designed limitations. The ECO-PCX and resource agencies have indicated support of the use of this model (see Attachment B).

2.3 Data Collection

For the PAV03B project area, an interagency team made up of USACE, TPWD, and USFWS was established to complete field work and review habitat survey results. Data collection sites were randomly selected within the areas of impact. A total of seven sample plots were assessed (Figure 3). The habitat assessment within the study area was conducted on April 27, 2022.

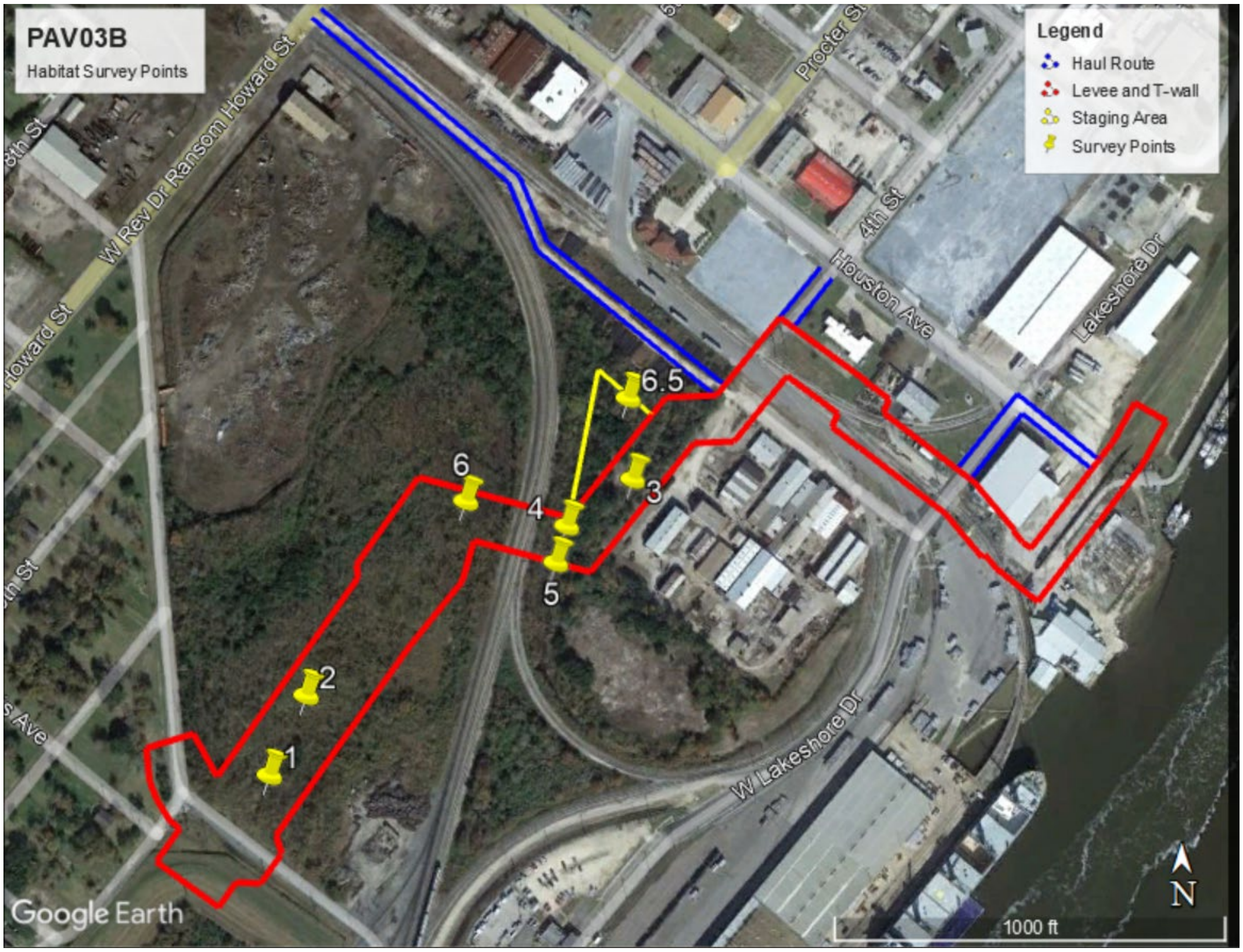

Figure 3. Habitat Survey Points for PAV03B

A team of USACE staff evaluated the habitat impacts associated with PAV03C on March 15, 2022. Two sample plots were collected; however, only one was used to evaluate the condition of palustrine wetlands in the project area (Figure 4).

Figure 4. Habitat Survey Points for PAV03C

2.4 Habitat Survey Results

After collecting variables in the field, baseline habitat conditions were assessed with HEP using the methodology presented in ESM 102 *Habitat Evaluation Procedures* (USFWS, 1980). The HSI for each sample plot was evaluated by applying field data to applicable variables for each species' model. Baseline HSI for each habitat type are presented in Table 1 (scores are rounded to the nearest decimal).

Table 1. Average Baseline HSI Scores for PAV03B and PAV03C

Area	Disturbed Coastal Prairie	Cattail Wetland	Wooded Coastal Prairie
PAV03B	0.46	0.76	0.23
PAV03C	--	0.76	--

3 Valuation of Impacts

The following sections discuss how the impacts are valued in comparison to habitat quality.

3.1 Habitat Units

The average value identified in Section 2 was used to quantify the habitat impacts from implementation of PAV03B and PAV03C. The HSI scores were multiplied by the net change acreages to calculate the net change in Habitat Units (HUs). Habitat Units represent a numerical combination of quality (i.e., HSI) and quantity (acres) existing at any given point in time.

Equation 1. Habitat Unit Calculation

$$Remaining\ Acres\ x\ Habitat\ Quality\ (HSI) = Habitat\ Units\ (HUs)$$

3.1.1 Annualization of Habitat Quality

The USACE quantifies the existing, FWOP conditions, and FWP conditions project benefits and impacts using an HU metric. Habitat Units are calculated as the product of the HSI and the number of acres of the habitat of interest. The net change in HUs is for a single point in time; however, the impacts of implementation of the S2G Port Arthur project would occur over the entire planning horizon (50 years). To account for the value of the loss over time, when HSI scores are not available for each year of analysis, the cumulative HUs are calculated using a formula that requires only the target year, in this case the FWOP value, and the area estimates (USFWS, 1980). The following formula was used:

Equation 2: Annualization of Habitat Units for the FWOP and FWP Conditions

$$\int_0^T HU\ dt = (T_2 - T_1)\left[\left(\frac{A_1H_1 + A_2H_2}{3}\right) + \left(\frac{A_2H_1 + A_1H_2}{6}\right)\right]$$

Where:

$$\int_0^T HU\ dt = Cumulative\ HUs$$

T_1= first target year of time interval

T_2 = last target year of time interval

A_1 = area of available habitat at the beginning of time interval

A_2= area of available habitat at the end of time interval

H_1 = Index score at the beginning of time interval

H_2 = Index score at the end of time interval

3 and 6 = constants derived from integration of Index score x Area for the interval between any two target years

This formula was developed to estimate cumulative HUs for the HSI and area between two time intervals (T_x to T_{x+1}). The sum of these time intervals over the period of analysis divided by the total number of years of that analysis (50 years) provides an Average Annual Habitat Unit (AAHU). This annualization accounts for the temporal shifts in the log rhythmic rate of accumulating ecological benefits that is common when dealing with the unevenness found in nature (USFWS, 1980).

The impact of a project can be quantified by subtracting the FWP benefits/impacts from FWOP benefits/impacts. The difference in AAHUs between the FWOP and the FWP represents the net impact attributable to the project in terms of habitat quantity and quality. Tables 2 and 3 show the remaining and net change value of habitats within the study area under the FWOP and the Port Arthur contracts.

3.1.2 Target Years

Target Year (TY) 0 habitat conditions are represented by the existing, or baseline, habitat conditions. The field and desktop collected data were used to quantify the habitat quality of that baseline condition. Target Year 0 conditions serve as a basis of comparison for both FWOP and FWP scenarios.

Additional TYs were identified based on when implemented measures would be expected to elicit community responses represented by changes in the projected habitat variables.

TY 1 is used as a standard comparison year to identify and capture changes in habitat conditions that occur within one year after measures have been constructed. Amount of wetted area, reduction in invasive species, and water regimes are likely variables that may increase or decrease within this time period.

TY 5 was selected to capture the increase in habitat quality associated with the construction or mitigation measures that provide ecological impacts or benefits relatively quickly such as vegetation clearing for impacts or natural plant establishment, aquatic vegetative abundance, and plant diversity for mitigation measures.

TY 10 is used as a point after the initial growth of vegetation and the likely increase in size and benefits plantings have sustained.

Similarly, TY 25 was selected to capture the growth of habitats. Plant abundance and diversity are also key response variables for this target year.

TY 50 is the planning life span of the project and is used as the last projected TY for the study. Impacts resulting from the project should be well known and mitigation measures should produce mature habitat by this target year and represent the habitat types within the study area.

3.2 Summary of Alternative Impact Valuation

3.2.1 PAV03B

The AAHUs lost through implementation of PAV03B are shown in Table 2 (see Attachment C).

Table 2. Average Annual Habitat Units of Habitats Evaluated for PAV03B

	Habitat	Acres	Target Year											
			0		1		5		10		25		50	
			HSI	HU	HSI	HU	HSI	HU	HSI	HU	HSI	HU	HSI	HU
FWOP	Disturbed Coastal Prairie	4	0.5	2	0.5	2	0.5	2	0.4	2	0.4	1	0.3	1
FWP	Disturbed Coastal Prairie	4	0.5	2	0	0	0	0	0	0	0	0	0	0
														AAHU Difference = 1

Habitat	Acres	Target Year					
		0	1	5	10	25	50

			HSI	HU	HSI	HU	HSI	HU	HSI	HU	HSI	HU	HSI	HU
FWOP	Cattail Wetland	1	0.8	1	0.8	1	0.8	1	0.8	1	0.8	1	0.7	1
FWP	Cattail Wetland	1	0.8	0	0	0	0	0	0	0	0	0	0	0
														AAHU Difference = 1

	Habitat	**Acres**	**Target Year**											
			0		**1**		**5**		**10**		**25**		**50**	
			HSI	**HU**	**HSI**	**HU**	**HSI**	**HU**	**HSI**	**HU**	**HSI**	**HU**	**HSI**	**HU**
FWOP	Wooded Coastal Prairie	2	0.2	0	0.2	0	0.2	0	0.2	0	0.2	0	0.2	0
FWP	Wooded Coastal Prairie	2	0.2	0	0	0	0	0	0	0	0	0	0	0
														AAHU Difference = 0
														Total = 2

Habitat Units have been rounded to the nearest whole number. Habitat Suitability Index has been rounded to the nearest decimal.

3.2.2 PAV03C

The AAHUs lost through implementation of PAV03C are shown in Table 3 (Attachment C).

Table 3. Average Annual Habitat Units of Habitats Evaluated for PAV03C

	Habitat	**Acres**	**Target Year**											
			0		**1**		**5**		**10**		**25**		**50**	
			HSI	**HU**	**HSI**	**HU**	**HSI**	**HU**	**HSI**	**HU**	**HSI**	**HU**	**HSI**	**HU**
FWOP	Cattail Wetland	1	0.8	1	0.8	1	0.8	1	0.8	1	0.8	1	0.7	1
FWP	Cattail Wetland	1	0.8	0	0	0	0	0	0	0	0	0	0	0
														AAHU Difference = 1
														Total = 1

Habitat Units have been rounded to the nearest whole number. Habitat Suitability Index has been rounded to the nearest decimal.

The tables above indicate an overall loss of 3 AAHUs due to implementation of PAV03B and PAV03C.

4 Mitigation

It is the policy of the USACE Civil Works program to demonstrate that damages to all ecological resources, both terrestrial and aquatic, have been avoided and minimized to the extent practicable, and that any remaining unavoidable damages have been compensated to the extent justified, as discussed in Engineering Regulation 1105-2-100, paragraph C-3(d)(3)(1).

Engineering Regulation 1105-2-100, paragraph C-3(e), requires the use of a habitat-based methodology, supplemented with other appropriate information to describe and evaluate the impacts of the project, and to identify the mitigation need of the FWP condition as measured against the FWOP condition. The recommended plan and the National Economic Development (NED) plan, if not one in the same, shall contain sufficient mitigation to ensure that either plan selected will not have more than negligible adverse impacts on ecological resources (Section 906(d) of WRDA 1986). Additionally, the WRDA 2016 Implementation Guidance indicates that ecological success criteria for mitigation is based on replacement of lost functions and values of habitat, including hydrologic and vegetative characteristics.

Once a mitigation need has been identified, preparation of mitigation plans can be developed, including objectives, plan designs, determination of success criteria and monitoring needs, in coordination with Federal and State resource agencies, to the extent practicable. Practicable mitigation sites within the Sabine Lake HUC are limited, however, two plans were evaluated for implementation

4.1 Mitigation Plans Evaluated

4.1.1 J.D. Murphee Wildlife Management Area

J.D. Murphee Wildlife Management Area is located in Jefferson County, Texas. It is owned in fee by TPWD. An opportunity exists to implement marsh mitigation measures on 70 acres of open water habitat created by historical storms (Figure 5) (Attachment D).

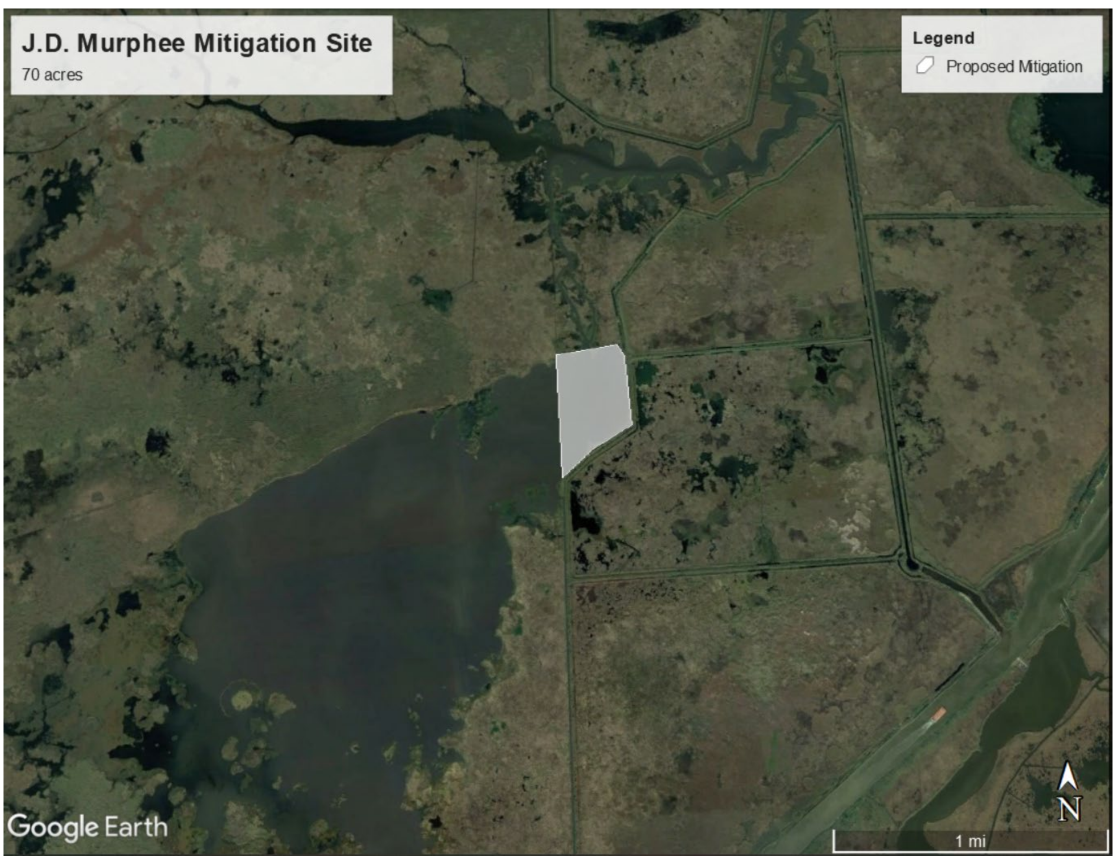

Figure 5. J.D. Murphee Wildlife Management Area Proposed Mitigation Site

This mitigation area would require clean fill material acquisition, hauling of the material, and disposal of the material onto TPWD-owned property. Upon settling, the new landscape would be planted with submergent aquatic vegetation (SAV) as well as native emergent wetland vegetation depending upon the elevation of the site. Implementation of any of these measures would require TPWD approval and additional agency review for real estate purposes. During resource agency coordination for this study, TPWD expressed support for the restoration activities associated with this area.

The cost associated with material acquisition, hauling, and disposal is expected to be approximately $10,000,000. Mitigation efforts to include planting, monitoring, adaptive management, and reporting would cost approximately $1,035,000, bringing the total for this mitigation plan to $11,035,000. This plan is expected to produce 50 AAHUs over a period of 50 years if implemented (Table 4).

Table 4. Average Annual Habitat Units for Potential J.D. Murphee Mitigation Site

			Target Year											
Area		Acres	0		1		5		10		25		50	
			HSI	HU	HSI	HU	HSI	HU	HSI	HU	HSI	HU	HSI	HU
FWOP	J.D. Murphee	70	0.4	30	0.4	30	0.4	26	0.3	21	0.2	16	0.2	16
FWP	J.D. Murphee	70	0.4	30	0.9	65	1.0	67	1.0	69	1.0	69	1.0	69
														AAHU Difference = 50

Habitat Units have been rounded to the nearest whole number. Habitat Suitability Index has been rounded to the nearest decimal.

4.1.2 Sea Breeze Wetland Mitigation Bank

Sea Breeze Wetland Mitigation Bank is located in Chambers County, Texas (Figure 6). The primary service area is defined by the 8-digit HUC that the bank is located within, which encompasses East Galveston Bay (HUC 12040202). The secondary service area is defined as the portion of HUC 12040201 (Sabine Lake) occurring within the state of Texas. Debiting ratios are as follows: Primary Service Area 1:1, Secondary Service Area 1.5:1. The service area specifically excludes the following: Bolivar Peninsula (including the adjacent shoreline of Galveston Bay, Rollover Bay, and East Bay) and all lands owned, leased, or managed by TPWD.

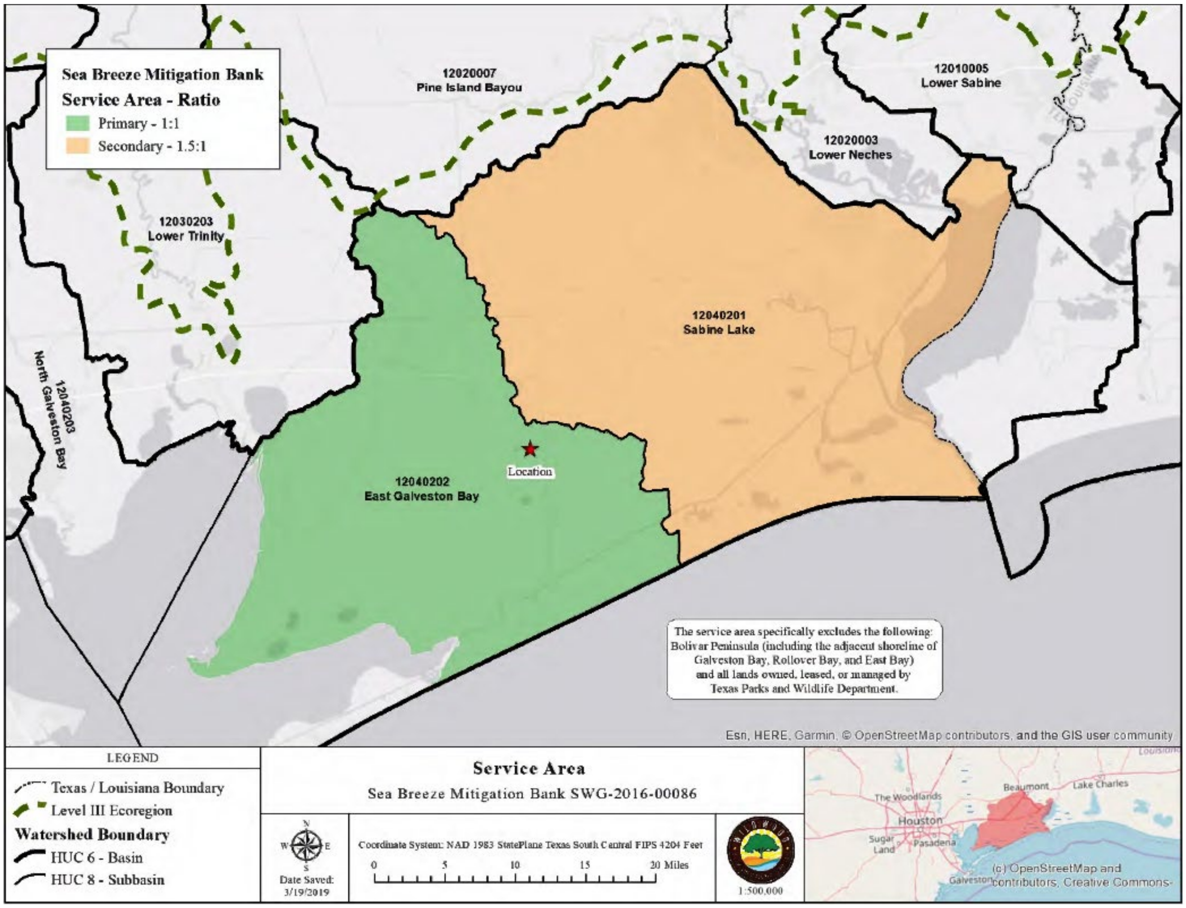

Figure 6. Primary and Secondary Service Areas for Sea Breeze Mitigation Bank

Sea Breeze is applicable for use of Riverine Herbaceous/Shrub credits, which can be used as mitigation for impacts to non-tidal wetlands that support an emergent/scrub-shrub wetland community in their current, natural, and/or undisturbed state. Examples of wetlands in this category (in-kind) include wet prairies, wet pastures/agricultural fields, scrub-shrub wetlands, constructed ponds or reservoirs that may exist as a different aquatic resource type (e.g. pond or reservoir), or vegetative community (e.g. tallow dominated) because of a lack of disturbance (e.g. fire suppression), or due to a previous disturbance (Sea Breeze Mitigation Bank, 2017).

This potential mitigation plan does not produce a comparison of FWOP and FWP AAHUs. The SWG Herbaceous Riverine Interim Hydrogeomorphic (iHGM) Wetland Functional Assessment was not used during data collection of the impact sites. Any model variables associated with iHGM have assumed a Functional Capacity Index (FCI) of 1.0 to ensure all wetland impacts are adequately compensated, without converting the data collected via WVA to iHGM (see Attachment E). The iHGM, as of August 2022, is not a USACE Civil Works certified model. The USACE is currently undergoing the Civil Works model certification process with the ECO-PCX. It is expected the iHGM will be certified before the purchase of any mitigation bank credits.

As described in this Appendix, there are approximately 8 acres of palustrine wetland impacts associated with the construction of PAV03B and PAV03C. The mitigation plan is predicated on an FCI of 1.0 for all variables and function categories (biological, chemical, and physical) for palustrine emergent wetlands, and another ratio of 1.5:1 due to the impact’s location within the Sea Breeze secondary service area to calculate the required Function Capacity Units (FCU)

Based on these assumptions, the following mitigation plan was prepared:

- 1.0 FCI x 8 acres Palustrine Emergent Wetland Impact = 8 FCU's
    - This results in 8 Biological FCU's, 8 Chemical FCU's, and 8 Physical FCU's
- 8 FCU's per Function Category x 1.5 (secondary service area multiplier) = 12 FCU's per Function Category
    - For additional clarification if comparing as a total:
        - 24 FCU's x 1.5 = 36 FCU Credits
- Total mitigation cost of $1,980,000.

The Sponsor of the Sea Breeze Mitigation Bank, D. Mayes Middleton II Non-Exempt Trust, is responsible for establishing and maintaining the official ledger for all bank transactions, as well as the legal responsibility for ensuring all mitigation terms are fully satisfied under the Mitigation Banking Instrument (SWG-2016-00086).

4.2 Mitigation Plan Selected

The proposed mitigation plan is the purchase of credits from the Sea Breeze Wetland Mitigation Bank. A variety of factors and constraints were considered while selecting the mitigation plan:

- Construction of PAV03B and PAV03C is anticipated to occur in the Fall of 2022.
- Impacts to the construction schedule adversely affect life safety within Port Arthur, TX.
- Real Estate approvals through USACE and TPWD are unknown and can adversely impact the construction schedule.
    - J.D. Murphee real estate approvals are unknown, but expected to exceed the proposed timeline for PAV03B and PAV03C construction.
    - The Sea Breeze Wetland Mitigation Bank once funded, can be implemented immediately.
- Cost of implementation
    - The overall cost of implementing the J.D. Murphee Mitigation Plan is $11,045,000.
    - The overall cost of purchasing credits from the Sea Breeze Mitigation Bank is $1,980,000.
- Both plans compensate for the loss of palustrine emergent wetland habitat.

Due to the constraints associated with the construction of PAV03B and PAV03C, USACE has determined that purchase of credits from the Sea Breeze Wetland Mitigation Bank is the most logical choice to compensate for habitat loss.

Upon public and resource agency review of the Draft SEA and its appendices, USACE is expecting to purchase the credits in full to comply with the previously mentioned laws and regulations associated with Civil Works projects.

5 References

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6 List of Preparers

Justyss Watson – Biologist, Regional Planning and Environmental Center; 6 years USACE experience.

ATTACHMENT A

PAV03B

PAV03B 01 North

PAV03B 01 East

PAV03B 01 South

PAV03B 01 West

PAV03B

PAV03B 02 North

PAV03B 02 East

PAV03B 02 South

PAV03B 02 West

PAV03B

PAV03B 03 North

PAV03B 03 East

PAV03B 03 South

PAV03B

PAV03B 04 North

PAV03B 04 East

PAV03B 04 South

PAV03B 04 West

PAV03B

No photos were taken at PAV03B 05.

PAV03B 06 North

PAV03B 06 East

PAV03B 06 South

PAV03B 06 West

PAV03B

PAV03B 06.5 North

PAV03B 06.5 East

PAV03B 06.5 South

PAV03B 06.5 West

PAV03C

PAV03C 01 North

PAV03C 01 East

PAV03C 01 South

PAV03C 01 West

PAV03C

PAV03C 01 North

PAV03C 01 East

PAV03C 01 South

PAV03C 01 West

ATTACHMENT B

U.S. Army Corps of Engineers
Planning Models Improvement Program

Wetland Value Assessment Coastal Marsh Community Models for Civil Works (Version 2.0)

Revised from the Coastal Marsh Community Models developed by the Environmental Working Group of the Coastal Wetlands Planning, Protection and Restoration Act

September 2017

Prepared by:
Patrick Smith and Daniel Meden
US Army Corps of Engineers, New Orleans District
Regional Planning and Environment Division South

Point of Contact:
Patrick Smith
US Army Corps of Engineers, New Orleans District
7400 Leake Ave
New Orleans, LA 70118
Email: Patrick.W.Smith@usace.army.mil
Office: (504) 862-1583

US Army Corps of Engineers
New Orleans District

WETLAND VALUE ASSESSMENT METHODOLOGY
Coastal Marsh Community Models

I. Introduction

This document describes revisions to the Wetland Value Assessment (WVA) Coastal Marsh Community Models (WVA Marsh Models) for certification as a planning tool under the Planning Models Improvement Plan (PMIP) (EC 1105-2-412) and for the specific use on US Army Corps of Engineers (USACE) civil works projects.

The WVA Marsh Models (Fresh/Intermediate Marsh, Brackish Marsh, and Saline Marsh) were initially developed as the primary means of measuring the wetland benefits of candidate projects proposed for funding under the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA). In addition, the WVA Marsh Models have also been used for determining potential impacts under USACE civil works projects and mitigation. Since their initial development, the WVA Marsh Models have undergone several revisions including the omission of certain variables, modifications to the Suitability Index (SI) graphs, and modifications to the Habitat Suitability Index (HSI) formulas. However, the PMIP established a process to review, improve and validate analytical tools and models for USACE Civil Works planning models.

Consistent with the PMIP and specific guidance from the USACE National Ecosystem Restoration Planning Center of Expertise (ECO-PCX), the following sections describe revisions to the process and assumptions used in the WVA Marsh Models. These revisions specifically address Variables 1, 2, and 3 with incorporation of Battelle Memorial Institute's (Battelle, 2010) recommendations specific to Comment 10 (Appendix IV, pages 70-71).

<u>USACE Planning Models Improvement Program</u>

The PMIP was established in 2003 to assess the state of USACE planning models and to assure that high quality methods and tools are available to provide informed decisions on investments in the Nation's water resources infrastructure and natural environment. The main objective of the PMIP is to carry out "a process to review, improve and validate analytical tools and models for USACE Civil Works business programs" (USACE EC 1105-2-407, May 2005). In accordance with the Planning Models Improvement Program: Model Certification (EC 1105-2-407, May 2005), certification is required for all planning models developed and/or used by USACE. On August 31, 2010, Battelle, in support of the PMIP, completed an independent external peer review and released the final report for the WVA Marsh Models.

The purpose of this revised manual is to incorporate updated guidance to users of the WVA Marsh Models for use under the USACE Civil Works Program. Incorporation of Battelle's recommendations specific to Comment 10 (Battelle Memorial Institute 2010) provided guidance for some aspects of the WVA Marsh Models. However, Battelle's recommendations did not provide sufficient guidance for a thorough and complete revision suitable for certifications. One of the general comments from Battelle suggested incorporating more scientific references (Battelle, 2010). Consequently, a literature review was conducted to document the state of the scientific knowledge and update each model beyond the specific recommendations from Comment 10. See Appendix II on pages 56-59 for Battelle's Comment 10 from the WVA Marsh Model Review.

In addition, USACE, Mississippi Valley Division, New Orleans District (CEMVN) coordinated with WVA experts from the US Fish and Wildlife Service (personal communication David Walther, September 29, 2017; personal communication Catherine Breaux, September 29, 2017; personal communication Kevin Roy, September 29, 2017; personal communication Ronald Paille, September 29, 2017), the National Marine Fisheries Service (personal communication Richard Hartman, September 29, 2017; personal communication Patrick Williams, September 29, 2017), and the USACE Galveston District (personal communication Janelle Stokes, 2017) during the development of the WVA Coastal Marsh Models Version 2.0.

Geographic Scope

Hydrographic factors including tidal inundation frequency and duration are particularly important for nekton as it determines the accessibility of the marsh surface and thus the potential for habitat use. These factors vary considerably geographically and as a result the supporting documentation within the model predominately focuses on the northern Gulf of Mexico. For example, in a literature review of salt marsh use by nekton, Minello et al. (2003) found greater use of salt marsh by nekton in the Gulf of Mexico than the Atlantic Coast. Although some of the scientific literature included studies along the Atlantic coast, the relative weights of the variables and forms of the SI graphs are based upon habitat characteristics of coastal marshes in eastern Texas and coastal Louisiana.

Wetlands often play an important role during certain times of the year with changes in tidal fluctuations. However, the geographic scope does not exhibit irregular tidal fluctuations that would impact the spawning or rearing of nekton, fish, and other animals. It should also be noted that the civil works projects under the WVA Marsh Models are limited to evaluate habitat year round.

Geographical Range of Applicability

The geographical range of applicability of the USACE Civil Works WVA Coastal Marsh Models (Version 2.0) is appropriate marsh habitats within the level IV ecoregions indicated in Figure 1 and Table 1. Ecoregions that occur within the Louisiana Coastal Zone, as determined by the Louisiana Department of Natural Resources, are selected for use in that state. Coordination with a USACE Galveston District Biologist familiar with these WVAs suggested the inclusion of the Texas ecoregions indicated in Figure 1 and Table 1 (personal communication Janelle Stokes, 2017). These models may be appropriate for other areas. Potential users outside of the geographical range of applicability presented here are encouraged to coordinate with ECO-PCX.

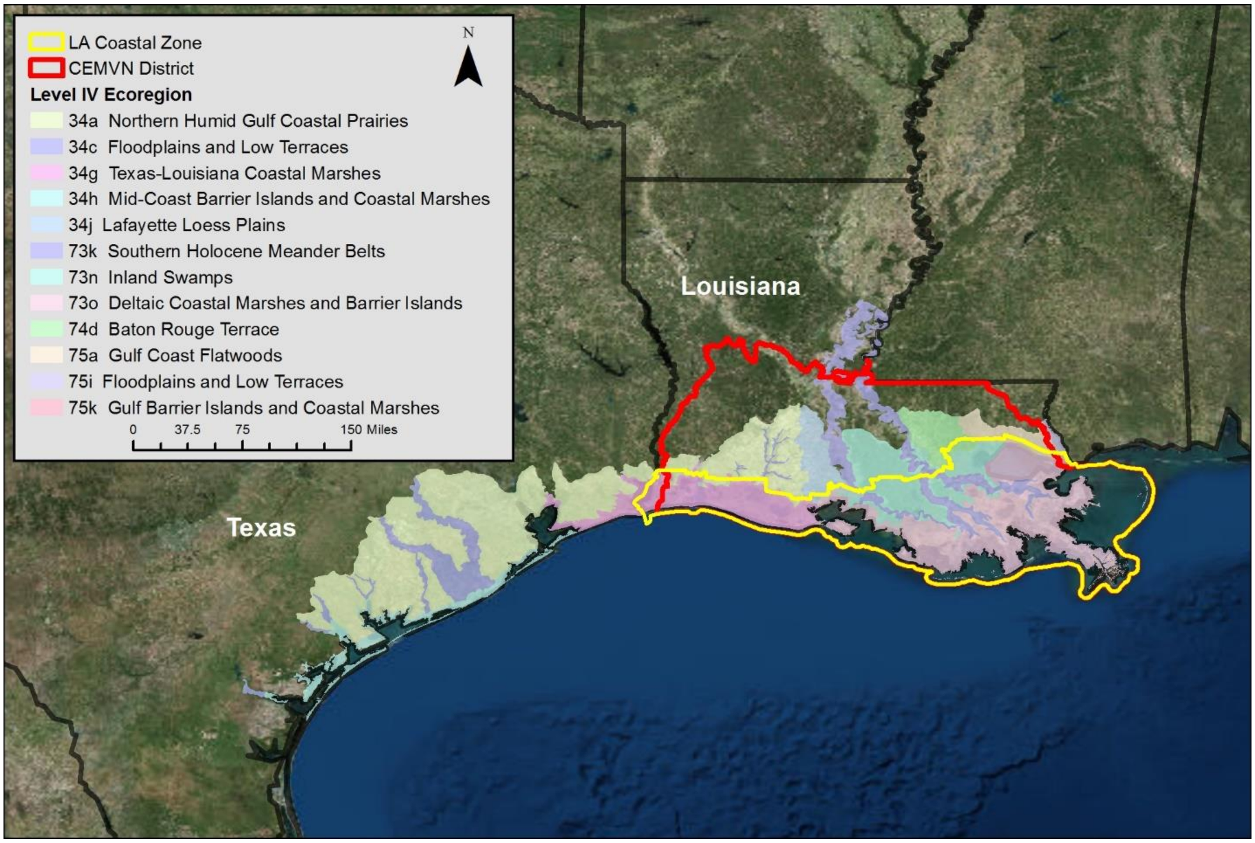


Figure 1. Appropriate marsh habitats within the level IV ecoregions above indicate the USACE Civil Works WVA Coastal Marsh Models (Version 2.0) geographical range of applicability. The Louisiana Coastal Zone boundary was provided by the Louisiana Department of Natural Resources, and the Ecoregions were provided by the Environmental Protection Agency (Daigle et al., 2006; Griffith et al., 2007).

Table 1. Level IV Ecoregions by State for Use in WVA Coastal Marsh Models ver. 2.0

Ecoregion	Description	State
34a	Northern Humid Gulf Coastal Prairies	LA/TX
34c	Floodplains and Low Terraces	TX
34g	Texas-Louisiana Coastal Marshes	LA/TX
34h	Mid-Coast Barrier Islands and Coastal Marshes	TX
34j	Lafayette Loess Plains	LA
73k	Southern Holocene Meander Belts	LA
73n	Inland Swamps	LA
73o	Deltaic Coastal Marshes and Barrier Islands	LA
74d	Baton Rouge Terrace	LA
75a	Gulf Coast Flatwoods	LA
75i	Floodplains and Low Terraces	LA
75k	Gulf Barrier Islands and Coastal Marshes	LA

Minimum Area of Application

Numerous species of wildlife and transient and resident nekton species reside in the tidal marshes of Louisiana and eastern Texas making it extremely difficult to assign an appropriate minimum habitat size for these species. It is important to recognize that tidal marsh landscapes have two major components, the vegetated intertidal zone and the aquatic habitats of pools and channels (Kneib 1997b). Any assessment of the value of a particular habitat should be large enough to include pools and channels if these were to develop in the area being examined. Another important factor influencing the minimum scale to which these models are being applied is the scale of the input data being used. If a project area is less than 25 acres, it is likely that this small area will not reflect the actual land loss in the vicinity. In this event, The Habitat Evaluation Team (HET) should agree on a larger project area that accurately depicts land loss.

II. Variable Selection

Variables for the WVA Marsh Models were selected through a two-part procedure. The first involved a listing of environmental variables thought to be important in characterizing fish and wildlife habitat in coastal marsh ecosystems (See Appendix I on pages 51-55 for a review of the variables' role in providing fish and wildlife habitat). The second part of the selection procedure involved reviewing variables used in species-specific HSI models published by the U.S. Fish and Wildlife Service. Review was limited to HSI models for those fish and wildlife species known to inhabit Louisiana coastal wetlands, and included models for 10 estuarine fish and shellfish, 4 freshwater fish, 12 birds, 3 reptiles and amphibians, and 3 mammals (Table 2). The number of models included from each species group was dictated by model availability.

Selected HSI models were then grouped according to the marsh type(s) used by each species. Because most species are not restricted to one marsh type, most models were included in more than one marsh type group. Within each wetland type group, variables from all models were then grouped according to similarity (e.g., water quality, vegetation, etc.). Each variable was evaluated based on 1) whether it met the variable selection criteria; 2) whether another, more easily measured/predicted variable in the same or a different similarity group functioned as a surrogate; and 3) whether it was deemed suitable for the WVA application (e.g., some freshwater fish model variables dealt with riverine or lacustrine environments). Variables that did not satisfy those conditions were eliminated from further consideration. The remaining variables, still in their similarity groups, were then further eliminated or refined by combining similar variables and/or culling those that were functionally duplicated by variables from other models (i.e., some variables were used frequently in different models in only slightly different format).

Table 2. HSI Models Consulted for Variables for Possible Use in the WVA Marsh Models

Estuarine Fish and Shellfish	Birds	Mammals
pink shrimp	white-fronted goose	mink
white shrimp	clapper rail	muskrat
brown shrimp	great egret	swamp rabbit
spotted seatrout	northern pintail	
Gulf flounder	mottled duck	Freshwater Fish
southern flounder	American coot	channel catfish
Gulf menhaden	marsh wren	largemouth bass
juvenile spot	snow goose	red ear sunfish
juvenile Atlantic croaker	great blue heron	bluegill
red drum	laughing gull	
	red-winged blackbird	
Reptiles and Amphibians	roseate spoonbill	
slider turtle		
American alligator		
bullfrog		

Variables selected from the HSI models were then compared to those identified in the first part of the selection procedure to arrive at a final list of variables to describe wetland habitat quality. That list includes six variables for each marsh type; 1) percent of the wetland covered by emergent vegetation, 2) percent of the open water covered by aquatic vegetation, 3) marsh edge and interspersion, 4) percent of the open water area $\leq$ 1.5 feet deep, 5) salinity, and 6) aquatic organism access.

III. Suitability Index Graph Development

A variety of resources was utilized to construct each SI graph, including the HSI models from which the final list of variables was partially derived, consultation with other professionals and researchers, published and unpublished data and studies, and personal knowledge of Environmental Working Group (EnvWG) and HET members. A review of contemporary, peer-reviewed scientific literature was also conducted for each of the variables, providing ecological support of the form of the SI graph for each of the variables (Appendix I, pages 51-55).

The Suitability Index graphs were developed according to the following assumptions.

Variable V_1 - Percent of wetland area covered by emergent vegetation (Revised September 2017).

Persistent emergent vegetation plays an important role in coastal wetlands by providing foraging, resting, and breeding habitat for a variety of fish and wildlife species and by providing a source of detritus and energy for lower trophic organisms that form the basis of the food chain. Coastal Louisiana is losing marsh faster than any other place in the US. Approximately one football field of marsh becomes water about every 34 minutes with rapid loss to about every 100 minutes at slower rates (Couvillion et al. 2017). Coastwide rates of wetland change have varied from -83.5 +/- 11.8 km^2 per year to -28.01 +/- 16.37 km^2 per year.

Battelle's recommendations from Comment 10 pertaining to V1 (B-15; Battelle Memorial Institute 2010; Appendix IV):

> *Change V1 to select an SI [suitability index] value of 1.0 when cover is between 60 and 80% emergent vegetation, as discussed in the model discussion or as the scientific literature supports for any given marsh ecosystem type.*

Consistent with Battelle's comment regarding V1 variable (% coverage emergent vegetation), V1 was modified for fresh/intermediate, brackish, and saline WVA Marsh Models specifying that 60 to 80% emergent vegetation has an SI of 1.0. In addition, the boundary conditions for 0 and 100% emergent vegetation were revised consistent with a sensitivity analysis and the most recent scientific information.

To update the 0% emergent vegetation the following were considered:

1) Open water conditions do provide some habitat benefit, and
2) A sensitivity analysis compared 0.1 and 10^{-10} for this boundary condition and found that it did not significantly alter which project was selected (See Appendix III for more information).

To update the SI value for 100% emergent vegetation we examined and averaged 22 different SI values for aquatic and terrestrial species that utilize coastal marsh in Louisiana (Roy 2010; Minello and Rozas 2002). See Appendix II (pages 56-59) for supporting information and a literature review.

<u>Variable V_2 - Percent of open water area covered by aquatic vegetation (Revised September 2017).</u>

Battelle's recommendations from Comment 10 pertaining to V2 (B-15, Battelle Memorial Institute 2010; Appendix IV, pages 70-71):

> *Change V2 – this variable only takes an SI value of 1.0 at 100% cover of SAV [sub aquatic vegetation] in areas of open water. This is unreasonable and it is unlikely that open water will ever have the optimal conditions. Further research is necessary and the SI optimum should be justified using the scientific literature, noting that a goal-oriented SI of 1.0 for 100% cover is still possible.*

An adjustment of V2 was made by assigning an optimal value (i.e. SI = 1) to habitats with SAV coverage less than or equal to 100% for three reasons:

1. Battelle (2010) suggested expanding optimal conditions to include values less than 100% coverage, as 100% coverage may be "unreasonable."
2. Measuring SAV is difficult and problematic (e.g., Merino et al, 2005).
3. For some organisms and marshes, 100% coverage is not optimal (e.g., juvenile Red Drum; Buckley 1984).

To update the SI value for aquatic vegetation coverage, a literature review was performed. When available, information on aquatic and terrestrial organisms that utilize coastal marsh in Louisiana was incorporated. In addition, we examined and averaged seven different SI values from species specific HSIs for aquatic and terrestrial species that utilize coastal marsh in Louisiana to determine the most appropriate SI graph for aquatic vegetation coverage (Roy 2010, USFWS ESM 103). See Appendix II (pages 56-59) for supporting information and a literature review.

<u>Variable V_3 - Marsh edge and interspersion (Revised September 2017).</u>

This variable takes into account the relative juxtaposition of marsh and open water for a given marsh:open water ratio, and is measured by comparing the project area to sample illustrations (refer to pages 33-40) depicting different degrees of interspersion. Interspersion is especially important when considering the value of an area as foraging and nursery habitat for freshwater and estuarine fish and shellfish, and associated predators (e.g., wading birds); the marsh/open water interface represents an ecotone where prey species often concentrate, and where post-larval and juvenile organisms can find cover. Isolated marsh ponds are often more productive in terms of aquatic vegetation than are larger ponds due to decreased turbidity, and, thus, may provide more suitable waterfowl habitat. However, certain interspersion classes can be indicative of marsh degradation, a factor taken into consideration in assigning suitability indices to the various interspersion classes.

Battelle's recommendations from Comment 10 pertaining to V3 (B-15 from Battelle Comment; Appendix IV, pages 70-71):

> *Change V3 so that a marsh with 100% emergent coverage and no interspersion cannot receive an SI value of 1.0*

The updates to V3 were based upon the Battelle comment and an attempt to match this SI as close to the updated V1. Percent marsh coverage is closely related to interspersion, so it was assumed here that the SI values for V3 should reflect the literature review from V1. Specifically, an SI value of 1.0 was applied to interspersion Class 2, SI=0.5 for Class 3, and SI=0.75 for Class 1. Interspersion Class 4 and 5 were unchanged and remain 0.2 and 0.1, respectively.

Variable V_4 - Percent of open water area ≤ 1.5 feet deep in relation to marsh surface.

Shallow water areas are assumed to be more biologically productive than deeper water due to a general reduction in sunlight, oxygen, and temperature as water depth increases. Also, shallower water provides greater bottom accessibility for certain species of waterfowl, better foraging habitat for wading birds, and more favorable conditions for aquatic plant growth. Optimal open water conditions in a fresh/intermediate marsh are assumed to occur when 80 to 90 percent of the open water area is less than or equal to 1.5 feet deep. The value of deeper areas in providing drought refugia for fish, alligators and other marsh life is recognized by assigning an SI=0.6 (i.e., sub-optimal) if all of the open water is less than or equal to 1.5 feet deep.

Shallow water areas in brackish marsh habitat are also important. However, brackish marsh generally exhibits deeper open water areas than fresh marsh due to tidal scouring. Therefore, the SI graph is constructed so that lower percentages of shallow water receive higher SI values relative to fresh/intermediate marsh. Optimal open water conditions in a brackish marsh are assumed to occur when 70 to 80 percent of the open water area is less than or equal to 1.5 feet deep.

The SI graph for the saline marsh model is similar to that for brackish marsh model, where optimal conditions are assumed to occur when 70 to 80 percent of the open water area is less than or equal to 1.5 feet deep. However, at 100 percent shallow water, the saline graph yields an SI= 0.5 rather than 0.6 as for the brackish model. That change reflects the increased abundance of tidal channels and generally deeper water conditions prevailing in a saline marsh due to increased tidal influences.

Variable V_5 - Salinity

For all models the minimum salinity is set to 0 ppt. For fresh, intermediate, brackish, and saline marsh the maximum salinity is 5, 7, 16, and 35 ppt respectively. Overlapping of salinity occurs in the deltaic system. In the marsh models, the range of optimal condition distinguishes fresh from intermediate marsh with all other variables remaining the same. The percent land cover from the entire project area for either type of marsh determines the habitat units.

It is assumed that periods of high salinity are most detrimental in a fresh/intermediate marsh when they occur during the growing season (defined as March through November, based on dates of first and last frost contained in Natural Resource Conservation Service soil surveys for coastal Louisiana). Therefore, mean salinity during the growing season (March-November) is used as the salinity parameter for the fresh/intermediate marsh model. Optimal conditions in fresh marsh are assumed to occur when mean salinity during the growing season is 0.5 parts per thousand (ppt) or less. Optimal conditions in intermediate marsh are assumed to occur when mean salinity during the growing season is 2.5 ppt or less. In USACE civil works projects, the percent of fresh to intermediate marsh is a reflection of the overall project area.

For the brackish and saline marsh models, average annual salinity is used as the salinity parameter. The SI graph for brackish marsh is constructed to represent optimal conditions when salinities are between 0 ppt and 10 ppt. Average annual salinities below 5 ppt will effectively define a marsh as fresh or intermediate, not brackish. However, the SI graph makes allowances for lower salinities to account for occasions when there is a trend of decreasing salinities through time toward a more intermediate condition. Implicit in keeping the graph at optimum for salinities less than 5 ppt is the assumption that lower salinities are not detrimental to a brackish marsh. However, average annual salinities greater than 10 ppt are assumed to be progressively more harmful to brackish marsh vegetation. Average annual salinities greater than 16 ppt are assumed to be representative of those found in a saline marsh, and thus are not considered in the brackish marsh model.

The SI graph for the saline marsh model is constructed to represent optimal salinity conditions between 0 ppt and 21 ppt. Average annual salinities below 10 ppt will effectively define a marsh as brackish, not saline. However, the suitability index graph makes allowances for lower salinities to account for occasions when there is a trend of decreasing salinities through time toward a more brackish condition. Implicit in keeping the graph at optimum for salinities less than 10 ppt is the assumption that lower salinities are not detrimental to saline marsh. Average annual salinities greater than 21 ppt are assumed to be slightly stressful to saline marsh vegetation.

Variable V_6 - Aquatic organism access

Access by aquatic organisms, particularly estuarine-dependent fishes and shellfishes, is considered to be a critical component in assessing the quality of a given marsh system. Additionally, a marsh with a relatively high degree of access by default also exhibits a relatively high degree of hydrologic connectivity with adjacent systems, and therefore may be considered to contribute more to nutrient exchange than would a marsh exhibiting a lesser degree of access. The SI for V_6 is determined by calculating an "access value" based on the interaction between the percentage of the project area wetlands considered accessible by aquatic organisms during normal tidal fluctuations, and the type of man-made structures (if any) across identified points of ingress/egress (bayous, canals, etc.). Standardized procedures for calculating the Access Value have been established (pages 41-43). It should be noted that access ratings for man-made structures were determined by consensus among EnvWG members and that scientific research has not been conducted to determine the actual access value for each of those structures. Optimal conditions are assumed to exist when all of the study area is accessible and the access points are entirely open and unobstructed.

A fresh marsh with no access is assigned an SI=0.3, reflecting the assumption that, while fresh marshes are important to some species of estuarine-dependent fishes and shellfish, such a marsh lacking access continues to provide benefits to a wide variety of other wildlife and fish species, and is not without habitat value. An intermediate marsh with no access is assigned an SI=0.2, reflecting that intermediate marshes are somewhat more important to estuarine-dependent organisms than fresh marshes. The general rationale and procedure behind the V_6 Suitability Index graph for the brackish marsh model is identical to that established for the fresh/intermediate model. However, brackish marshes are assumed to be more important as habitat for estuarine-dependent fish and shellfish than fresh/intermediate marshes. Therefore, a brackish marsh providing no access is assigned an SI of 0.1. The Suitability Index graph for aquatic organism access in the saline marsh model is the same as that in the brackish marsh model.

IV. Habitat Suitability Index Formulas

For all WVA Marsh Models, V_1 receives the strongest weighting (Table 3). The relative weights of V_1, V_2, and V_6 differ by WVA Marsh Model to reflect differing levels of importance for those variables between the marsh types. For example, the amount of aquatic vegetation was deemed more important in a fresh/intermediate marsh than in a saline marsh, due to the relative contributions of aquatic vegetation between the two marsh types in terms of providing food and cover. Therefore, V_2 receives more weight in the fresh/intermediate HSI formula than in the saline HSI formula. Similarly, the degree of aquatic organism access was considered more important in a saline marsh than a fresh/intermediate marsh, and V_6 receives more weight in the saline HSI formula than in the fresh/intermediate formula. The Habitat Suitability Index formulas were developed by consensus among the EnvWG members.

In order to ensure that the value of open water components of the marsh environments to fish and wildlife communities is appropriately represented in the model, the WVA Marsh Models use a spilt model approach. The split model utilizes two HSI formulas for each marsh type; one HSI formula characterizes the emergent habitat within the project area and another HSI formula characterizes the open water habitat. The HSI formula for the emergent habitat contains only those variables important in assessing habitat quality for marsh (i.e., V_1, V_3, V_5, and V_6). Likewise, the open water HSI formula contains only those variables important in characterizing the open water habitat (i.e., V_2, V_3, V_4, V_5, and V_6). Individual HSI formulas were developed for marsh and open water habitats for each marsh type.

As with the development of a single HSI model for each marsh type, the split models follow the same conventions for weighting and grouping of variables as previously discussed.

V. Benefit Assessment

As previously discussed, the WVA Marsh Models are split into marsh and open water components and an HSI is determined for both. Subsequently, net AAHUs are also determined for the marsh and open water habitats within the project area. Net AAHUs for the marsh and open water habitat components must be combined to determine total net benefits for the project.

The weighting of the open water and marsh components reflects the relative value of these environments for fish and wildlife in each marsh type, A weighted average of the net benefits (net AAHUs) for marsh and open water is calculated with the marsh AAHUs weighted proportionately higher than the open water AAHUs. The weighted formulas to determine net AAHUs for each marsh type are shown below. Table 3 shows the overall value of each of the variables after weighting.

$$\text{Fresh/Intermediate Marsh: } \frac{2.1(\text{Marsh AAHUs}) + \text{Open Water AAHUs}}{3.1}$$

$$\text{Brackish Marsh: } \frac{2.6(\text{Marsh AAHUs}) + \text{Open Water AAHUs}}{3.6}$$

$$\text{Saline Marsh: } \frac{3.5(\text{Marsh AAHUs}) + \text{Open Water AAHUs}}{4.5}$$

Table 3. The relative contribution (%) of each of the variables to the Marsh and Water HSI equation and the overall (total) HSI equation.

	Fresh/Intermediate			Brackish			Saline		
Variable	Marsh	Water	Total	Marsh	Water	Total	Marsh	Water	Total
V1	64.8%	0.0%	43.9%	59.8%	0.0%	43.2%	58.3%	0.0%	45.4%
V2	0.0%	58.3%	18.8%	0.0%	46.7%	13.0%	0.0%	22.2%	4.9%
V3	11.1%	7.4%	9.9%	11.1%	7.4%	10.1%	11.1%	7.4%	10.3%
V4	0.0%	7.4%	2.4%	0.0%	7.4%	2.1%	0.0%	7.4%	1.6%
V5	11.1%	7.4%	9.9%	11.1%	7.4%	10.1%	11.1%	7.4%	10.3%
V6	13.0%	19.4%	15.1%	17.9%	31.1%	21.6%	19.4%	55.6%	27.5%

WETLAND VALUE ASSESSMENT COASTAL MARSH COMMUNITY MODEL

Fresh/Intermediate Marsh

Vegetation:

Variable V_1 Percent of wetland area covered by emergent vegetation.

Variable V_2 Percent of open water area covered by aquatic vegetation.

Interspersion:

Variable V_3 Marsh edge and interspersion.

Water Depth:

Variable V_4 Percent of open water area $\leq$ 1.5 feet deep, in relation to marsh surface.

Water Quality:

Variable V_5 Mean high salinity during the growing season (March through November).

Aquatic Organism Access:

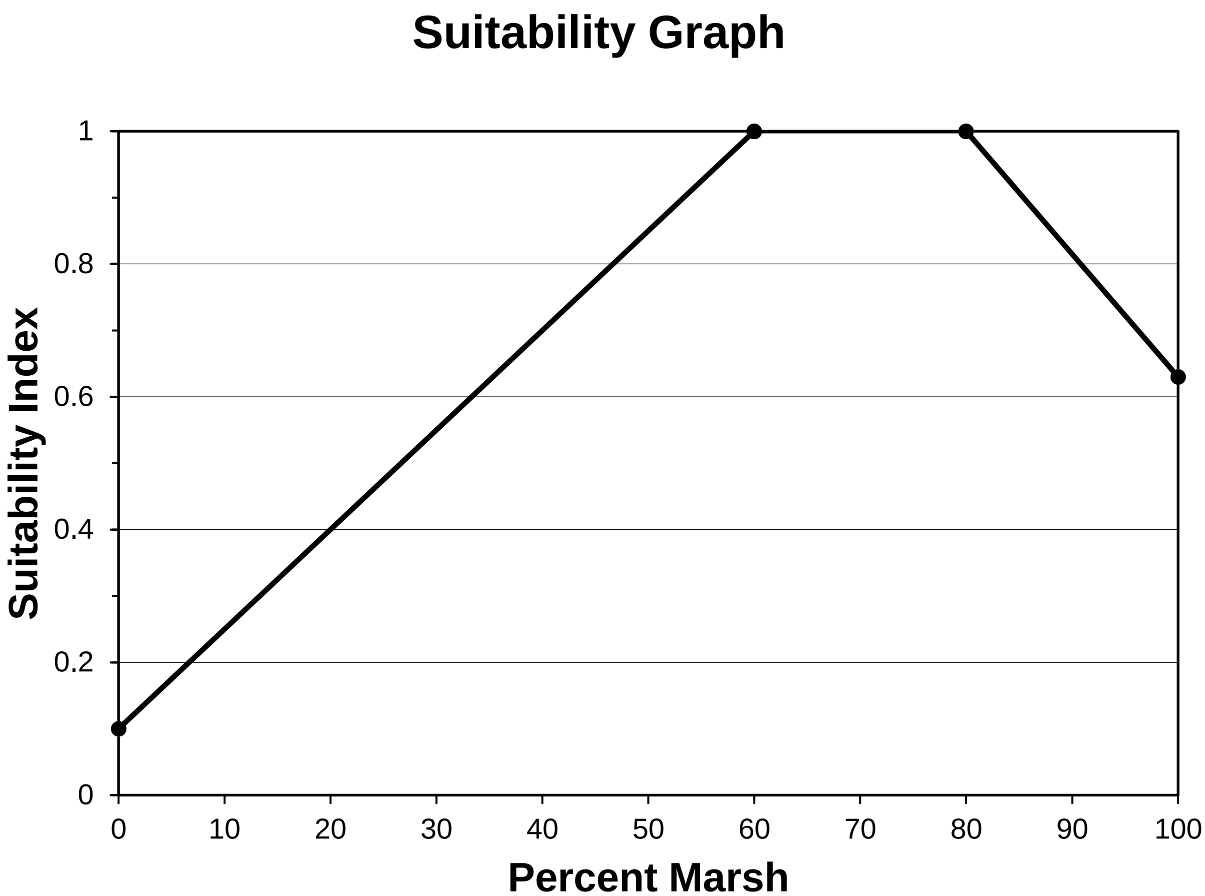
Variable V_6 Aquatic organism access.

HSI Calculations:

$$Marsh\ HSI = \left[\{3.5 \times (SIV_1^5 \times SIV_6)^{(1/6)}\} + (SIV_3 + SIV_5)/2\right] \Big/ 4.5$$

$$Open\ Water\ HSI = \left[\{3.5 \times (SIV_2^3 \times SIV_6)^{(1/4)}\} + (SIV_3 + SIV_4 + SIV_5)/3\right] \Big/ 4.5$$

Variable V_1 Percent of wetland area covered by emergent vegetation (Revised September 2017).



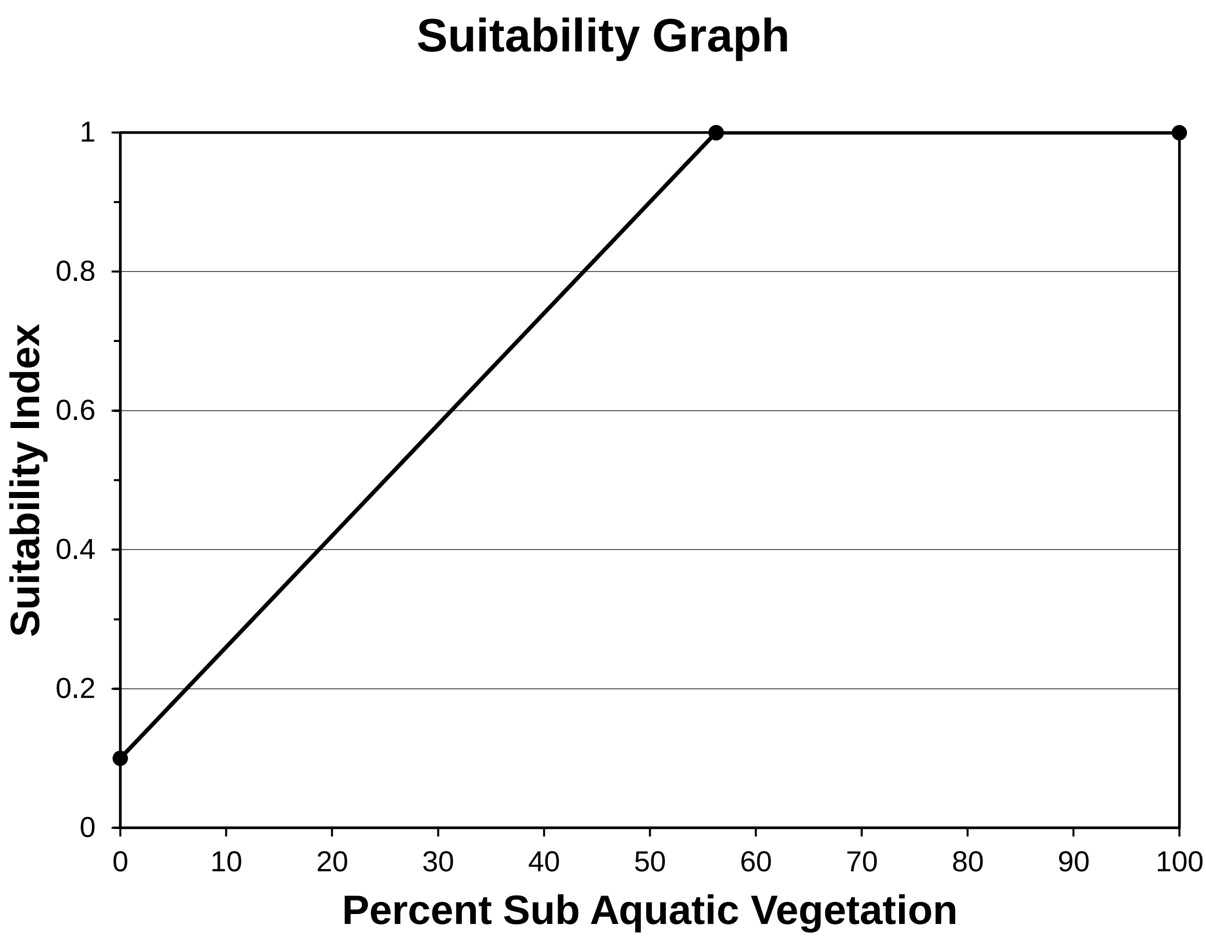
Line Formula

If $0 \leq \% < 60\%$, then SI = (0.015 * %) + 0.1

If $60 \leq \% \leq 80\%$, then SI = 1

If % > 80, then SI = (-0.0185 * %) + 2.48

Variable V_2 Percent of open water area covered by aquatic vegetation (Revised September 2017).

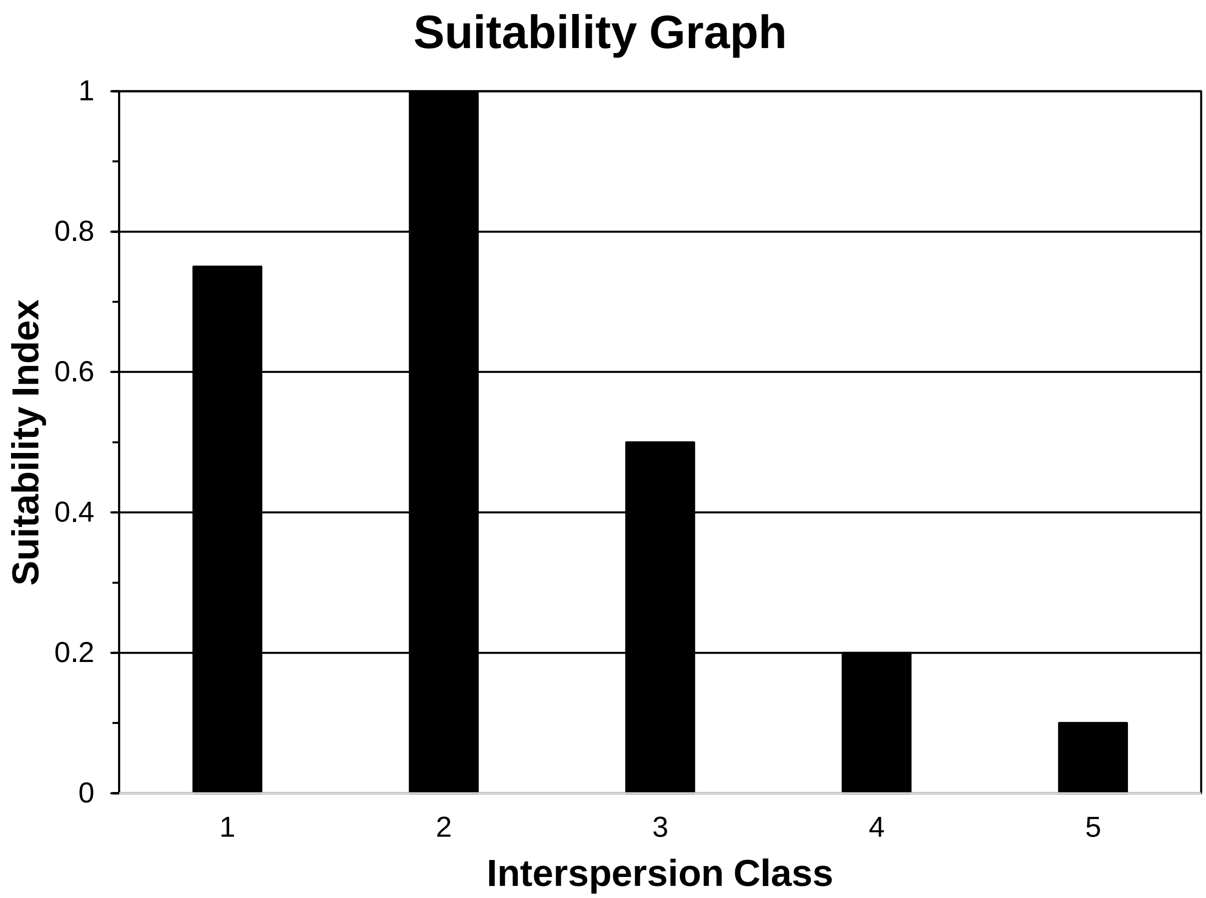


Line Formula

If $0 \leq \% < 56.25\%$, then SI = (0.016 * %) + 0.1

If $\% \geq 56.25\%$, then SI = 1

Variable V_3 Marsh edge and interspersion (Revised September 2017).

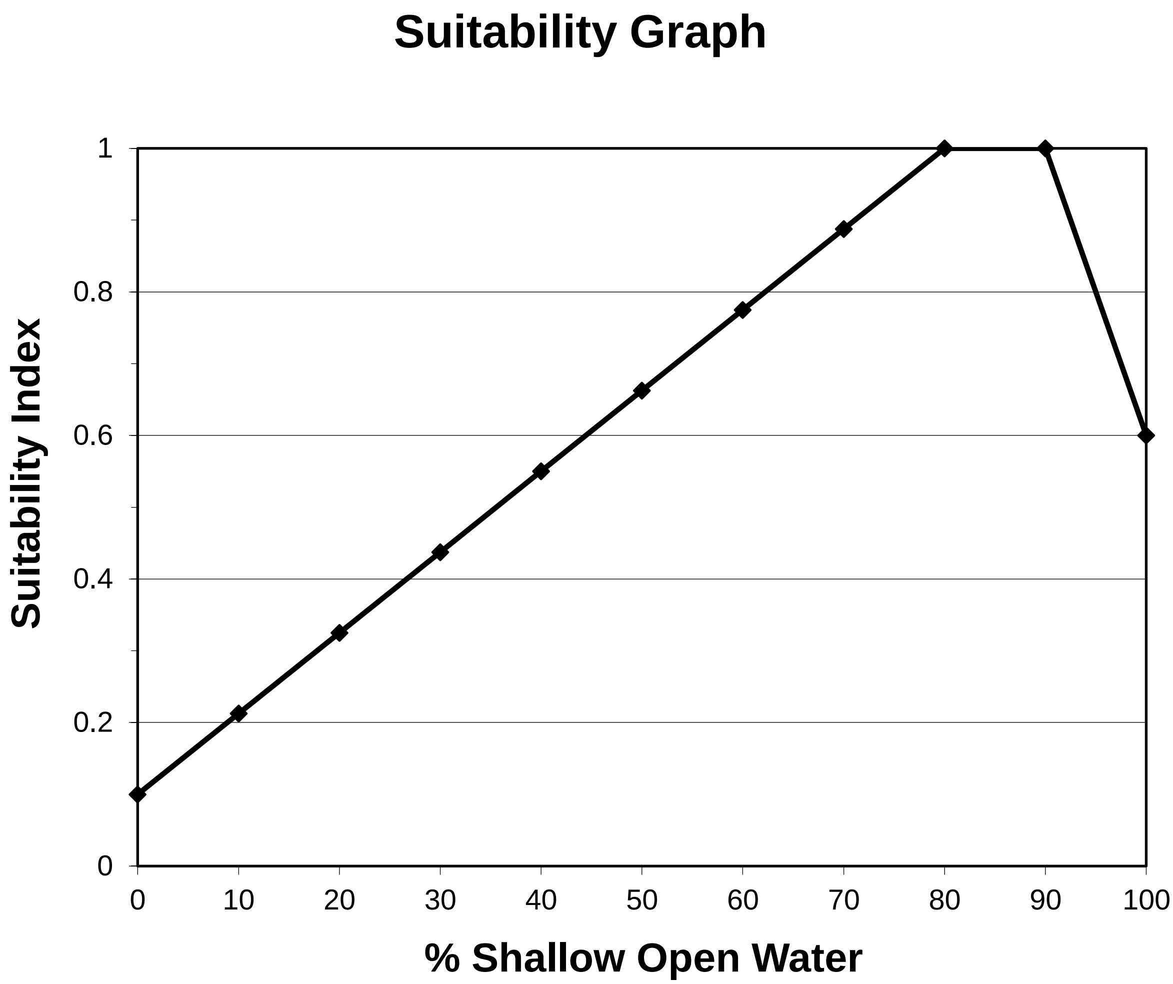


Instructions for Calculating the SI for Variable V_3:

1. Refer to pages 33-40 for examples of the different interspersion classes.

2. Estimate percent of project area in each class.

Variable V_4 Percent of open water area $\leq$1.5 feet deep, in relation to the marsh surface.



Line Formulas

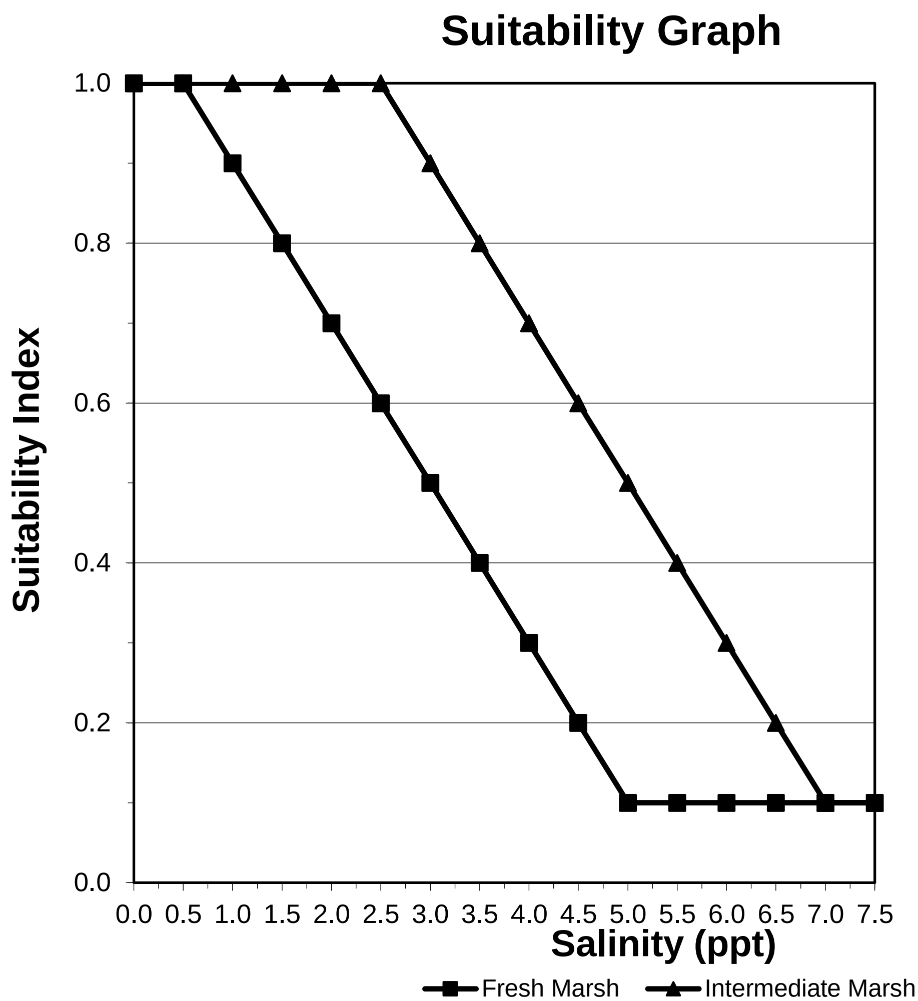
If $0 \leq \% < 80$, then SI = (0.01125 * %) + 0.1

If $80 \leq \% \leq 90$, then SI = 1.0

If % > 90, then SI = (-0.04 * %) + 4.6

FRESH/INTERMEDIATE MARSH

Variable V_5 Mean salinity during the growing season (March to November).

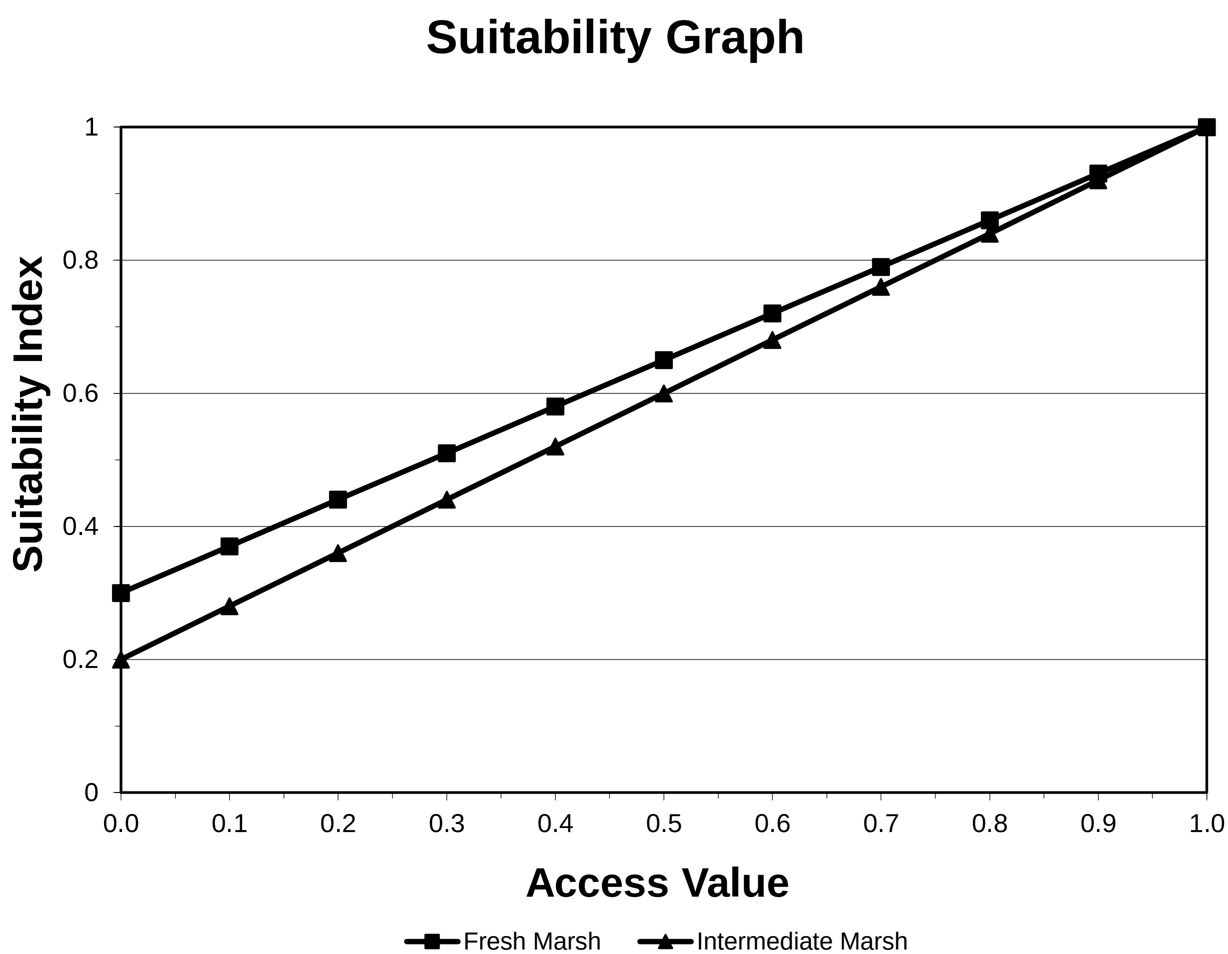


Line Formulas

Fresh Marsh
If 0 < ppt <= 0.5, then SI = 1.0
If ppt > 0.5, and ppt < 5.5, then SI = (-0.20 * ppt) + 1.10
If ppt >= 5.5 then SI = 0.1

Intermediate Marsh
If 0 < ppt <= 2.5, then SI = 1.0
If ppt > 2.5, and ppt <7.5, then SI = (-0.20 * ppt) + 1.50
If ppt >= 7.5 then SI = 0.1

Variable V_6 Aquatic organism access.



Line Formulas

Fresh Marsh SI = (0.7 * Access Value) + 0.3

Intermediate Marsh SI = (0.8 * Access Value) + 0.2

<u>NOTE</u>: Access Value = P * R, where "P" = percentage of wetland area considered accessible by estuarine organisms during normal tidal fluctuations, and "R" = Structure Rating.

Refer to pages 41-43 for complete information on calculating the Access Value.

WETLAND VALUE ASSESSMENT COASTAL MARSH COMMUNITY MODEL

<u>Brackish Marsh</u>

Vegetation:

Variable V_1 Percent of wetland area covered by emergent vegetation.

Variable V_2 Percent of open water area covered by aquatic vegetation.

Interspersion:

Variable V_3 Marsh edge and interspersion.

Water Depth:

Variable V_4 Percent of open water area $\leq$ 1.5 feet deep, in relation to marsh surface.

Water Quality:

Variable V_5 Average annual salinity.

Aquatic Organism Access:

Variable V_6 Aquatic organism access.

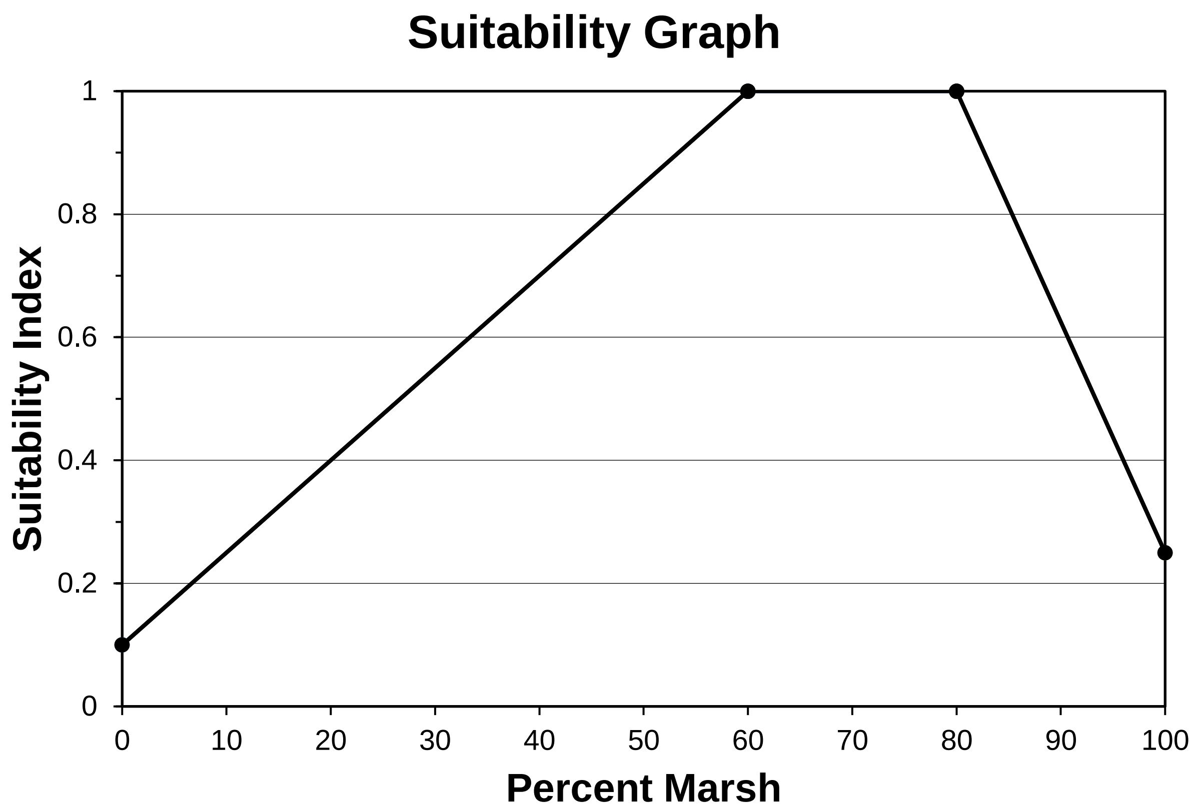
HSI Calculations:

$$\textit{Marsh HSI} = \left[\{3.5 \times (SIV_1^{5} \times SIV_6^{1.5})^{(1/6.5)}\} + (SIV_3 + SIV_5)/2\right] \Big/ 4.5$$

$$\textit{Open Water HSI} = \left[\{3.5 \times (SIV_2^{3} \times SIV_6^{2})^{(1/5)}\} + (SIV_3 + SIV_4 + SIV_5)/3\right] \Big/ 4.5$$

BRACKISH MARSH

Variable V_1 Percent of wetland area covered by emergent vegetation (Revised September 2017).



Line Formula

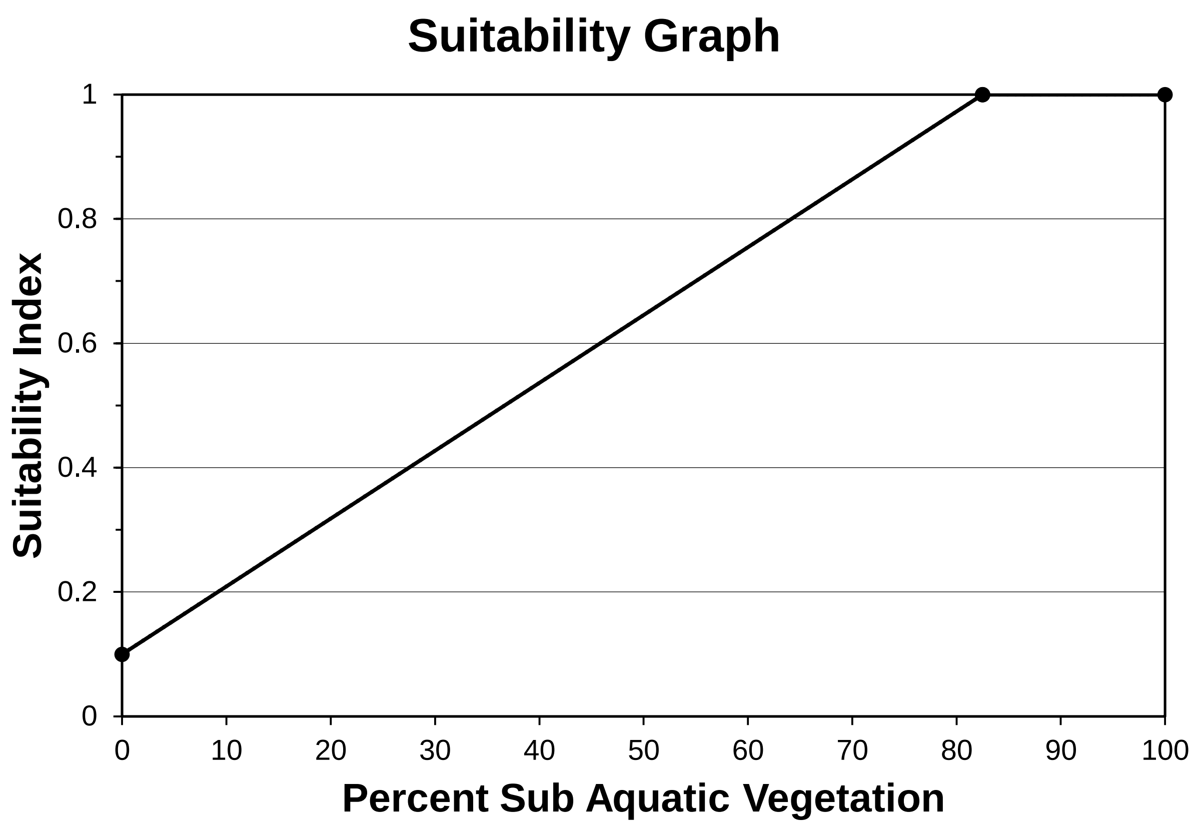
If $0 \leq \% < 60\%$, then SI = (0.015 * %) + 0.1

If $60\% \leq \% \leq 80\%$, then SI = 1.0

If % > 80%, then SI = (-0.0375 * %) + 4

BRACKISH MARSH

Variable V_2 Percent of open water area covered by aquatic vegetation (Revised September 2017).

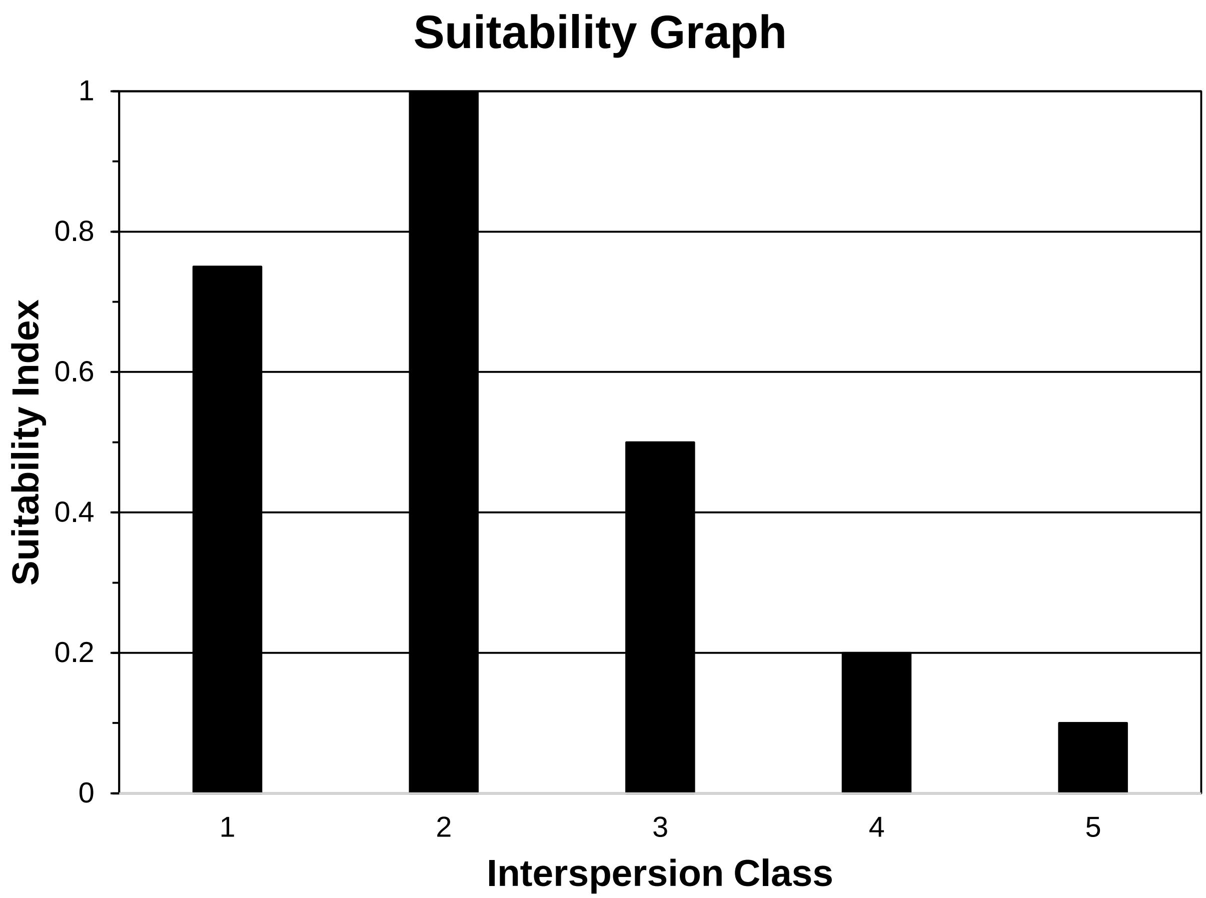


Line Formula

If $0 \leq \% < 82.5\%$, then SI = (0.0109 * %) + 0.1

If $\% \geq 82.5\%$, then SI = 1

Variable V_3 Marsh edge and interspersion. (Revised September 2017).



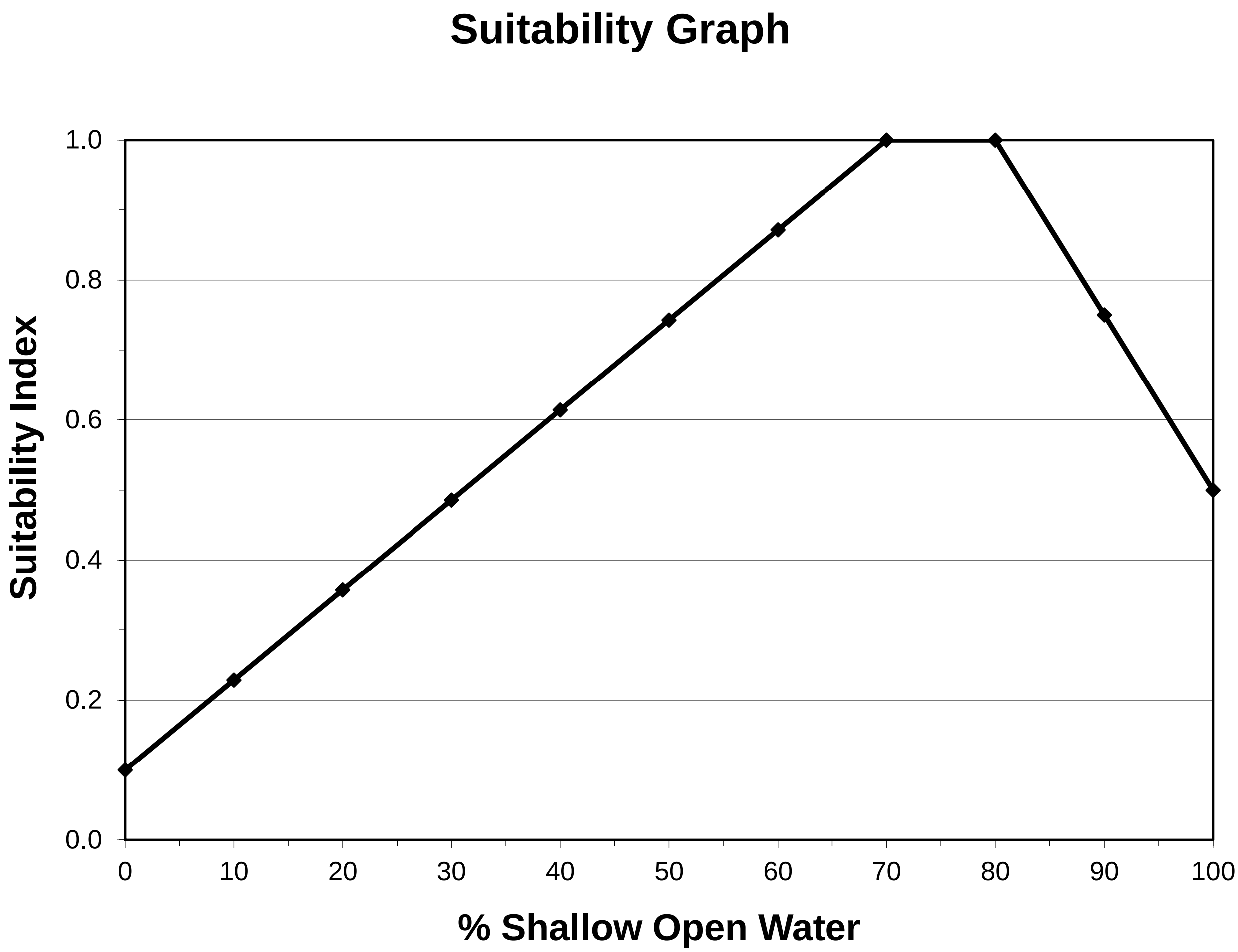
Instructions for Calculating SI for Variable V_3:

1. Refer to pages 33-40 for examples of the different interspersion classes.

2. Estimate the percent of project area in each class.

BRACKISH MARSH

Variable V_4 Percent of open water area $\leq$ 1.5 feet deep, in relation to marsh surface.



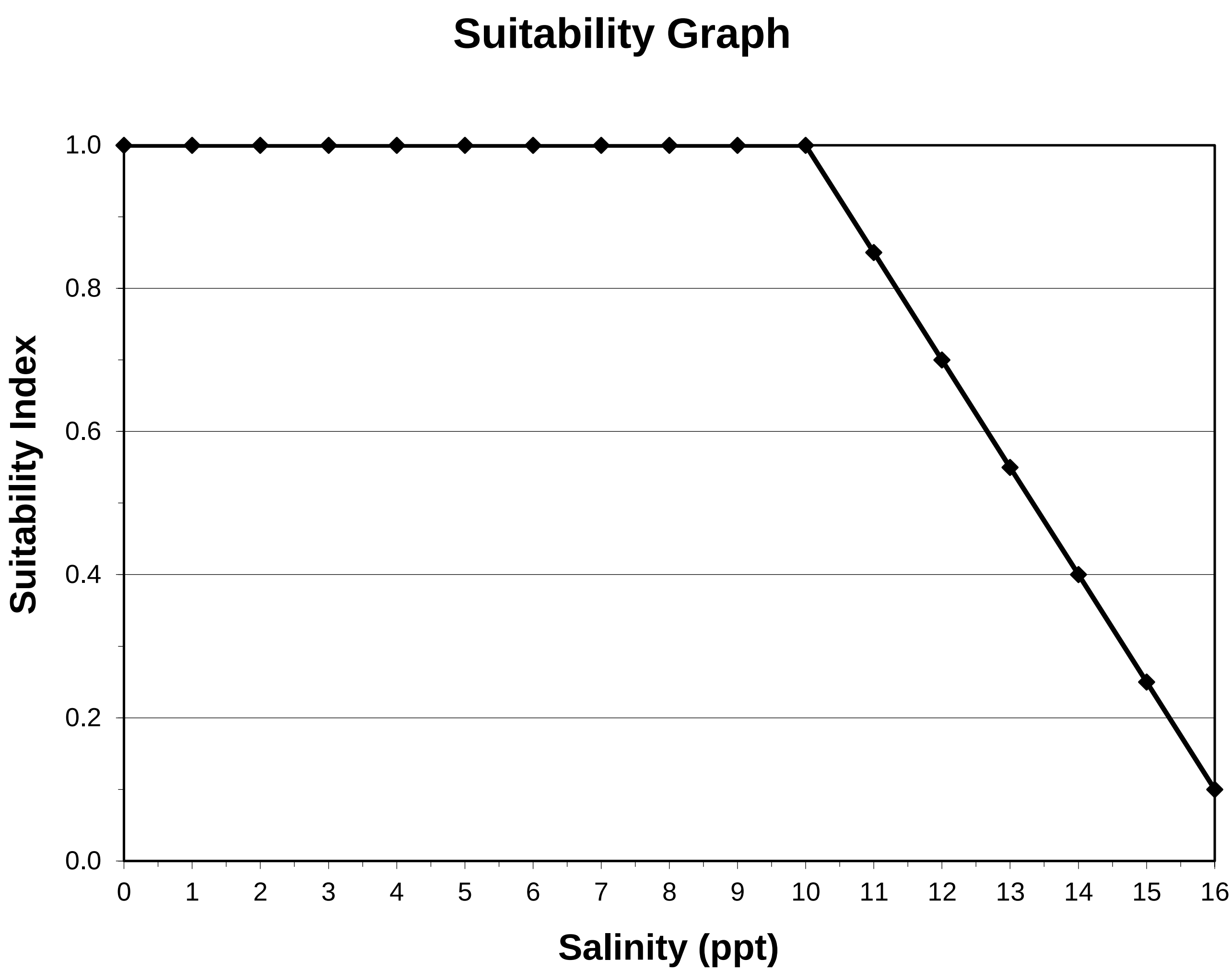
Line Formulas

If $0 \leq \% < 70$, then SI = (0.01286 * %) + 0.1

If $70 \leq \% \leq 80$, then SI = 1.0

If % > 80, then SI = (-0.02 * %) + 2.6

Variable V_5 Average annual salinity.

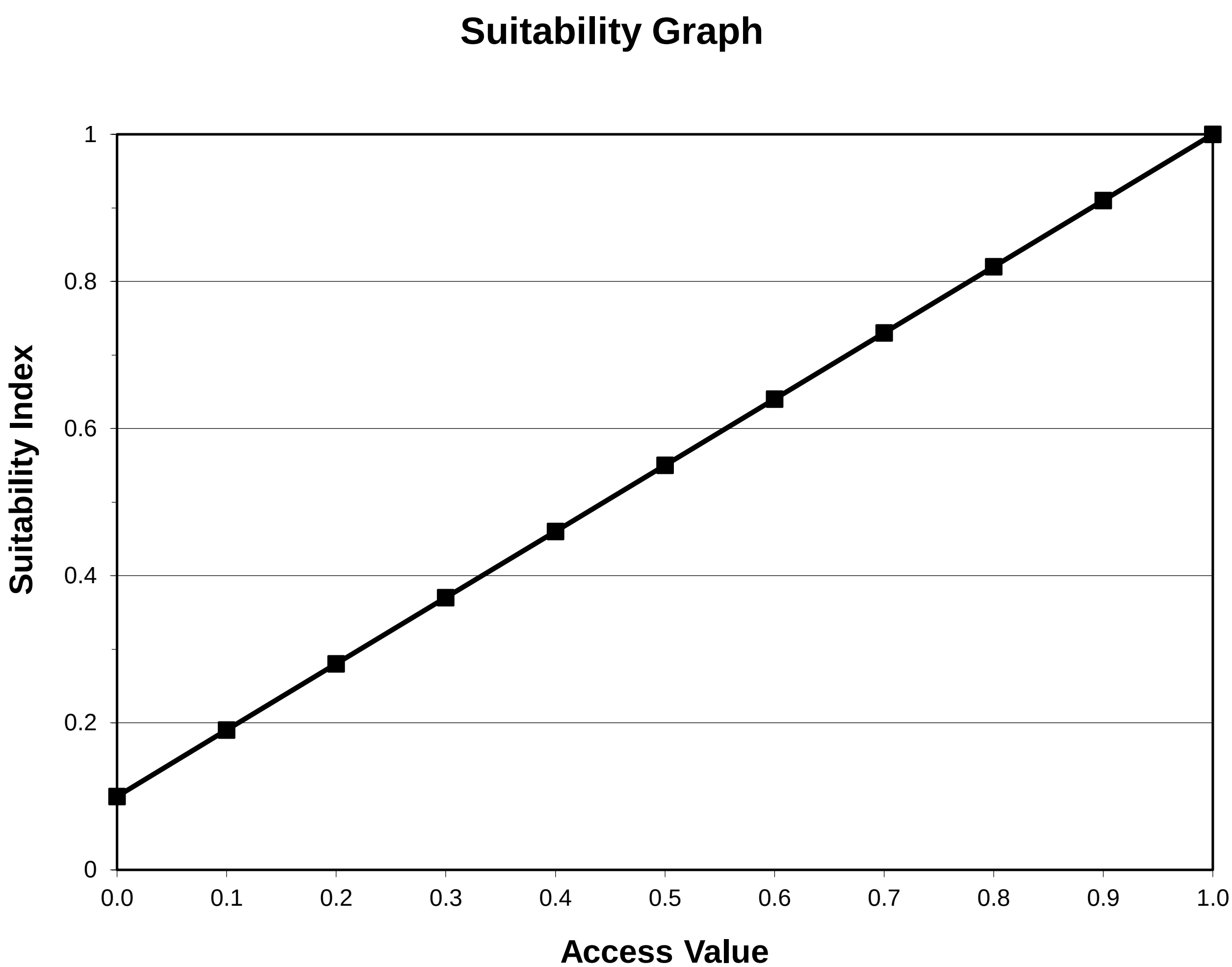


Line Formulas

If $0 \leq ppt \leq 10$, then SI = 1.0

If ppt > 10, then SI = (-0.15 * ppt) + 2.5

Variable V_6 Aquatic organism access.



Line Formula

SI = (0.9 * Access Value) + 0.1

Note: Access Value = P * R, where "P" = percentage of wetland area considered accessible by estuarine organisms during normal tidal fluctuations, and "R" = Structure Rating.

Refer to pages 41-43 for complete information on calculating the Access Value.

WETLAND VALUE ASSESSMENT COASTAL MARSH COMMUNITY MODEL

Saline Marsh

Vegetation:

Variable V_1 Percent of wetland area covered by emergent vegetation.

Variable V_2 Percent of open water area covered by aquatic vegetation.

Interspersion:

Variable V_3 Marsh edge and interspersion.

Water Depth:

Variable V_4 Percent of open water area $\leq$ 1.5 feet deep, in relation to marsh surface.

Water Quality:

Variable V_5 Average annual salinity.

Aquatic Organism Access:

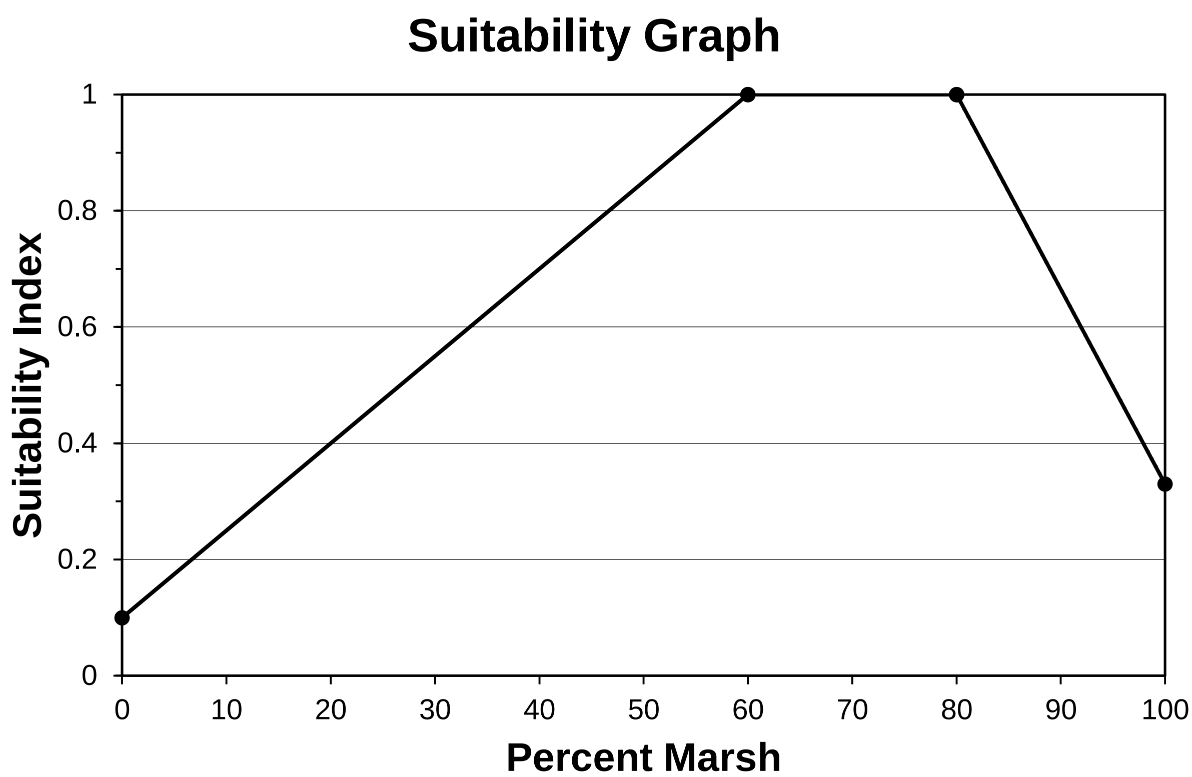
Variable V_6 Aquatic organism access.

HSI Calculation:

$$Marsh\ HSI = \left[\{3.5 \times (SIV_1^{3} \times SIV_6)^{(1/4)}\} + (SIV_3 + SIV_5)/2\right] \Big/ 4.5$$

$$Open\ Water\ HSI = \left[\{3.5 \times (SIV_2 \times SIV_6^{2.5})^{(1/3.5)}\} + (SIV_3 + SIV_4 + SIV_5)/3\right] \Big/ 4.5$$

Variable V_1 Percent of wetland area covered by emergent vegetation (Revised September 2017).



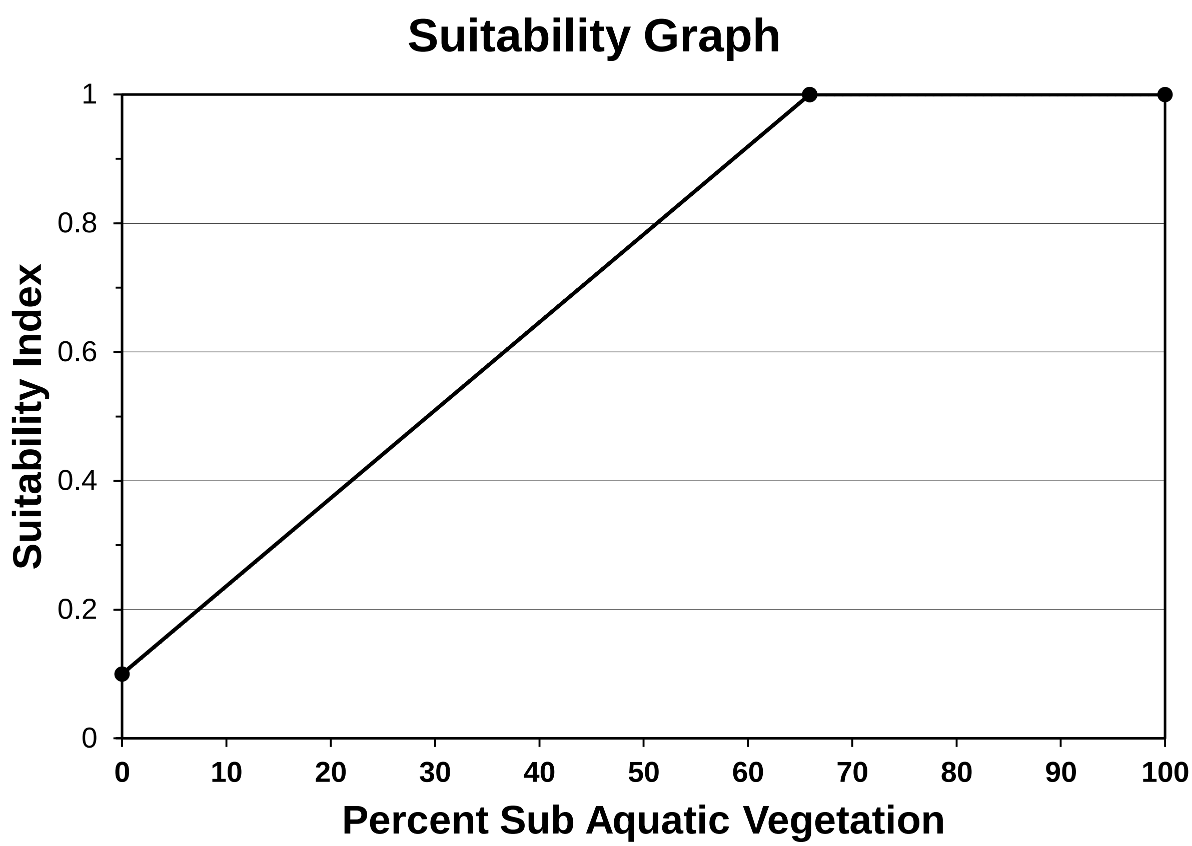
Line Formula

If $0 \leq \% < 60\%$, then SI = (0.015 * %) + 0.1

If $60\% \leq \% \leq 80\%$, then SI = 1.0

If % > 80%, then SI = (-0.0335 * %) + 3.68

Variable V_2 Percent of open water area covered by aquatic vegetation (Revised September 2017).

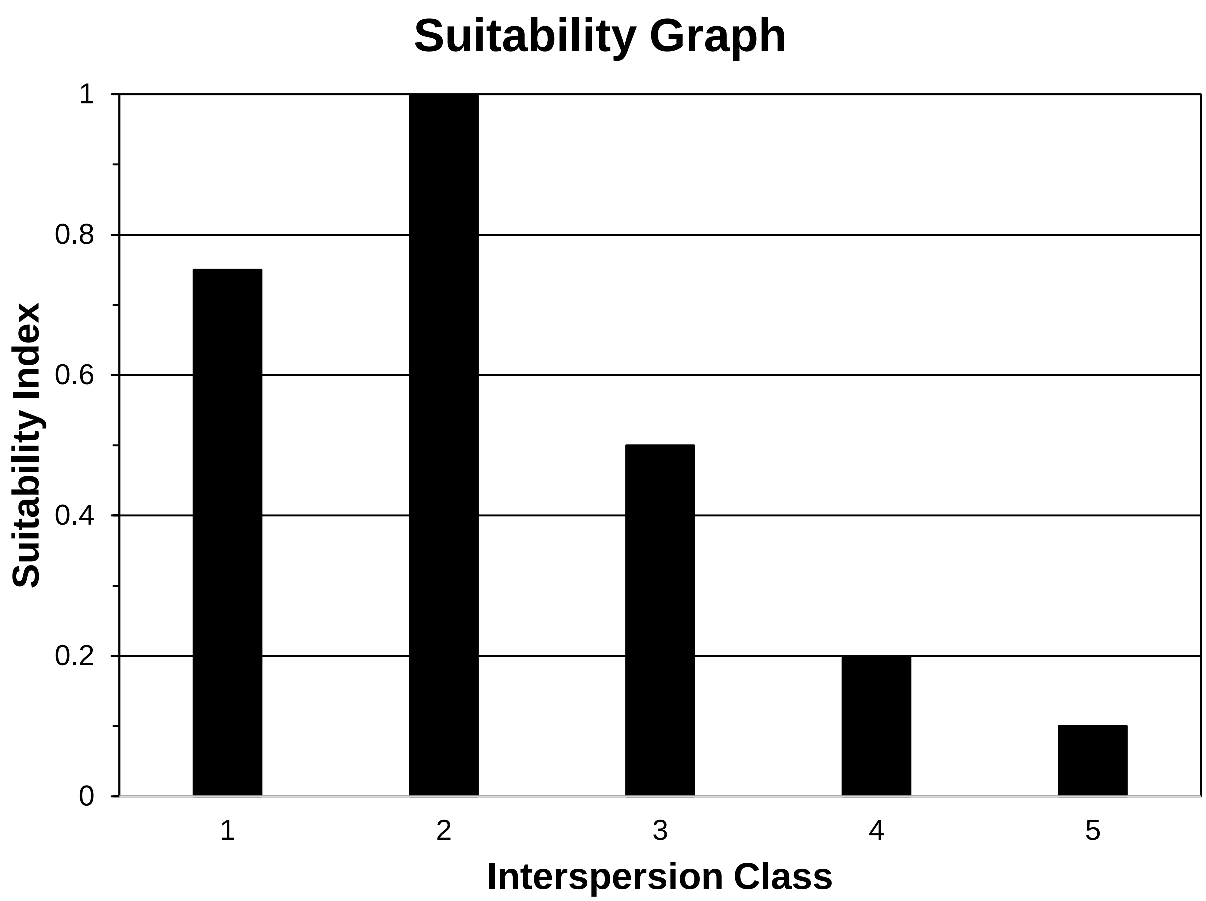


Line Formula

If $0 \leq \% \leq 65.91\%$, then SI = (0.0137 * %) + 0.1

If % > 65.91%, then SI = 1

Variable V_3 Marsh edge and interspersion. (Revised September 2017).



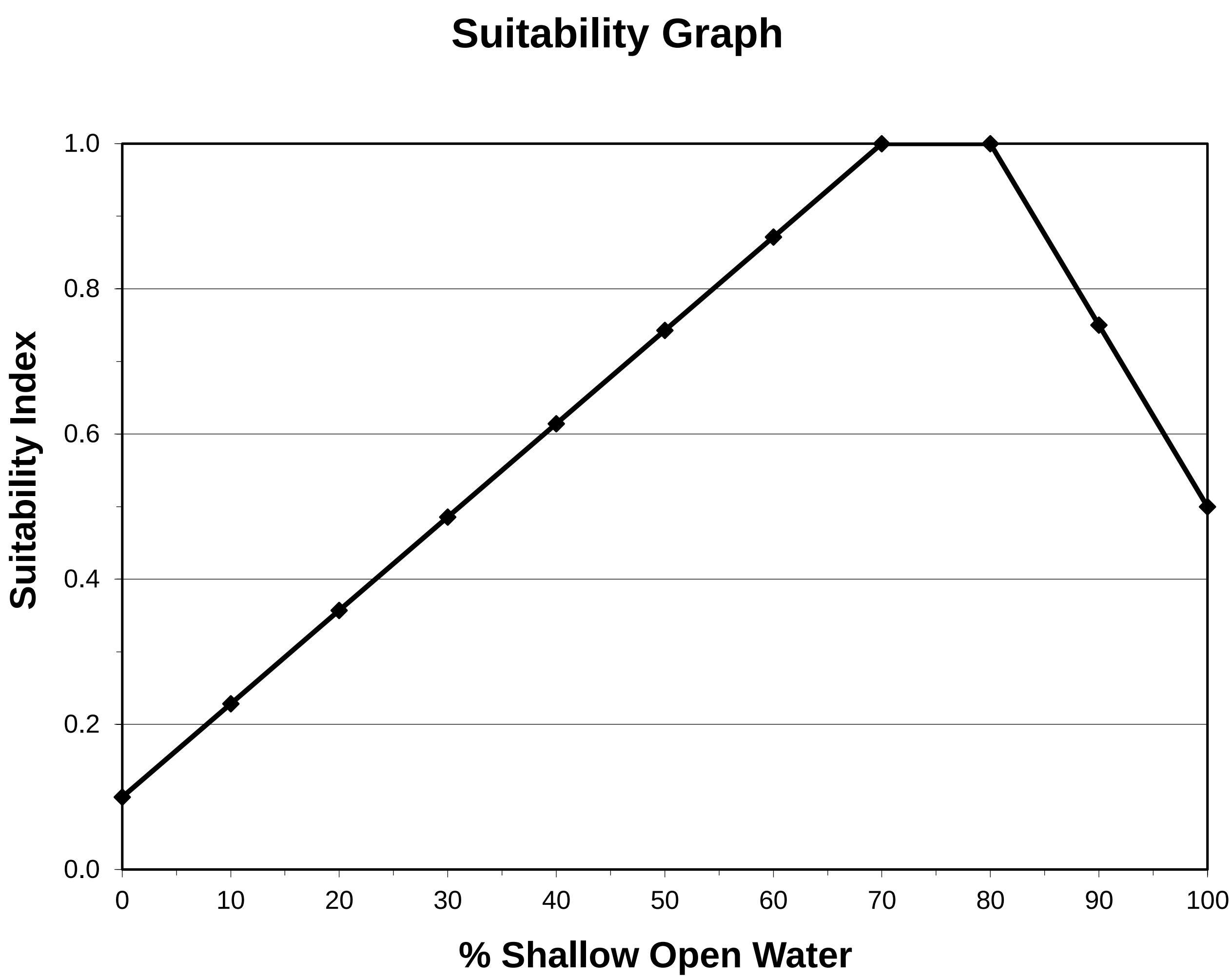
Instructions for Calculating SI for Variable V_3:

1. Refer to pages 33-40 for examples of the different interspersion classes.

2. Estimate percent of project area in each class.

SALINE MARSH

Variable V_4 Percent of open water area $\leq$ 1.5 feet deep, in relation to marsh surface.



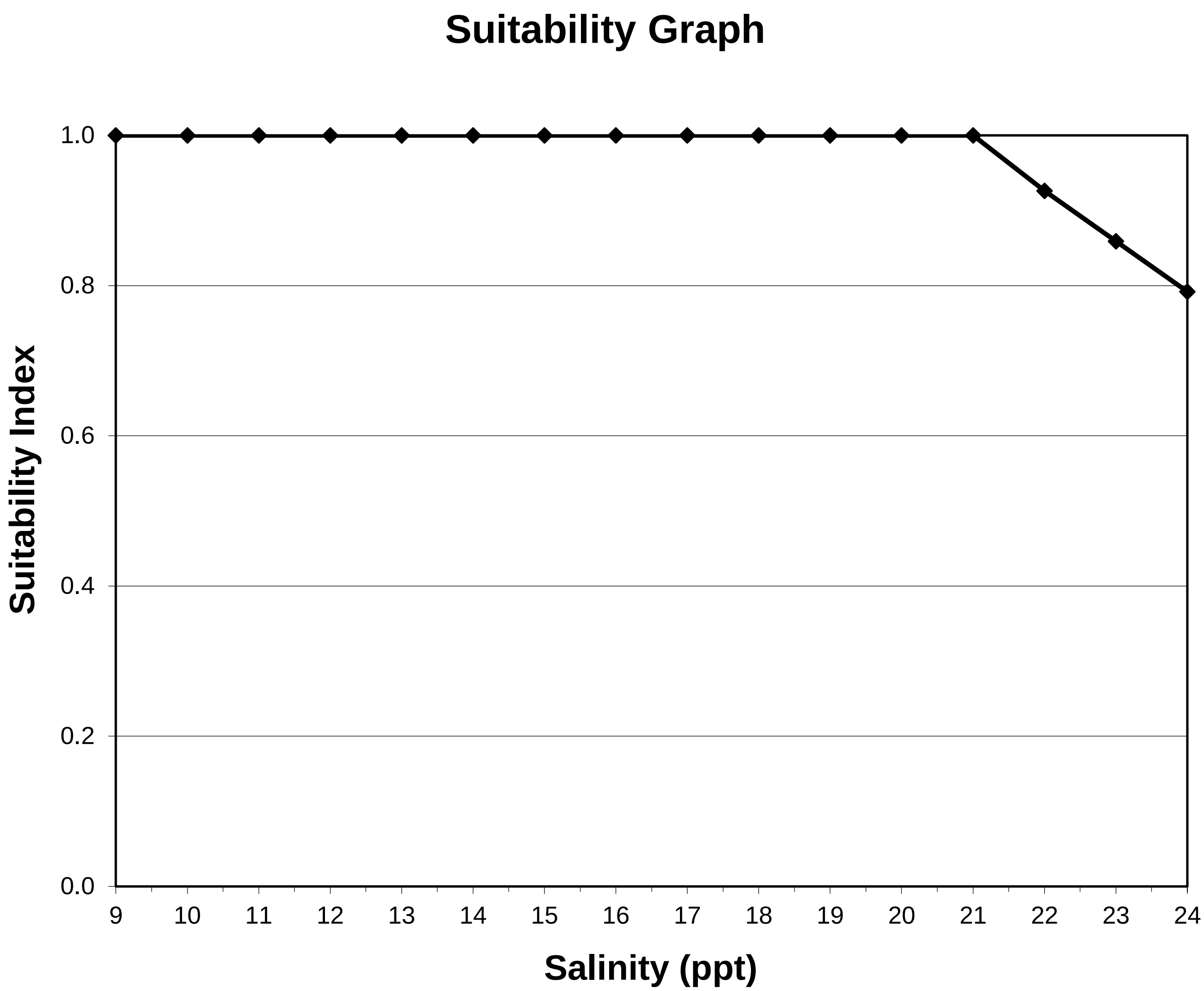
Line Formulas

If $0 \leq \% < 70$, then SI = (0.01286 * %) + 0.1

If $70 \leq \% \leq 80$, then SI = 1.0

If % > 80, then SI = (-0.025 * %) + 3.0

Variable V_5 Average annual salinity.

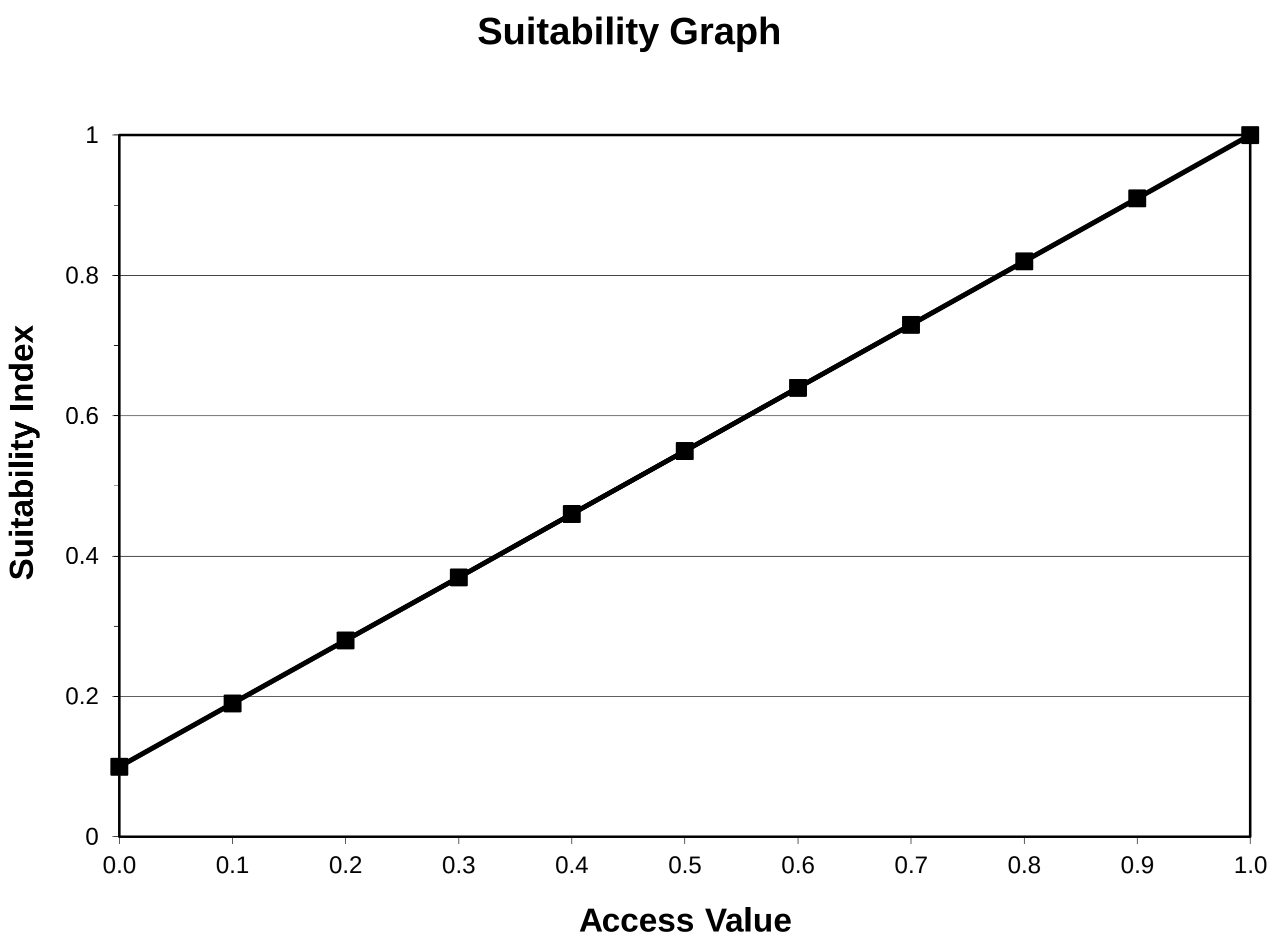


Line Formulas

If $9 \leq ppt \leq 21$, then SI = 1.0

If ppt > 21, then SI = (-0.067 * ppt) + 2.4

Variable V_6 Aquatic organism access.



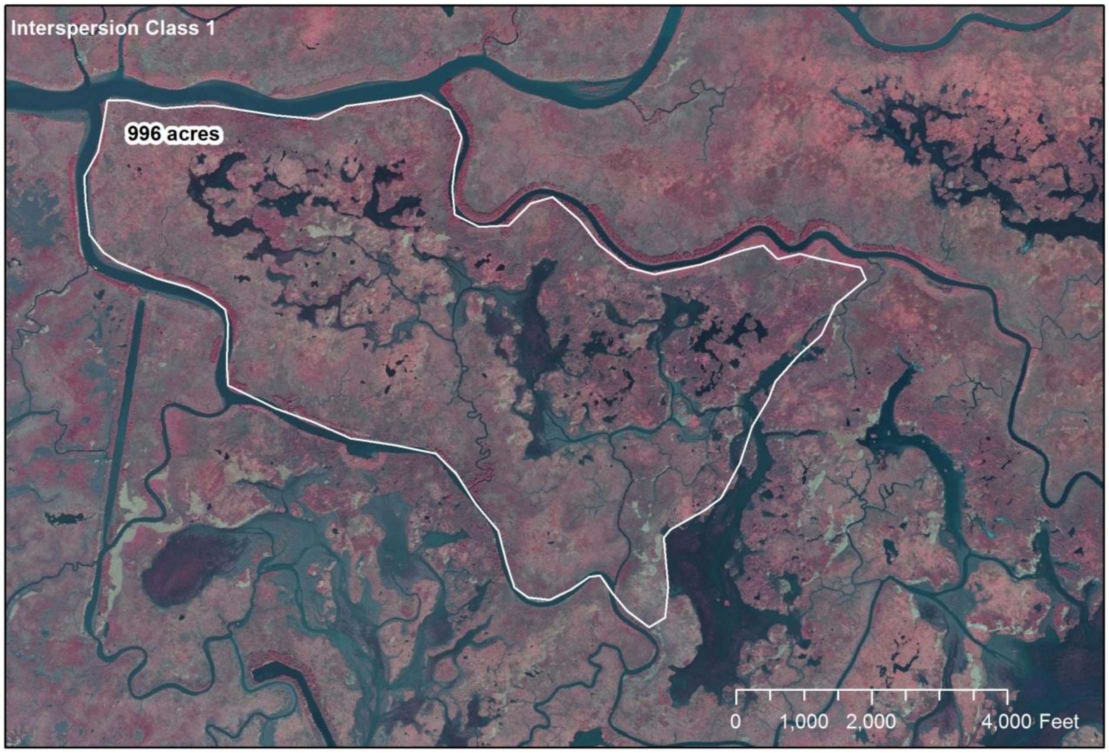
Line Formula

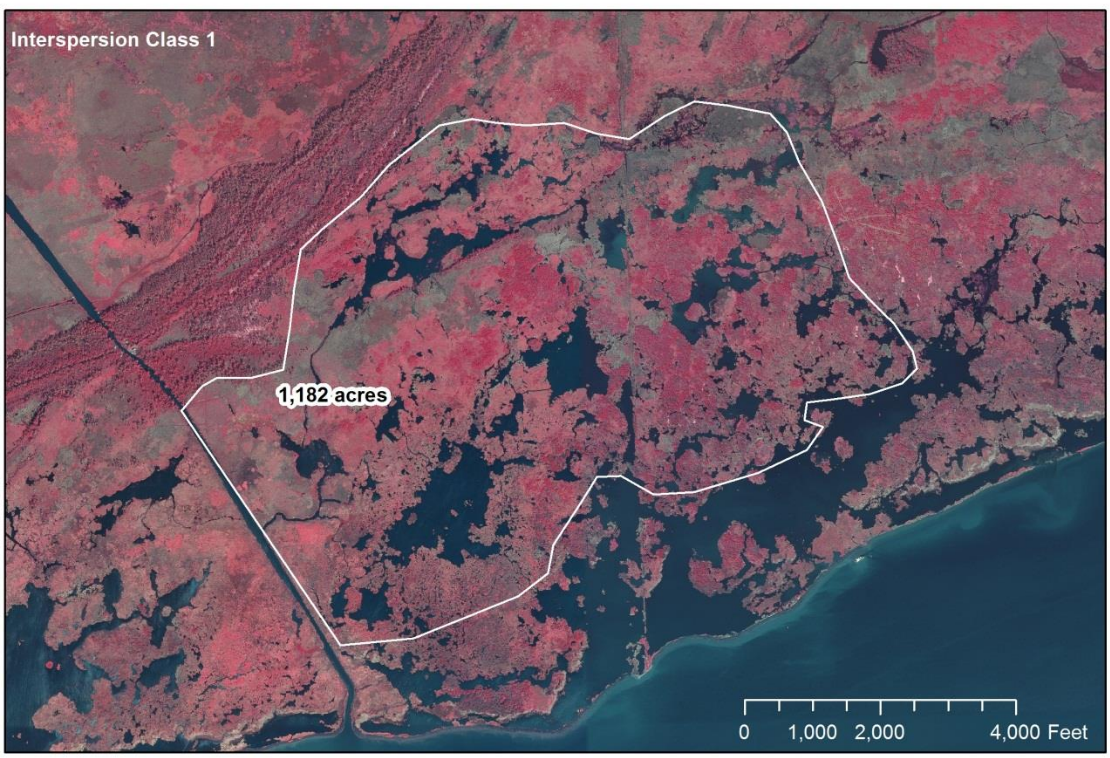
SI = (0.9 * Access Value) + 0.1

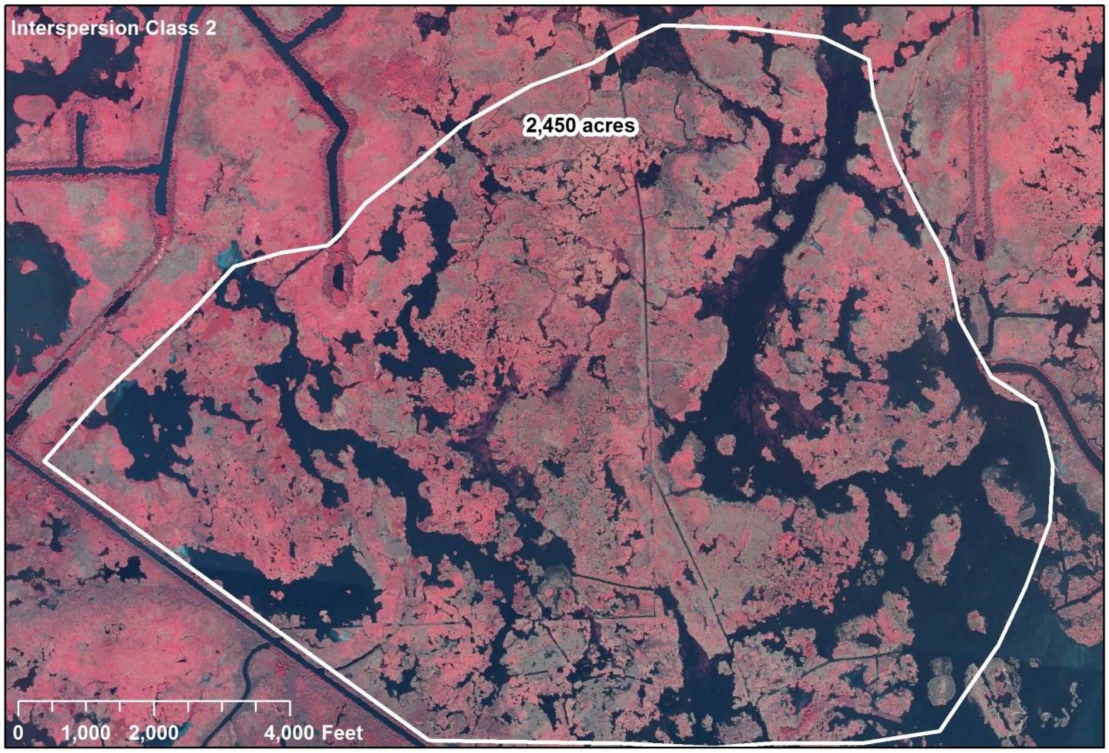
<u>Note</u>: Access Value = P * R, where "P" = percentage of wetland area considered accessible by estuarine organisms during normal tidal fluctuations, and "R" = Structure Rating.

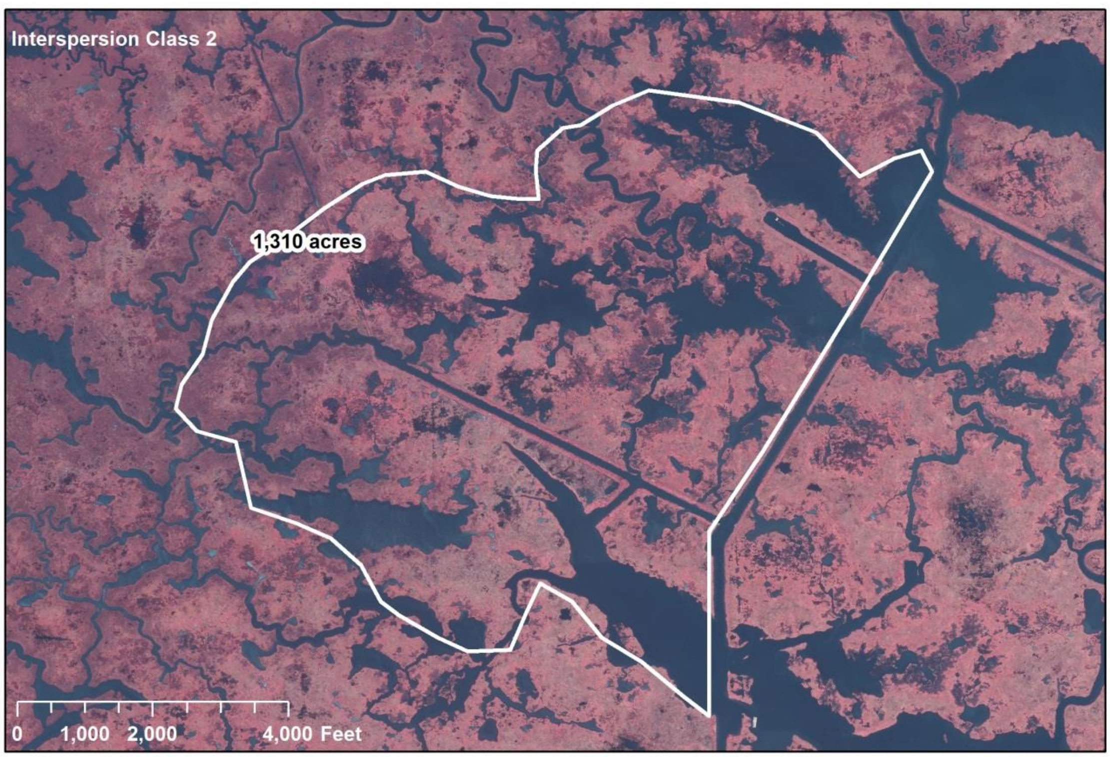
Refer to pages 41-43 for complete information on calculating the Access Value.

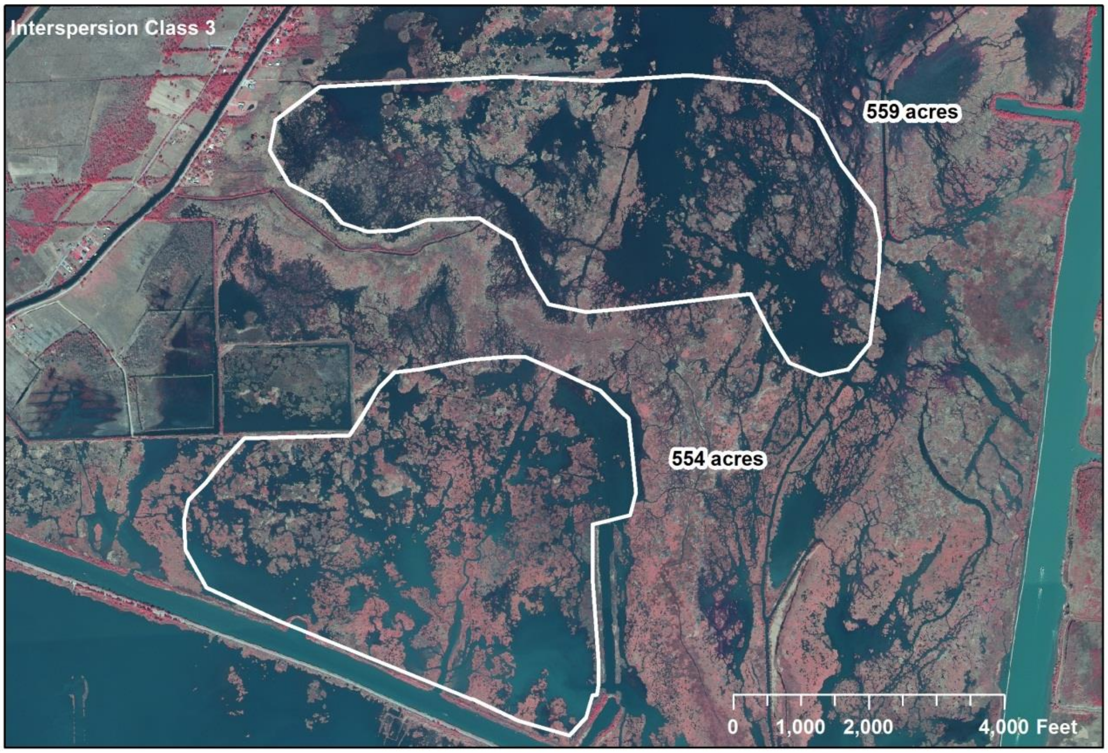
Examples of Marsh Edge and Interspersion Classes

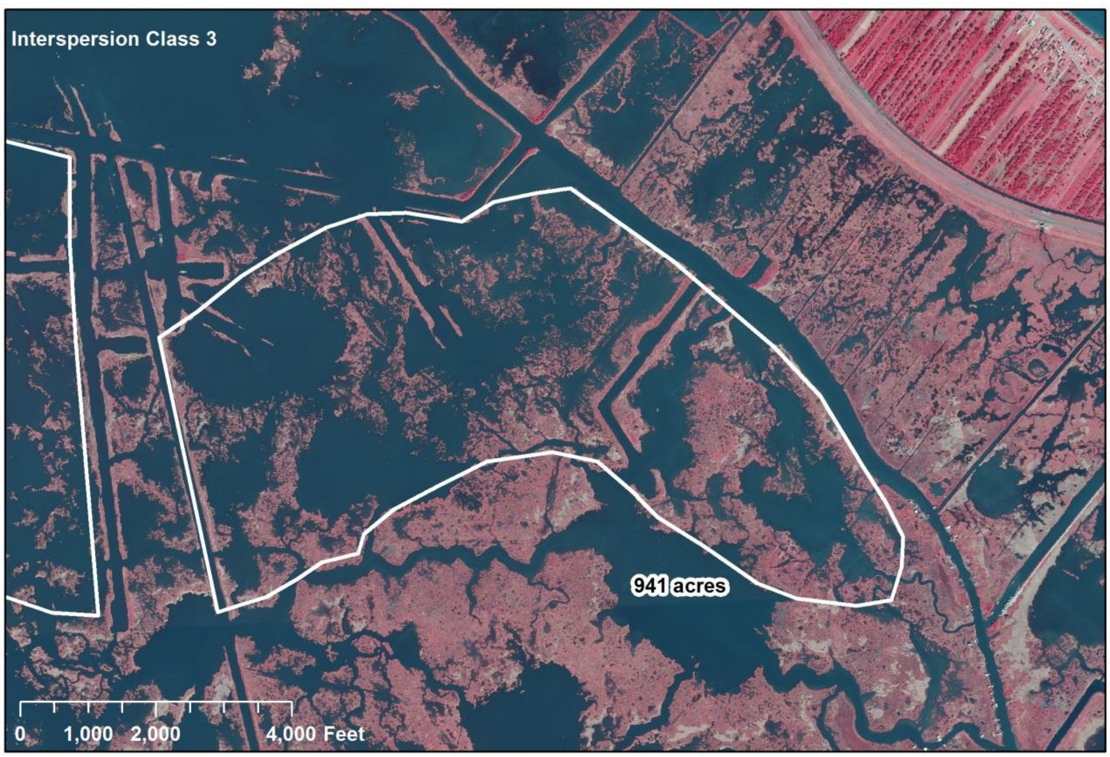


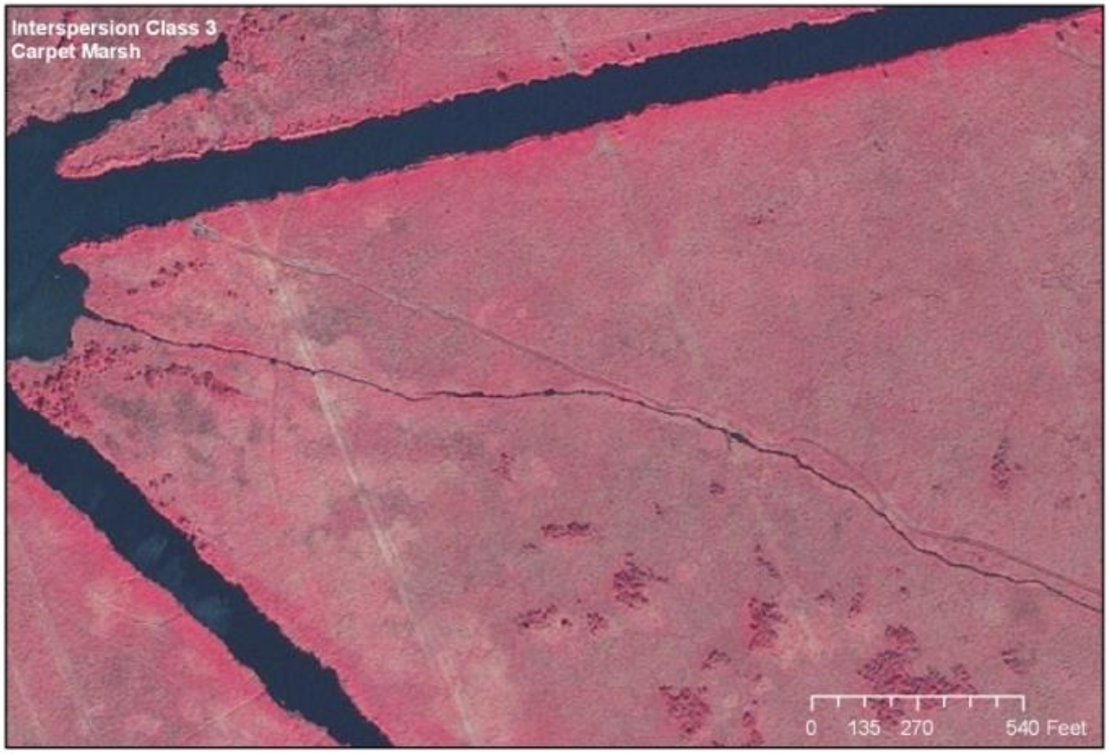


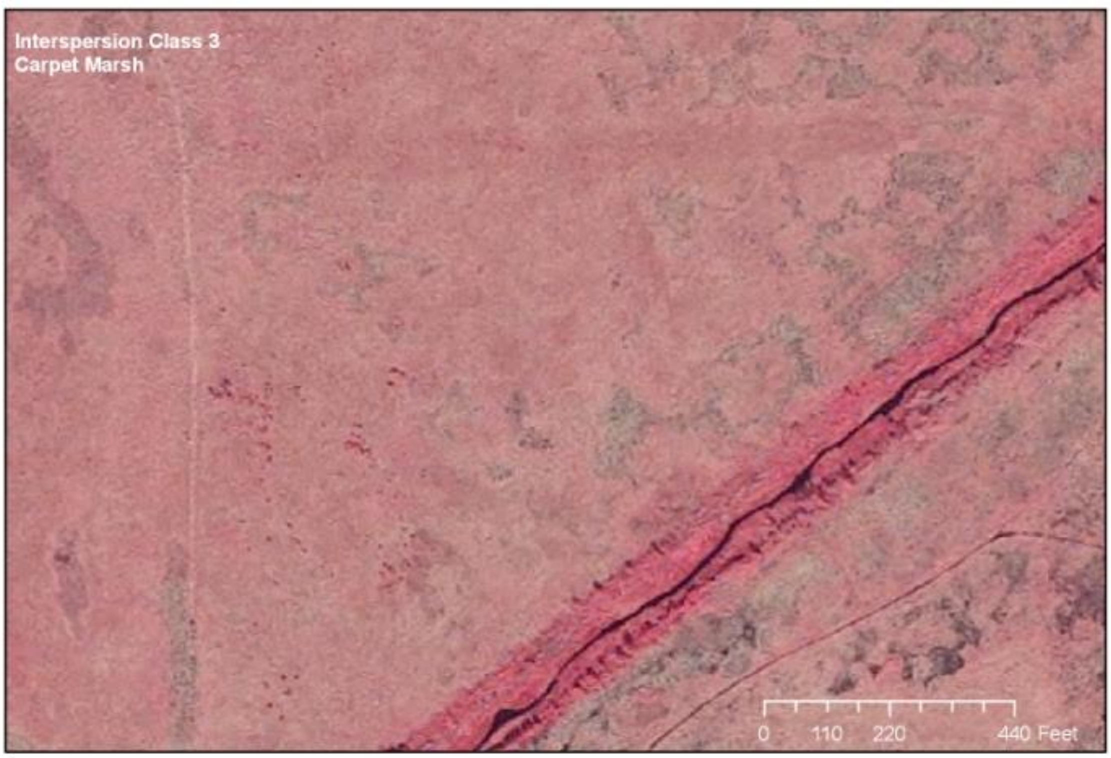

Interspersion Class 2
2,450 acres
0 1,000 2,000 4,000 Feet


Interspersion Class 2
1,310 acres
0 1,000 2,000 4,000 Feet


Interspersion Class 3
559 acres
554 acres
0 1,000 2,000 4,000 Feet


Interspersion Class 3
941 acres
0 1,000 2,000 4,000 Feet


Interspersion Class 3
Carpet Marsh
0 135 270 540 Feet


Interspersion Class 3
Carpet Marsh
0 110 220 440 Feet


Interspersion Class 3
Terrace Spacing approx 300ft
0 500 1,000 2,000 Feet


NOT Interspersion Class 3
Terrace Spacing approx 400-500ft
0 500 1,000 2,000 Feet


Interspersion Class 4
1,040 acres
0
1,000
2,000
4,000 Feet


Interspersion Class 4
0
1,000
2,000
4,000 Feet
1,140 acres


Interspersion Class 5
1,863 acres
0 1,000 2,000 4,000 Feet


Interspersion Class 5
1,006 acres
0 1,000 2,000 4,000 Feet


Interspersion Class 5
Marsh Creation Platform
0 250 500 1,000 Feet


Interspersion Class 5
Marsh Creation Platform
0 250 500 1,000 Feet

Procedure for Calculating Access Value

1. Determine the percent (P) of wetland area accessible by estuarine organisms during normal tidal fluctuations for baseline (TY0) conditions. P may be determined by examination of aerial photography, knowledge of field conditions, or other appropriate methods.

2. Determine the Structure Rating (R) for each project structure as follows:

Structure Type	Structure Rating
Open system	1.0
Rock weir set at 1ft below marsh level (BML), w/ boat bay	0.8
Rock weir with boat bay	0.6
Rock weir set at ≥ 1 ft BML	0.6
Slotted weir with boat bay	0.6
Open culverts	0.5
Weir with boat bay	0.5
Weir set at ≥ 1 ft BML	0.5
Slotted weir	0.4
Flap-gated culvert with slotted weir	0.35
Variable crest weir	0.3
Flap-gated variable crest weir	0.25
Flap-gated culvert	0.2
Rock weir	0.15
Fixed crest weir	0.1
Solid plug	0.0001

For each structure type, the rating listed above pertains only to the standard structure configuration and assumes that the structure is operated according to common operating schedules consistent with the purpose for which that structure is designed. In the case of a "hybrid" structure or a unique application of one of the above-listed types (including unique or "non-standard" operational schemes), the WVA analyst(s) may assign an appropriate Structure Rating between 0.0001 and 1.0 that most closely approximates the relative degree to which the structure in question would allow ingress/egress of estuarine organisms. In those cases, the rationale used in developing the new Structure Rating shall be documented.

Natural marsh, where aquatic organism access is not restricted by any of the above structures or surrounded by spoil banks, is considered an open system and assigned a Structure Rating of 1.0.

3. The Access Value is calculated as P * R. Where multiple openings provide access into an area, the EnvWG shall determine the percentage (P) of the area accessed by each opening. The Structure Rating (R) of the structure proposed for each opening is then used to calculate a weighted Access Value for the entire area.

   In some instances of multiple openings, a "major" access point for the area may be designated by the EnvWG. A major access point is defined as an opening capable of providing a sufficient level of access such that the restriction/closure of all other openings would be inconsequential, in terms of estuarine organism access.

Examples: The following examples provide guidance for calculating the Aquatic Organism Access value. They are not intended to represent an all-inclusive group of scenarios. Many deviations of the following examples will be encountered.

a. One opening into the project area; no structure.

   Access Value = P * R
   = 1.0 * 1.0
   = 1.0

b. One opening into the project area. A flap-gated culvert with slotted weir is placed in the opening.

   Access Value = P * R
   = 1.0 * 0.35
   = 0.35

c. Two openings into the project area, each capable by itself of providing sufficient access to the entire project area. Either opening could be designated as a major access point. A flap-gated culvert with slotted weir is placed in opening #1. Opening #2 is left unaltered.

   Access Value = P * R
   = 1.0 * 1.0
   = 1.0

   Note: In this case, either opening could be designated as a major access point. Structure #1 had no bearing on the Access Value because its presence did not reduce access (opening #2 was determined to be capable of providing sufficient access to the entire project area and access through that route was not altered).

d. Two openings into the project area. No major access point is designated. Opening #1 provides access to approximately 30% of the project area. Opening #2 provides access to the remaining 70% of the project area. A flap-gated culvert with slotted weir is placed in opening #1. Opening #2 is left open.

   Access Value = weighted average of the two Structure Ratings
   = $(P_1*R_1) + (P_2*R_2)$
   = (0.3*0.35) + (0.7*1.0)

$= 0.11 + 0.7$
$= 0.81$

Note: Neither opening was designated as a major access point. Therefore, the percentage of the area accessed by each opening was determined and a weighted average calculated for the Access Value.

e. Three openings into the project area. Opening #1 is blocked with a solid plug. Opening #2 is fitted with a flap-gated culvert with a slotted weir. Opening #3 is fitted with a fixed crest weir. However, it was determined that opening #2 serves as a major access point due to its size, connectivity to interior tidal creeks and other channels, and direct connection to the adjacent bay.

Access Value $= P * R_2$
$= 1.0 * 0.35$
$= 0.35$

Note: Structures #1 and #3 had no bearing on the Access Value calculation because their presence did not reduce access. Opening #2 was determined beforehand to be the major access point; thus, it was the flap-gated culvert with a slotted weir that actually served to limit access.

f. Three openings into the project area. Opening #1 provides access to an isolated subarea (i.e., surrounded by spoil banks) comprising 20% of the project area. Openings #2 and #3 provide access to the remaining 80% of the project area. However, opening #3 is determined to be the major access point relative to opening #2. Opening #1 is fitted with an open culvert, #2 with a flapgated culvert with a slotted weir, and #3 with a fixed crest weir.

Access Value $= (P_1*R_1) + (P_2*R_3)$

$= (0.2*0.5) + (0.8*0.35)$
$= 0.1 + 0.28$
$= 0.38$

g. Three openings into the project area. Opening #1 provides access to 25% of the area; opening #2 provides access to 50% of the area, and opening #3 provides access to 25% of the area. None of the openings are determined to be the major access point. Opening #1 is fitted with an open culvert, #2 with a flapgated culvert with a slotted weir, and #3 with a fixed crest weir.

Access Value $= (P_1*R_1) + (P_2*R2) + (P3*R3)$

$= (0.25*0.5) + (0.50*0.35) + (0.25*0.0001)$
$= 0.125 + 0.175 + 0.000025$
$= 0.3$

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Appendix I: Description of Model WVA Variables from Scientific Literature

A description of the relative role of the model variables in providing habitat to the modeled community based on available, contemporary peer-reviewed scientific literature is provided below.

Variable V_1 - Percent of wetland area covered by emergent vegetation

Numerous studies have suggested that salt marsh habitat plays a critical role in providing foraging, cover, and breeding habitat for nekton (Baltz et al., 1993; Boesch and Turner 1984; Chesney et al., 2000; Rozas and Reed 1993; Zimmerman et al., 2000) as well as providing environmental refuge and optimum conditions for enhancement of physiological processes (Deegan et al. 2000; Roundtree and Able 2007). Within the United States, the largest percentage of salt marsh occurs along the Gulf of Mexico coast and is dominated by *Spartina alterniflora*, *S. patens*, *Juncus roemerianus*, and *Distichilis spicata* (Mitsch and Gosselink, 2000). The emergent marsh vegetation of these systems, specifically *Spartina spp.* has been shown as a source of detritus for marsh resident species and provides important trophic support in salt marsh estuaries (Deegan et al 2000; Dittel et al., 2006; Fry 2008; Peterson et al., 1986). More importantly, invertebrates such as polychaetes and oligochaetes, snails, insects, and a multitude of crustaceans are considered the primary consumers of these systems, contributing trophic support by providing marsh-derived organic matter to support both transient and resident nekton species (Deegan et al. 2000; Kneib 1997a). The high primary productivity of these systems support a variety of pelagic and to a larger degree, benthic-feeding nekton such as killifish, blue crab, penaeid shrimp, and juvenile Gulf menhaden (Deegan et al. 2000). Resident species dominate the nekton assemblages of the vegetated marsh surface and are predominately from the families Cyprinodontidae and Palaemonidae (Kneib 1997b). For instance, Hettler (1989) found 54% more resident fish than transient fish on a flooded *Spartina alterniflora* marsh. Along the Gulf of Mexico coast, field experiments have shown high densities of nekton on a flooded marsh surface including Gulf and diamond killifish, brown, white and daggerblade grass shrimp, sheepshead minnows, striped mullet, and blue crabs (Peterson and Turner 1994; Rozas and Reed 1993).

In addition to utilizing these areas for foraging, these species may also be using the emergent vegetation as cover. Although it has been difficult to determine whether or not the emergent vegetation offers lower mortality rates for nekton compared to other habitats they utilize (Sheaves 2001), some studies have suggested that the marsh surface can serve a refuge from predators (Baltz 1993; Kneib 1987; Paterson and Whitfield 2000). Most nekton do not live continuously among emergent vegetation; however, so it has been suggested that marsh structure along the edge and shallow depth play a greater role in providing protection from predatory species (Deegan et al. 2000).

Reproduction in salt marshes occurs in less than ten families of fishes and only a few crustacean families; however, their large populations contribute considerably to estuarine and marine systems (Rountree and Able 2007). In a coastal salt marsh near Sapelo Island, Georgia, Kneib (1997b) collected only eight nekton taxa in their early life stages on the marsh surface, with the most common species being mummichog, daggerblade grass shrimp, and spotfin killifish. Similarly, Hettler (1989) only collected 8 species of resident fish versus 26 estuarine-dependent transients. However, more resident individuals were collected than the transients. Fluctuating tides, temperatures and salinity may explain why reproduction is extremely difficult in these systems (Rountree and Able 2007).

Few studies exist on the value of the vegetated tidal freshwater or intermediate habitat for nekton of the northern Gulf of Mexico coast (Castellanos and Rozas 2001; Heck et al. 2001; Rozas and Minello 2006). Castellanos and Rozas (2001) found vegetated areas support higher densities of most nekton during high tide events than unvegetated sites. Rozas and Minello (2006) documented rainwater killifish, Harris mud crab, speckled worm eel and saltmarsh topminnow in their marsh sites and these were more abundant than in the nearby SAV beds or non-vegetated areas. In the Chickahominy River drainage, Virginia, McIvor and Odum (1988) found that large number of fish and grass shrimp utilized densely vegetated marsh surfaces adjacent to depositional creek banks rather than deeper, erosional banks. This in part was due to higher food availability and fewer piscivorous predators. Piscivorous fishes were rarely captured on the marsh surface, and if so, were small and considered secondary piscivores (McIvor and Odum 1988).

The success of marshes in providing nekton habitat may influence the distribution of other fauna that inhabitat these areas. Freshwater marsh provides some of the most important habitat for waterfowl in coastal Louisiana (Chabreck 1989). Migratory waterfowl including mallards, American wigeons, gadwalls, redheads and teals use coastal marshes as wintering grounds as well as stopover areas during fall and spring migrations. Salt marshes also support wading birds such as egrets, herons, woodstorks and roseate spoonbills. Freshwater marshes; however, may support the largest and most diverse populations of birds. Waterfowl, shorebirds, wading birds, shrub birds, and others extensively utilize marshes as nesting and foraging grounds (Mitsch and Gosselink 2000).

Variable V_2 - Percent of open water area covered by aquatic vegetation

Submerged aquatic vegetation can serve as additional habitat for nekton to forage or provide cover from predation. In Louisiana, several studies point to the important role SAV plays in coastal marsh habitats for nekton species (Castellanos and Rozas 2001; Duffy and Baltz 1998; Kanouse 2003; Kanouse et al. 2006; Rozas et al. 2005; Rozas and Minello 2006), and elsewhere large densities of nekton have been associated with SAV beds in salt marshes (Glancy et al. 2003; Irlandi and Crawford 1997; Minello et al. 2003; Raposa and Oviatt 2000; Thomas et al. 1990). In a *Spartina alterniflora* marsh in North Carolina, Irlandi and Crawford (1997) found that twice as many pinfish were taken from the marsh edge when there was an adjacent seagrass bed. A similar trend was reported by Raposa and Oviatt (2000) who found higher abundances of *Gobiosoma ginsburgi*, *Apeltes quadracus*, and *Opsanus tau* in eelgrass beds that were adjacent to salt marshes. The nursery values of these habitats; however, is dependent upon the geographic location, tidal range, salinity, and the landscape features (Minello et al. 2003). Further, in a literature review of the relative role of seagrass meadows as nurseries, Heck et al. (2003) found significantly greater survival of nekton in seagrasses than in unvegetated substrates; however, no significant difference was detected between seagrasses and other structures (e.g., oyster reefs, emergent vegetation).

In a brackish marsh, Kanouse (2003) observed higher densities of nekton in SAV habitats with the greatest densities and biomass coinciding with a peak in SAV biomass. Similarly, Kanouse et al. (2006) found significantly higher uses of *Ruppia maritima* by nekton versus non-vegetated brackish habitats in south central Louisiana. *Ruppia maritima* biomass and nekton biomass were also strongly positively correlated. An increase in SAV biomass was used as proxy for vegetative structural complexity which may provide increased refuge and food. In the Chesapeake Bay, an increase in grass shrimp, mummichogs, and banded killifish was also seen in SAV compared to non-vegetated habitat (Ruiz et al. 1993).

As in saline and brackish marsh systems, submerged aquatic vegetation is often used by some species as a refuge from predators or as a feeding ground when the marsh surface is inaccessible (McIvor and Odum 1988; Rozas and Minello 2006; Rozas and Odum 1987a; Rozas and Odum 1987b; Rozas and Odum 1988). Few studies exist on the relative roles of submerged aquatic vegetation (SAV) as nekton habitat in the freshwater and intermediate marshes of Louisiana, but these studies indicate that the presence of SAV can extend the overall habitat available when found adjacent to emergent vegetation (Castallenos and Rozas 2001; Rozas et al. 2005; Rozas and Minello 2006). Rozas and Minello (2006) found up to 10 times more brown shrimp and 30 times more of white shrimp in *Vallisneria* than non-vegetated sites. Harris mud crab, Ohio shrimp, daggerblade grass shrimp, rainwater killifish, naked goby and gulf pipefish were also found in *Vallisneria* with densities at least as high as in emergent vegetation (Rozas and Minello 2006). These results are consistent with Castellanos and Rozas (2001) who found that densities of most species were similar in flooded marsh and SAV.

Variable V_3 - Marsh edge and interspersion.

In microtidal systems such as those along the northern Gulf of Mexico, the marsh edge and adjacent shallow water has often been characterized as serving as important habitat for fish and crustaceans as well as providing access to the intertidal marsh, which in itself is considered essential habitat (Baltz et al. 1993; Chesney 2000). Large densities of nekton have been associated with edge habitat (Baltz et al. 1993; Minello 1999; Peterson and Turner 1994; Rakocinski et al. 1992, Rozas and Reed 1993, Rozas and Zimmerman 2000). Marsh vegetation along the edge may provide protection from piscivorous fishes but the relative importance of this edge habitat for refuge will vary with the amount of edge, rates of subsidence, and tidal amplitude (Deegan 2000). For instance, along the Gulf coast, penaeid shrimp were most abundance in a fragmented *Spartina* marsh with high rates of subsidence possibly as a result of greater marsh edge or increased flooding allowing for more time to forage (Rozas and Reed 1993, Zimmerman et al. 2000). Rozas and Zimmerman (2000) also observed significantly more species and total number of crustaceans along the marsh edge than in adjacent non-vegetated areas, although this was not always the case for fish species. Differences in habitat use (e.g., marsh edge, inner marsh, non-vegetated areas) by nekton was species specific as well as seasonally dependent. Marsh grass shrimp was nearly exclusive to the marsh edge during the fall whereas gulf killifish, sheepshead minnow, and heavy crab were restricted to the marsh surface. Further, nekton assemblages on the marsh surface occurred in low marsh located at the marsh-water interface.

Studies of the effects of restoration efforts on nekton have produced similar results in terms of nekton inhabitance of inner and edge marsh as well as non-vegetated areas. In a study evaluating nekton use of terraced areas and coconut mats, Thom et al. (2004) observed nekton densities two and four times greater in terraced and coconut matted areas, respectively, than those found in open water sites. These areas increased edge habitat and produced submerged aquatic vegetation, thereby providing habitat for nekton use. Similarly, Rozas and Minello (2001) found greater densities of white shrimp, brown shrimp, and blue crab in terrace marsh vegetation than in ponds. The marsh terraces constructed in non-vegetated areas provide emergent marsh along the edge and may provide protection from large predators.

Few studies exist on the value of the vegetated tidal freshwater habitat for nekton of the northern

Gulf of Mexico coast (Castellanos and Rozas 2001; Heck et al. 2001; Rozas and Minello 2006). Castellanos and Rozas 2001 found vegetated areas support higher densities of most nekton during high tide events than unvegetated sites. Rozas and Minello (2006) documented rainwater killifish, Harris mud crab, speckled worm eel and saltmarsh topminnow in their marsh sites and these were more abundant than in the nearby SAV beds or non-vegetated areas.
In the Chickahominy River drainage, Virginia, McIvor and Odum (1988) found that large number of fish and grass shrimp utilized densely vegetated marsh surfaces adjacent to depositional creek banks rather than deeper, erosional banks. This in part was due to higher food availability and fewer piscivorous predators.

Interspersion characteristics are also critical for larger fauna. Alligators require open water areas for nesting females and breeding adults (Newsom et al., 1987). Waterbirds prefer shallow areas along the marsh edge. Waterbird densities were monitored in terraced and unterraced ponds in coastal Louisiana where terrace ponds created 3.5 times more marsh edge. Higher densities of waterbirds were found in terraced ponds, possibly because of the abundance of food near the edge (O'Connell and Nyman 2009).

Variable V_4 - Percent of open water area ≤ 1.5 feet deep in relation to marsh surface.

The shallow, turbid waters of coastal Louisiana are partially responsible for the high productivity of the system. The shallow waters, especially those close to the marsh edge allow for easy access to the marsh surface during tidal flooding during low tide events (Chesney 2000). Large densities of Gulf menhaden have been associated with shallow, open water, but other nekton such as Callinectes spp., brown shrimp, white shrimp, bay anchovy, and naked goby (and others) have been collected in shallow, open water as well (Minello et al. 1999). These areas may provide better protection, especially if turbid than in nearby deep open water. Ruiz et al. (1993) in a brackish marsh in the Chesapeake Bay found a greater mortality of grass shrimp, mummichogs, and small blue crabs in the deepest areas (60-80cm) than in the shallow areas (15-20 cm) possibly due to a lack of predators in the shallow zone. Rozas and Minello (2006) observed greater densities of bay anchovies and Gulf menhanden in shallow, non-vegetated areas (depths <1m) than in nearby vegetated areas. Similarly, Castellanos and Rozas (2001) observed great abundance of bay anchovies in non-vegetated bottoms than in emergent vegetation.

Shallow areas are also frequently used by young alligators, although adults require areas of deeper open water for breeding (Newsom et al., 1987). In fresh, intermediate, and brackish marshes, these shallow areas provide an abundance of prey including mammals, arthropods, fish, birds and reptiles (McNease and Joanen 1977). Water depth is also an important characteristic influencing waterbird communities. Not only do these birds have specific morphological characteristics that allow them to feed in shallow areas, the food resources that are produced in shallow depths are critical for waterbird communities (Bolduc and Afton 2004).

Variable V_5 – Salinity

The differences from tidal freshwater to salt marshes communities are strongly related to the salinity gradient (Odum 1988). Change in salinity can have substantial effects on the system's productivity; however, the degree and direction of response is difficult to predict because of interspecific competition (Naidoo et al. 1992; Vasquez et al. 2006) as well as the role of other abiotic factors (Gough and Grace 1998; Hester et al. 2001). For instance, Baldwin et al. (1998)

observed a synergistic effect of salinity and flooding stresses following an experimental disturbance for *Spartina patens* and *Sagittaria lancifolia*. When exposed to increased salinity levels and prolonged flooding, *Sagittaria lancifolia* biomass declined compared to increased salinity under non-flooding conditions. However, *Spartina patens* was affected by a combination of flooding and disturbance but not by salinity. Hester et al. (1996; 1998) also showed intraspecific variation in the salt tolerance of *S. alterniflora, Panicum hemitomon,* and *Spartina patens.*

Salinity is also a primary abiotic factor influencing fish community structure (Rakocinski et al. 1992). In Matagorda Bay, Gulf of Mexico, Gelwick et al. (2001) found a strong association between fish assemblages and salinity. Three salinity zones were identified by patterns of maximal occurrence of fish species, <5ppt, 10-20ppt, and >20ppt, and a considerable shift from freshwater to marine nekton was observed across these zones. However, a few species did occur across both ends of the gradient: gizzard shad, sheepshead minnow, bayou killifish, and striped mullet. Species diversity and community structure was also strongly affected by the connectivity between freshwater wetland and brackish zones (Gelwick et al. 2001). Peterson and Ross (1991) observed declines in centrarchids, cyprinodontids and freshwater fundulids in Old Fort Bayou, MS with salinity increases in freshwater sites.

Variable V_6 - Aquatic organism access

Water control structures have been used for decades in Louisiana for waterfowl management and to provide human access by maintaining water levels (Rogers et al. 1992a). The level at which water control structure limit marine transient organisms is dependent upon not only the structure itself but tidal amplitude, water depth, marsh area affected, and the species involved (Rogers et al. 1992b).

Across a fresh and brackish marsh in south central Louisiana, Rogers et al (1992a) found nearly 90% fewer marine-transient organisms in an area managed with a variable-crest double flap-gated structure and fixed-crest weirs versus an unmanaged area. Species showing significant declines in the managed area were blue crab, gulf menhaden, and striped mullet. Conversely, nearly 2.5 times more resident organisms were collected in the managed area than in the unmanaged areas, including grass shrimp, least killifish, western mosquitofish, and golden topminnow. This in part may have been attributed to an increase in submerged aquatic vegetation and overall lower water depths in the managed area.

In a brackish marsh in southwest Louisiana, Rogers et al. (1992b) examined the effects of a low elevation fixed weir (installed 30 cm below average marsh soil level), a slotted weir, and a fixed-crest weir on resident and transient nekton abundance. They concluded that an increase in water control corresponded to an increase on the impact of transient marine organisms. For instance, catches were smaller overall in the fixed-crest weir sampling area versus the slotted-weir, as well as in the low-weir area versus the no-weir area. The results of the study also suggested that increased water control may prevent immigration and emigration of brown shrimp (and possibly other migratory species) dependent upon the timing of openings/closings of the water control structures.

Appendix II: Supporting evidence for USACE Revisions to V1, V2

Table 1. Aquatic and terrestrial species considered in revising V1, V2, and V3. F = freshwater/intermediate marsh, B = brackish marsh, S = saline marsh, NA = not applicable, and NC = information not clear.

Common Name	% coverage marsh	% coverage SAV	Habitat	Citation
American alligator	Yes	Yes	F	Newsom et al, 1987
Atlantic croaker (juvenile)	No	No	B,S	Diaz and Onuf, 1985
bluegill	No	Yes	F	Stuber and Maughan, 1982
brown shrimp	Mix		B,S	Minello and Rozas, 2002; Turner and Brody 1983
bullfrog	Yes	Yes	F	Graves and Anderson, 1987
channel catfish	No	No	F	McMahon and Terrell, 1982
great blue heron	No	No	NA	Short and Cooper, 1985
great egret	Yes	No	NC	Willard, 1997
Gulf flounder	No	No	NA	Enge and Mulhall, 1985
Gulf menhaden	No	No	NA	Christmas et al, 1982
largemouth bass	No	Yes	F	Stuber et al, 1982
laughing gull	Yes	No	NC	Mulholland, 1985
marsh wren	Yes	No	NC	Gutzwiller and Anderson, 1987
mink	Yes	No	NC	Allen, 1986
mottled duck	Yes	No	F	White, 1975
muskrat	Yes	No	F	Allen and Hoffman, 1984
northern pintail	Yes	No	F,B	White and James, 1978
pink shrimp	Yes	Yes	B,S	Mulholland, 1984
red drum (larval and juvenile)	No	Yes	B,S	Buckley, 1984
redear sunfish	No	Yes	F	Twomey et al, 1984
red-winged blackbird	Yes	No	NA	Short, 1985
roseate spoonbill	Yes	No	NA	Lewis, 1983
slider turtle	Mix		F	Morreale and Gibbons, 1986
snow goose	Yes	No	NC	Hobaugh, 1982
southern flounder	No	No	NA	Enge and Mulhall, 1985
spot (juvenile)	No	No	NA	Stickney and Cuenca, 1982
spotted seatrout	Mix		BS	Kostecki, 1984
swamp rabbit	Yes	No	F	Allen, 1985
white shrimp	Mix		BS	Minello and Rozas, 2002; Turner and Brody 1983
white-fronted goose	No	No	NA	Kaminiski, 1986

Updated V1

A literature review was performed to determine the SI value for 100% emergent vegetation coverage. Several studies from the northern Gulf of Mexico have suggested the importance of marsh edge to nekton (e.g., Chesney et al, 2000; Minello and Rozas 2002; Clancy et al, 2003). Minello and Rozas (2002) quantified the change in density for brown shrimp (*Farfantepenaeus aztecus*), white shrimp (*Litopenaeus setiferus*), blue crabs (*Callinectes sapidus*), and other nekton, finding an optimal conditions for approximately 20-25% to 70% open water for created marsh islands. Others determining habitat suitability for these organisms in coastal Louisiana have used an emergent vegetation SI with an optimal range between 30% and 80% for brown shrimp, white shrimp, and blue crabs (Hijuelos et al, 2017, O'Connell et al, 2017a, O'Connell et al, 2017b, O'Connell et al, 2017c). For brown and white shrimp an SI value was considered, based on empirical data from Minello and Rozas (2002) was used. For other aquatic and terrestrial organisms that use coastal marsh in Louisiana, USFWS HSIs were considered (Table 1; USFWS ESM 103).

Each animal was assigned to one or more marsh habitat types based upon their life history traits and salinity ranges. Four critical parameters were calculated for each organism and averaged:

1. SI value at 0% coverage
2. minimum percent coverage value where an SI = 1
3. maximum percent coverage value where SI = 1
4. SI value at 100% coverage.

These averages, combined with Battelle's recommendations, were used to develop the recommended SI curves for each WVA Marsh Model V1 (Table 2). The average parameter value for 0% coverage SI was higher than 0.1.

Table 2. Average value for each parameter by WVA Marsh Model type as determined by aquatic and terrestrial species considered.

Marsh Type	0% coverage SI	Minimum % Coverage, SI = 1	Maximum % Coverage, SI = 1	100% coverage SI
Freshwater/Intermediate	0.21	59.00	83.75	0.63
Brackish	0.32	25.00	66.67	0.25
Saline	0.15	33.33	80.00	0.33

Updated V2

Estimating percent SAV coverage can be difficult and problematic because SAV coverage varies across different environmental conditions. Previous research from coastal Louisiana found that submerged aquatic vegetation abundance and distribution varies seasonally (Cho and Poirrer, 2005a, and Merino et al, 2005) and may be cyclical across years (Cho and Poirrer, 2005b). Some of the across year variation may be related to changes in weather patterns (e.g., El Niño/La Niña cycle) that affect rainfall and salinity, which can influence SAV abundance and distribution (Cho and Poirrer, 2005b). Additionally, accurate measurement of percent coverage of SAV can be difficult due to high turbidity (Merino et al, 2005) and percent coverage measurements alone were found to inadequately describe SAV conditions (Fores-Verdugo et al, 1988, and Merino et al, 2005). Roy (2010) stated similar findings and suggested that professional judgment, emphasizing salinity and marsh type, followed by turbidity, should be used.

A large amount of literature exists on the impacts of submerged aquatic vegetation and its ecological benefits. However, little information was found directly comparing habitat use (or benefit) by organisms with respect to percent coverage of aquatic vegetation. One exception to this was gadwall (*Anas strepera*) in Texas. Others have cited White (1975), which could not be found by the current authors, as indicating a sigmoidal and not trapezoidal relationship between SI value and SAV percent coverage (Leberg, 2017). The same four parameters were taken from this sigmoidal curve and were used here. Other primary research indicates that SAV is of particular importance to gadwall foraging with two found that focus on coastal Louisiana (Gray, 2010, Paulus, 1984). Similar to waterfowl, a large amount of literature exists on the importance of SAV to nekton and other aquatic organisms. Many relationships compare it to unvegetated water bottoms, with SAV habitats associated with increased diversity and biomass (Clancy et al, 2003, Rozas and Minello, 1998), and foraging opportunities and refugia (Rozas and Odum, 1988). However, no studies directly examining how percent coverage of SAV were found for coastal Louisiana. For gadwall, SI values were based on empirical data (White, 1975, Leberg, 2017). For other aquatic and terrestrial organisms that use coastal marsh in Louisiana, USFWS HSIs were considered (Table 1; USFWS ESM 103).

Each aquatic or terrestrial organism was assigned to one or more marsh habitat types based upon their life history traits and salinity ranges. Four critical parameters were calculated for each organism and averaged:

1. SI value at 0% coverage
2. minimum percent coverage value where an SI = 1
3. maximum percent coverage value where SI = 1
4. SI value at 100% coverage.

These averages, combined with Battelle's recommendations, were used to develop the recommended SI curves for each WVA Marsh Model V2 (Table 3). The average parameter value for 0% coverage SI was higher than 0.1.

Table 3. Average value for each parameter by WVA Marsh Model type as determined by aquatic and terrestrial that utilize coastal marsh habitats.

Marsh Type	0% coverage SI	Minimum % Coverage, SI = 1	Maximum % Coverage, SI = 1	100% coverage SI
Freshwater/Intermediate	0.11	56.25	87.50	0.45
Brackish	0.02	82.50	95.83	0.83
Saline	0.08	65.91	90.91	0.60

Appendix III: ERDC-Sensitivity Analysis Case Study

ERDC TN-EMRRP-EBA-20
July 2014

Case Study: Sensitivity Analysis of the Barataria Basin Barrier Shoreline Wetland Value Assessment Model[1]

by S. Kyle McKay[2] and J. Craig Fischenich[3]

OVERVIEW: Sensitivity analysis is a technique for systematically changing parameters in a model to determine the effects of such changes on model outcomes (Schmolke et al. 2010). It is an essential tool for model building and quality assurance. Sensitivity analysis also compliments uncertainty analysis because sensitivity analysis orders input importance by determining variation in output and by identifying important response thresholds. This technical note provides an example application of sensitivity analysis in support of ecosystem restoration planning. It is intended to supplement other publications about Environmental Benefits Analysis (EBA) that discuss a broader array of sensitivity techniques and applications. In this instance, the application of sensitivity analysis addresses the relevance of questions posed during an Independent External Peer Review (IEPR).

BARATARIA BASIN BARRIER SHORELINE (BBBS) STUDY: On average, Louisiana's coastal marshes are receding at alarming rates – over 27 mi^2/yr – due to a number of factors, including: sea level rise, river-marsh disconnection, local consolidation and subsidence, and coastal erosion (Barras et al. 2008). These coastal systems provide numerous ecosystem goods and services, including fish and wildlife production, storm damage reduction, and recreation. Federal, state, and local partners have jointly pursued large-scale restoration projects to reduce marsh loss and maintain these wetlands as healthy functioning ecosystems. The Barataria Basin Barrier Shoreline (BBBS) restoration project was identified through the Louisiana Coastal Area (LCA) program as critical to maintaining the Caminada Headland and Shell Island reaches of the Gulf shoreline to prevent larger scale, potentially irreversible ecosystem impacts.

Large-scale ecosystem restoration projects require extensive planning and analysis prior to implementation to ensure the most effective alternatives are selected. Alternatives are compared on the basis of forecasted "benefits" of restoration determined using numerical models such as the commonly applied Habitat Evaluation Procedures (HEP). HEP combines habitat quantity (e.g., acres) with an assessment of habitat quality scored from zero to one, a Habitat Suitability Index (HSI). This index is determined from measured data or professional judgment, and is generally represented as a "habitat suitability curve" that assigns a quality score to a range of values for a given parameter. HEP was originally developed for individual species, and suitability curves were developed to capture environmental tolerances of the focal species (USFWS 1981). Since

[1] This manuscript incorporates portions of a letter report submitted to the USACE New Orleans District and the Ecosystem Restoration Planning Center of Expertise on September 21, 2009.
[2] Environmental Laboratory, Athens, GA, 601-415-7160, *Kyle.McKay@usace.army.mil*
[3] Environmental Laboratory, Vicksburg, MS, 601-634-3449, *Craig.J.Fischenich@usace.army.mil*

ecosystem management and restoration rarely centers on optimizing habitat for a single species, more recent HEP models have focused on ecological communities rather than specific taxa (e.g., Gulf Coast salt marsh ecosystems; EWG 2006). For these models (e.g., Wetland Value Assessment), the HSI represents an aggregation of multiple habitat suitability curves covering a variety of parameters describing ecosystem structure or process.

Wetland Value Assessment. Based on its quantitative nature and historical application in the region, the Wetland Value Assessment (WVA) was selected as an appropriate model for assessing the relative merits of BBBS alternatives. WVA was developed by an interdisciplinary and inter-agency team of scientists specifically for determining suitability of coastal wetlands in providing resting, foraging, breeding, and nursery habitat to a diverse assemblage of fish and wildlife species in coastal Louisiana (EWG 2006). Strictly speaking, WVA is not a single model, but rather a procedure that applies a family of models addressing seven ecological communities of the region: (1) fresh/intermediate marsh; (2) brackish marsh; (3) saline marsh; (4) barrier island; (5) barrier headland; (6) swamp; and (7) coastal chenier/ridge. WVA is a HEP-type approach whereby habitat quality, or suitability, is correlated to relevant components of ecosystem structure on a zero to one scale. For instance, in the WVA saline marsh model, suitability is assumed to vary linearly from 0.1 to 1.0 as the percentage of marsh area with emergent vegetation increases (Figure 1a). Each of these "suitability index curves" is then combined into a composite habitat suitability index (HSI) through a specific aggregation algorithm which is then multiplied by the quantity of habitat, in acres, to obtain the number of "habitat units" (HU) provided by a given alternative. Whereas traditional HEP models focused on specific taxa, WVA assesses the fish and wildlife community collectively.

For each alternative, WVA quantifies changes in habitat quality. The results are combined with habitat quantity estimates and costs to compare the effectiveness of different alternatives. Because WVA outputs (HUs) are snapshots of conditions at a given time, benefits must be assessed at several points over the project life (50 years) then annualized to provide a consistent metric in the form of average annual habitat units (AAHUs). In addition, the basis for assessing benefits of a restoration project is not the number of habitat units provided by an alternative, but the improvement the alternative provides over a baseline condition, which is the future condition of the site without the proposed restoration. Thus, net benefits are the difference in AAHUs provided by the alternative and the future without project (FWOP) condition (i.e., $AAHU_{net} = AAHU_{alternative} - AAHU_{FWOP}$; USACE 2009).

Model Certification. The USACE requires that planning models be reviewed for technical and system quality and usability. The purpose of model review is to ensure the scientific validity and technical quality of tools used for planning, and to ensure the tools conform to policy and usability requirements (USACE 2005, USACE 2007). WVA models were evaluated in accordance with EC 1105-2-412 (Assuring Quality of Planning Models, USACE 2011). Review of the WVA model identified two concerns associated with model construct (BMI 2009):

Comment 1. Starting the SI curves for all variables at 0.1 is problematic because even habitat with no ecological value appears to have some ecological value.

Comment 18. The use of the geometric mean may be more appropriate than the arithmetic mean to derive some HSIs. Provide scientific basis for the decision to use one over the other.

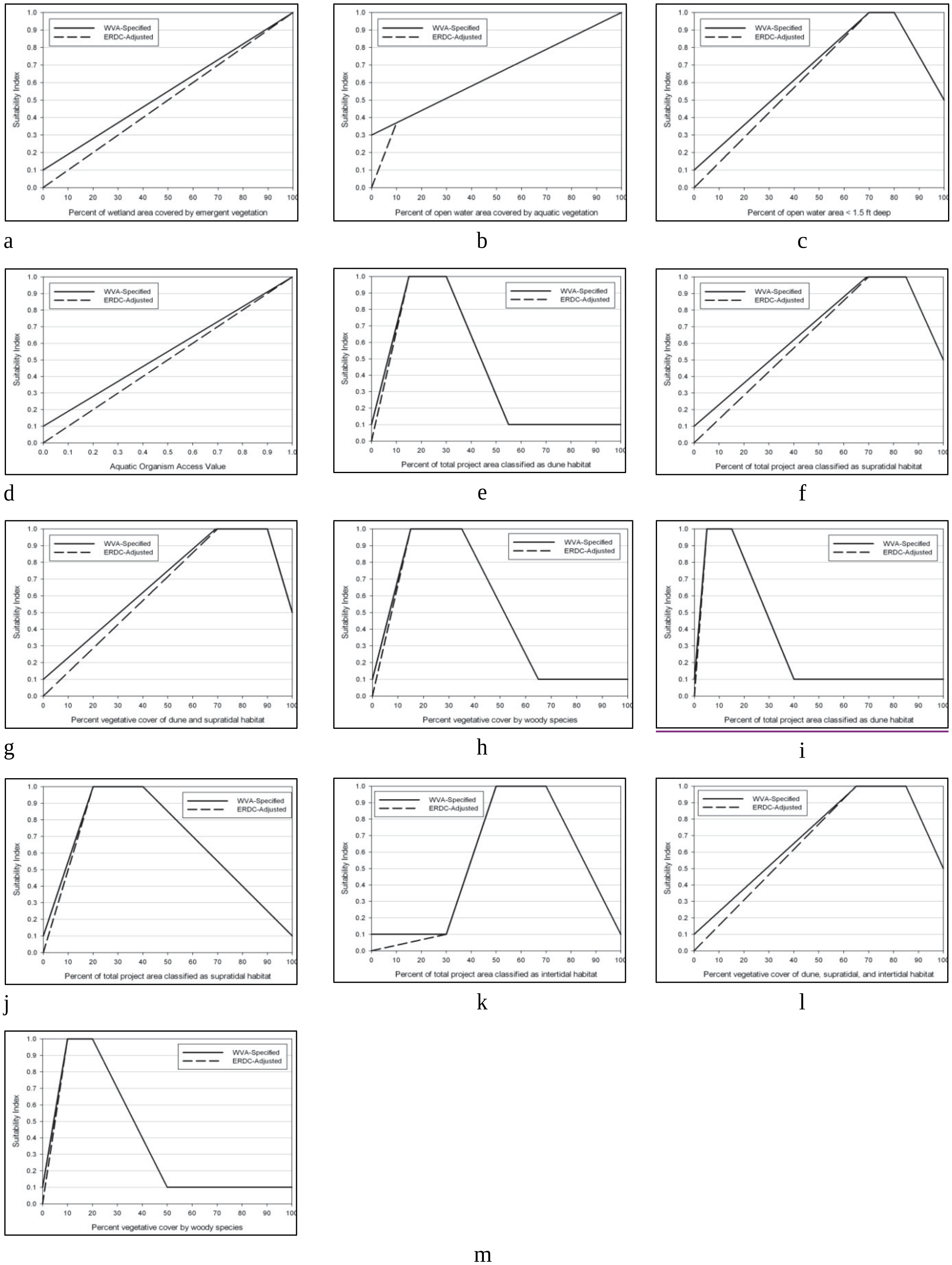

Figure 1. Suitability index curves as specified by WVA (solid lines) and adjusted by ERDC (dashed lines) to address review comments. (a-d) saline marsh (SIV_1, SIV_2, SIV_4, SIV_6); (e-h) barrier headland (SIV_1, SIV_2, SIV_3, SIV_4); and (i-m) barrier island (SIV_1, SIV_2, SIV_3, SIV_4, SIV_5).

SENSITIVITY ANALYSIS: Regardless of purpose or function, all models are limited by scientific understanding of the process being modeled, validity of input parameters, and ability of the model structure to capture understood processes (Schmolke et al. 2010, Schultz et al. 2010). As such, there is value in examining the sensitivity of a model to changes in one or all of these factors and how that sensitivity alters conclusions. For BBBS, the WVA model was selected based on time, funding, and resource availability, among other factors. Given that each WVA sub-model (e.g., saline marsh) has several input parameters (usually 5-7) which are assessed for multiple times (at least: year 0, year 1, year 20, and year 50) and multiple alternatives, comprehensive examination of input uncertainty would be a prohibitively large task beyond the scope of the review comments. Herein, the authors apply sensitivity analysis to the WVA to examine the influence of model structure on restoration decision making. The analysis examines two components of model structure: 1) the influence of suitability curve boundary conditions and 2) the influence of aggregation techniques for combining suitability curves into a Habitat Suitability Index (HSI). WVA model sensitivity was examined specifically for relative comparison of alternatives in the Barataria Basin Barrier Shoreline restoration project by examining the influences of boundary conditions and aggregation methods on conclusions reached in the BBBS restoration study. Although seven WVA sub-models exist, only the WVA sub-models applied to the BBBS study were addressed: saline marsh with both emergent and open water components (EWG 2007), barrier headlands (EWG 2002a), and barrier islands (EWG 2002b).

Boundary Conditions. Each of the WVA sub-models specifies a set of parameters that influence marsh community health (Table 1) and identifies a relationship between each of these parameters and habitat suitability for the community. These relationships are presented as graphs of functions (e.g., for Figure 1a, $SalineSIV_1 = 0.009 * \%_{emergentveg} + 0.1$), as well as constructed scales or tables (e.g., Saline Marsh SIV_3 is a scale for marsh connectivity that provides users with a suitability index based on photographs of reference marshes). In these models, some suitability curves have non-zero y-intercepts indicating that some value always exists for fish and wildlife. Model reviewers expressed concern that HSI values should always approach zero to indicate that quality is insufficient for the community as a whole and is only providing habitat for a few species under these conditions (i.e., Comment 1, BMI 2009).

Table 1. Suitability index parameters of relevant WVA sub-models.

Suitability Index	Saline Marsh	Barrier Headland	Barrier Island
SIV_1	Percent of wetland area covered by emergent vegetation	Percent of area classified as dune	Percent of area classified as dune
SIV_2	Percent of open water area covered by emergent vegetation	Percent of area classified as supratidal	Percent of area classified as supratidal
SIV_3	Marsh edge and interspersion	Percent of vegetative cover of dune and supratidal habitat	Percent of area classified as intertidal
SIV_4	Percent of open water < 1.5 ft deep relative to marsh surface	Percent vegetative cover by woody species	Percent vegetative cover of dune, supratidal, and intertidal habitat
SIV_5	Average annual salinity	Beach/surf zone features	Percent vegetative cover by woody species
SIV_6	Aquatic organism access	n/a	Edge and interspersion
SIV_7	n/a	n/a	Beach/surf zone features

The sensitivity of the three WVA models was tested to adjustments in the suitability curve intercepts. The situation in which all intercepts are as specified in WVA model documentation (EWG 2002a, 2002b, 2006, 2007) was compared with one in which the suitability index curves are forced through a near-zero intercept (explained in greater detail below). Figure 1 shows the WVA-specified and zero-intercept suitability index curves that were assessed. It is important to note that not all WVA parameters were evaluated in this manner; some suitability relations are pictorial or categorical and the zero-intercept concerns do not apply, while some relations provide for maximum suitability at zero values (i.e., *SIV* = 1 at parameter = 0). The two assessed scenarios reflect maximum model sensitivity to this type of structural change.

Aggregation Methods. Suitability indices are combined in numerous ways to generate the composite HSI (see USFWS 1981 for guidelines on HSI development). For instance, model components can be aggregated through arithmetic, geometric, or harmonic means (Equation 1 a, b, & c, respectively), nested averages (e.g., Equation 1d), or hybridized versions of each (e.g., Equation 1e), all of which may be valid approaches. The aggregation algorithms used for WVA are discussed in the model documentation (EWG 2002a, 2002b, 2006, 2007). The approach was to evaluate changes in model outcomes using four alternative aggregation techniques: (1) the WVA-specified formula which contains weighting factors; (2) a geometric mean without weighting factors; (3) an arithmetic mean without weighting factors; and (4) a harmonic mean without weighting factors (Table 2). The arithmetic, geometric, and harmonic averaging methods do not capture the relative importance of parameters as they were developed for WVA. However, these scenarios provide a relative comparison of aggregation algorithms and the sensitivity of the model to these options.

$$\text{(a)}\quad \bar{x} = \frac{x_1 + x_2 + x_3}{3} \qquad \text{(b)}\quad \bar{x} = \sqrt[3]{x_1 x_2 x_3} \qquad \text{(c)}\quad \bar{x} = \frac{3}{\frac{1}{x_1} + \frac{1}{x_2} + \frac{1}{x_3}}$$

$$\text{(d)}\quad \bar{x} = \frac{x_1 + \left(\frac{x_2 + x_3}{2}\right)}{2} \qquad \text{(e)}\quad \bar{x} = \frac{x_1 + \sqrt{x_2 x_3}}{2} \tag{1}$$

Due to complications arising from zero values input to these aggregation schemes, an intercept of 10^{-10} was used. This value was deemed sufficiently small to test the influence of zero-intercepts while maintaining numerical continuity. The figure was chosen by averaging quantities of seven, five, and three variables with one small value (e.g., 0.001) and the rest equal to one using arithmetic, geometric, and harmonic means. The motivation behind suggesting alternative aggregation methods is that geometric and harmonic means will more accurately reflect limiting factors in the analyses; therefore, the authors wanted to test how small a value had to be to become a "limiting factor" which was assumed to be $HSI_{combined} < 0.05$ (Figure 2). These near-zero intercepts will be referred to as the zero-intercept condition.

Test Matrix. In order to test sensitivity to changes in both boundary conditions (i.e., intercepts) and aggregation techniques, the authors examined all possible combinations of the two conditions as shown in Table 3, and will refer to these tests as indicated in the table.

Table 2. Aggregation formulae used in analyses.

Aggregation Technique[1]	Saline: Emergent Marsh	Saline: Open Water	Barrier Headland	Barrier Isand
WVA Specified	$\dfrac{3.5\sqrt[4]{SIV_1^{3}SIV_6} + \dfrac{SIV_3 + SIV_5}{2}}{4.5}$	$\dfrac{3.5\sqrt[7]{SIV_2^{2}SIV_6^{5}} + \dfrac{SIV_3 + SIV_4 + SIV_5}{3}}{4.5}$	$0.23SIV_1 + 0.23SIV_2 + 0.18SIV_3 + 0.18SIV_4 + 0.18SIV_5$	$0.14SIV_1 + 0.14SIV_2 + 0.17SIV_3 + 0.20SIV_4 + 0.10SIV_5 + 0.15SIV_6 + 0.10SIV_7$
Geometric Mean	$\sqrt[4]{SIV_1SIV_3SIV_5SIV_6}$	$\sqrt[5]{SIV_2SIV_3...SIV_6}$	$\sqrt[5]{SIV_1SIV_2...SIV_5}$	$\sqrt[7]{SIV_1SIV_2...SIV_7}$
Arithmetic Mean	$\dfrac{SIV_1 + SIV_3 + SIV_5 + SIV_6}{4}$	$\dfrac{SIV_2 + SIV_3 + ... + SIV_6}{5}$	$\dfrac{SIV_1 + SIV_2 + ... + SIV_5}{5}$	$\dfrac{SIV_1 + SIV_2 + ... + SIV_7}{7}$
Harmonic Mean	$\dfrac{4}{\dfrac{1}{SIV_1} + \dfrac{1}{SIV_3} + \dfrac{1}{SIV_5} + \dfrac{1}{SIV_6}}$	$\dfrac{5}{\dfrac{1}{SIV_2} + \dfrac{1}{SIV_3} + ... + \dfrac{1}{SIV_6}}$	$\dfrac{5}{\dfrac{1}{SIV_1} + \dfrac{1}{SIV_2} + ... + \dfrac{1}{SIV_5}}$	$\dfrac{7}{\dfrac{1}{SIV_1} + \dfrac{1}{SIV_2} + ... + \dfrac{1}{SIV_7}}$

[1] SIV_i refers to the model specified and does not necessarily represent the same parameter between models. For instance, saline emergent marsh SIV_1 is not equal to barrier headland SIV_1. See Table 2 for variable naming.

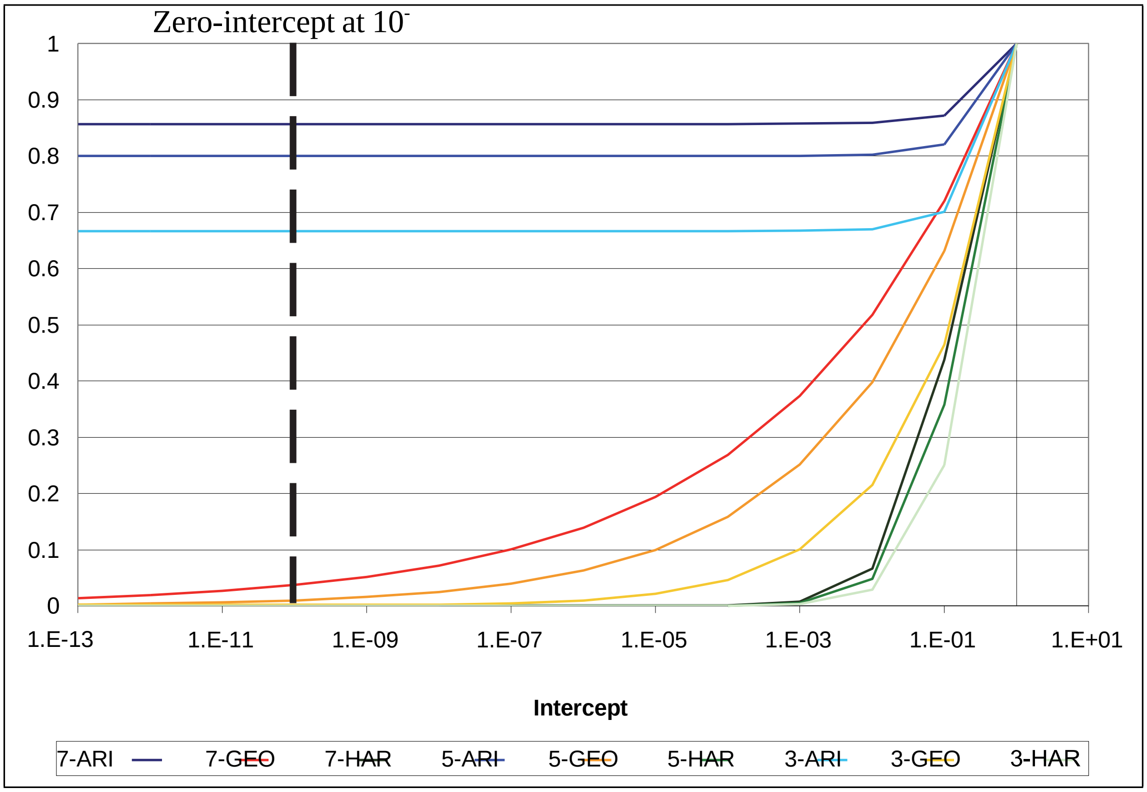

Figure 2. Combined habitat suitability indices (HSI) for “near-zero” intercepts with seven-, five-, and three-factor analyses and arithmetic (ARI), geometric (GEO), and harmonic (HAR) means.

Table 3. Test matrix.

Aggregation Technique	**Non-Zero Intercept Suitability Curves**	**Zero Intercept Suitability Curves**
WVA-specified	WVA-i	WVA-0
Geometric mean	GEO-i	GEO-0
Arithmetic mean	ARI-i	ARI-0
Harmonic mean	HAR-i	HAR-0

RESULTS: The sensitivity analysis provided important insight into the response of the WVA models relative to the two concerns expressed by reviewers, namely: (1) variation in Y-intercepts for suitability curves and (2) the method for aggregating suitability indices. Table 4 presents net average annual habitat units (AAHUs) for each of the intercept and aggregation scenarios described above. Table 5 summarizes these differences as the percent change in net AAHUs for changes in both intercept and aggregation technique. In terms of the overall magnitude of computed AAHUs, the WVA models examined were more sensitive to changes in aggregation method (average change in model results of 15.8%) than adjustments to the Y-intercepts of the suitability curves (average change in model results of 8.7%). The individual models varied in sensitivity; the saline direct model was the most sensitive to change and the barrier headland the least.

Table 4. Net average annual habitat units (AAHUs) for each alternative under multiple intercept and aggregation scenarios.

Model	Alternative	WVA-i	GEO-i	ARI-i	HAR-i	WVA-0	GEO-0	ARI-0	HAR-0
Saline Direct	Alt5	52.6	92.7	81.5	101.8	92.6	107.8	86.2	106.4
	Alt6	166.3	229.4	215.3	238.4	203.3	234.5	218.7	225.3
	Alt7	158.2	222.2	207.7	231.4	194.0	224.2	210.4	216.5
	Alt9	275.6	333.2	322.0	337.8	308.4	329.0	324.0	323.5
Saline Indirect	Alt5	52.3	61.5	69.0	53.8	59.5	53.0	70.0	47.8
	Alt6	94.6	107.0	109.2	101.2	109.3	112.3	110.5	100.1
	Alt7	46.4	52.0	52.7	49.5	61.2	56.1	54.9	53.9
	Alt9	75.0	64.6	71.4	50.2	95.1	84.9	73.8	65.4
Barrier Headland	Alt5	163.9	145.9	168.7	123.5	157.3	139.5	162.1	119.7
	Alt6	324.9	288.6	335.3	231.7	316.8	283.8	327.2	230.6
	Alt7	418.6	358.4	434.2	265.4	405.5	348.4	421.0	261.2
	Alt9	401.8	327.2	423.4	211.1	384.7	314.1	406.5	206.7
Barrier Island	Alt1_East	248.1	233.2	245.9	213.6	247.9	183.2	245.2	178.8
	Alt1_West	54.9	45.5	55.7	35.4	52.6	22.2	53.3	17.7
	Alt2_East	460.6	464.3	458.1	459.0	466.6	468.8	463.9	462.8
	Alt2_West	212.4	211.9	212.2	210.1	212.1	214.4	211.9	209.7
	Alt3	523.2	501.9	517.7	461.0	525.8	431.5	519.5	405.1
	Alt5	730.9	735.8	727.1	732.8	737.1	764.8	733.0	746.9

Table 5. Percent change in Net AAHUs.

	Change in Intercept			Change in Aggregation		
Model	**Avg**	**Min**	**Max**	**Avg**	**Min**	**Max**
Saline Direct	11.5	0.6	76.0	26.6	4.9	93.5
Saline Indirect	13.0	1.1	31.9	13.6	0.1	33.1
Barrier Headland	3.0	0.5	4.4	17.1	2.9	47.5
Barrier Island	7.8	0.1	51.2	9.1	0.1	66.3
All Models	8.7	0.1	76.0	15.8	0.1	93.5

While the absolute value of these changes might be considered large, in relative terms they're virtually inconsequential. Figure 3 presents the relative rankings of each alternative for each sensitivity analysis scenario. Of 144 possible rankings, only 20 were changed as a result of the eight intercept/aggregation combinations. **In no case was the highest scoring alternative replaced by another alternative as a consequence of the adjustments to intercept or to aggregation method.**

DISCUSSION: This analysis provides insight into the sensitivity of the models relative to the two conditions highlighted by model reviewers (BMI 2009). **The combined effects of the two response variables can affect the absolute magnitude of the output from the models, but they do not meaningfully affect the relative ranking of the alternatives.** Consequently, the model sensitivity analysis allowed the project team to respond to review comments as follows:

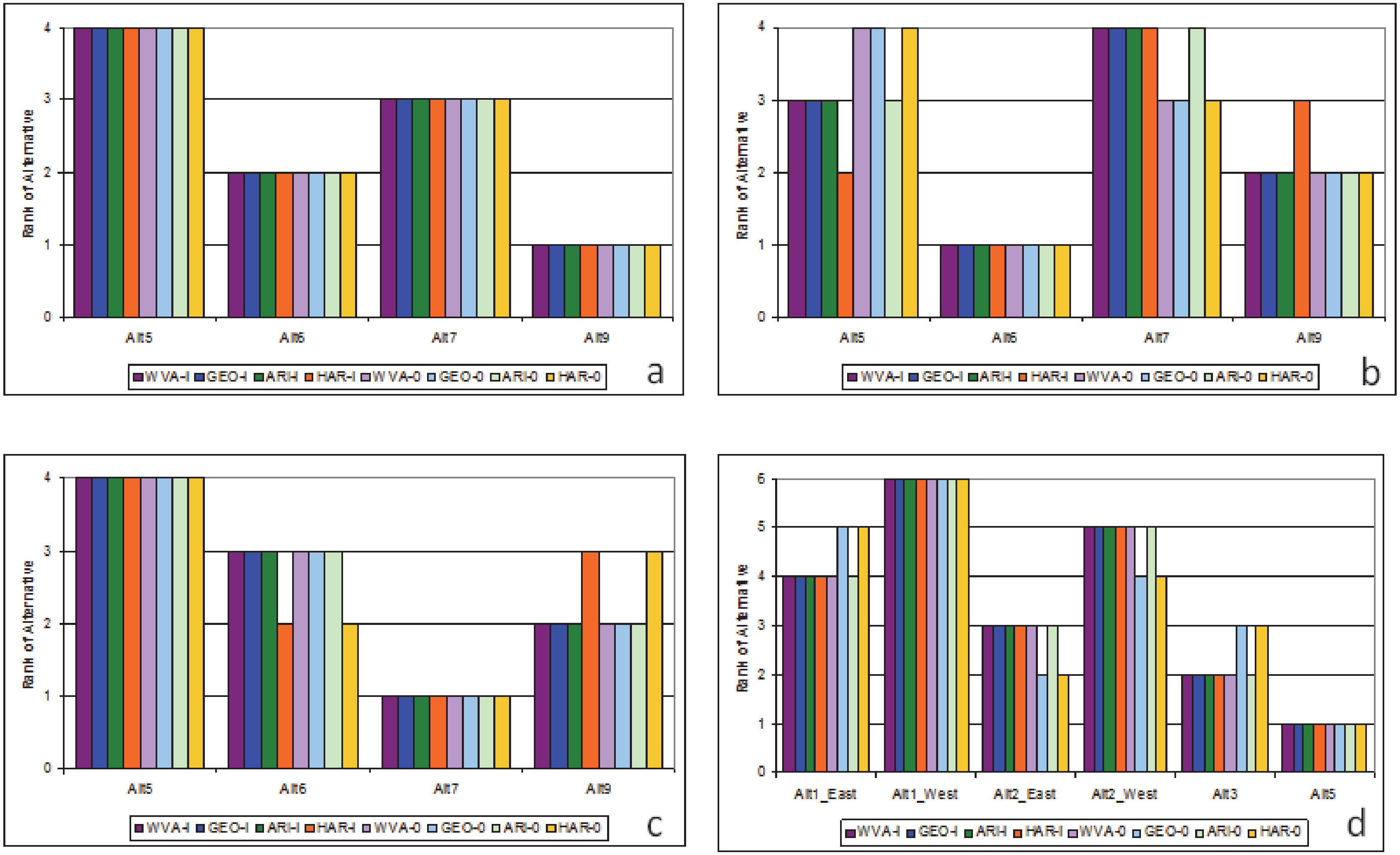

Figure 3. Relative rank of alternatives under different sensitivity scenarios (Refer to Table 3 for naming system) for each WVA model: (a) saline direct; (b) saline indirect; (c) barrier headlands; and (d) barrier islands.

Comment 1. Starting the SI curves for all variables at 0.1 is problematic because even habitat with no ecological value appears to have some ecological value.

This analysis shows that, for the BBBS study, application of zero-intercept suitability curves would not affect the relative rankings of project alternatives and has limited effect on the computed outputs. Given the relative and absolute magnitude of the changes, it appears unlikely that changing to a zero intercept would affect decisions. Furthermore, because model developers established the ecological basis for non-zero intercepts in the WVA model and given the lack of a strict requirement for a zero-slope intercept in community HEP models, the authors support the use of non-zero intercepts in WVA model applications.

Comment 18. The use of the geometric mean may be more appropriate than the arithmetic mean to derive some HSIs. Provide scientific basis for the decision to use one over the other.

The authors disagree with the reviewers' comment. The basis for the comment appears to be a presumption that there might be limiting factors for habitat best addressed through geometric averaging. For community-based models, it is not clear that there is an ecological basis for this assumption. Furthermore, sensitivity analysis shows that, while applying geometric averaging as well as other aggregation schemes that accomplish the same aim may change the overall magnitude of the output, it does not affect the relative ranking of alternatives in the case of the BBBS study.

CONCLUSIONS: Regardless of purpose or function, all models are limited by scientific understanding of the process being modeled, validity of input parameters, and ability of the model structure to capture understood processes. As shown here, there is value in examining model sensitivity to changes in one or all of these factors and how that sensitivity alters conclusions drawn from model results. While the authors recommend moving beyond sensitivity analysis and suggest accounting for uncertainty explicitly, simple sensitivity analyses like those shown here are helpful in almost any model application.

SYMBOLS:

AAHU	Average Annual Habitat Unit
BBBS	Barataria Basin Barrier Shoreline
BMI	Battelle Memorial Institute
EBA	Environmental Benefits Analysis
ERDC	U.S. Army Engineer Research and Development Center
EWG	Environmental Working Group
HEP	Habitat Evaluation Procedures
HSI	Habitat Suitability Index
HU	Habitat Unit
IEPR	Independent External Peer Review
LCA	Louisiana Coastal Area
SIV	Suitability index value
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
WVA	Wetland Value Assessment

ADDITIONAL INFORMATION: Research presented in this technical note was developed under the Environmental Benefits Analysis (EBA) Research Program. The USACE Proponent for the EBA Program is Ms. Rennie Sherman, and the Technical Director is Dr. Al Cofrancesco. Publication of this case study was at the request of Shawn Komlos (USACE Institute for Water Resources) and Jodi Staebell (Ecosystem Restoration Planning Center of Expertise). Permission to publish this analysis was provided by Fay Lachney and Bill Klein (USACE New Orleans District). Technical reviews by Drs. Bruce A. Pruitt and Burton Suedel are appreciated.

For additional information, contact the authors, Mr. S. Kyle McKay (601)-415-7160, *Kyle.McKay@usace.army.mil*), or Dr. Craig Fischenich (601)-634-3449, *Craig.J.Fischenich@usace.army.mil*), or the manager of the Environmental Benefits Analysis Research Program, Mr. Glenn Rhett (601)-634-3717, *Glenn.G.Rhett@usace.army.mil*). This technical note should be cited as follows:

McKay S.K. and J.C. Fischenich (2014). *Case study: Sensitivity analysis of the Barataria Basin Barrier shoreline wetland value assessment model*. EBA Technical Notes Collection. ERDC TN-EMRRP-EBA-20. Vicksburg, MS: U.S. Army Engineer Research and Development Center. *http://cw-environment.usace. army.mil/eba/*

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Appendix IV: Battelle's Comment 10 from (Battelle Memorial Institute 2010)

Comment 10:
For some model variables, policy decisions appear to supersede what is known about the ecology and hydrology of the relationships.
Basis for Comment:
Habitat Suitability Index (HSI) models are intended to capture, within the constraints of the approach, the ecological and hydrologic relationships of habitat suitability to the species/community being modeled. Accordingly, the Suitability Index (SI) relationships that are developed for each variable should reflect the best data available, and include citations from the primary literature for justification. For two variables in the Coastal Marsh Community Models it appears that the needs of CWPPRA have overridden logical SI relationships. This specifically occurs for : V_1 – Percent of wetland area covered by emergent vegetation. On page 4 of the model we read: *"Optimal vegetative coverage is assumed to occur at 100 percent (SI=1.0). That assumption is dictated primarily by the constraint of not having graph relationships conflict with the CWPPRA's purpose of long term creation, restoration, protection, or enhancement of vegetated wetlands. The EnvWG had originally developed a strictly biologically-based graph defining optimal habitat conditions at marsh cover values between 60 and 80 percent, and sub-optimal habitat conditions outside that range. However, application of that graph, in combination with the time analysis used in the evaluation process (i.e., 20-year project life), often reduced project benefits or generated a net <u>loss</u> of habitat quality through time with the project."* The authors clearly acknowledge that that optimal percent cover of emergent vegetation in a marsh is between 60-80%; this is biologically sound, and can be well supported from the literature. However, apparently because of the CWPPRA goal of establishing marshes with 100% cover, the SI curve for V_1 only achieves a value of 1.0 at 100% cover which makes V_1 more likely to generate successful outcomes for restoration projects but not ecologically defensible. Tidal marshes by definition cannot be 100% marsh because tidal creeks are necessary to convey tidal water and energy. The actual marsh:open water optimum will depend on tidal range (which equates to energy), land slope, etc. These values should come from the primary literature. V_3 – Marsh edge and interspersion – the effects of the SI curve developed for V_1 directly impact the edge/interspersion variable. This is a good, logical variable and marshes with good interspersion of open water and emergent cover are biologically optimal for the greatest number of species. For example, a considerable amount of research has been done and published on how marsh edge:area ratios relate to shrimp use of intertidal marsh (though this literature was not cited). Given this, it was surprising to see that interspersion Class 1, which has little or no marsh edge and very few tidal creeks, was given an SI of 1.0. The justification for this seems to be that Class 2 is probably a marsh that has deteriorated from a Class 1 status. This makes neither biological nor physical sense. Intertidal marshes have an inherent drainage dendrology that is related to tidal range and tidal energy. This creek network is essential to the movement of tidal water and its contents (animals, nutrients, organic matter, etc.) and thus to the functioning of the marsh ecosystem. Interspersion Class 1 should probably have a lower SI than Class 2. Notably, on page 5 of the model the following rationale is presented: *"A relatively high degree of interspersion in the form of stream courses and tidal channels (Interspersion Class 1) is assumed to be optimal (SI=1.0); streams and channels offer interspersion, yet are not indicative of active marsh deterioration. Areas exhibiting a high degree of marsh cover are also ranked as optimal, even though interspersion may be low, to avoid conflicts with the premises underlying the SI graph for variable V_1."* While this reduces potential conflict with V_1, it also is not logical, that two substantially different marsh conditions, solid emergent vegetation, and marsh with a high degree of interspersion of open water and emergent vegetation, should have the same value of 1.0.

There is a conflict here that confounds the model. If the goal is to develop marshes with 100% emergent cover, then that is the only variable that need be considered, and a model is not necessary. If, however, the goal is to develop marshes with the highest ecological value possible to the associated animal community/assemblages, then V_1 and V_3 must be changed to reflect ecological and hydrologic/physical reality rather than policy.
Significance – High:
The marsh models as they now exist do not reflect ecological reality and their application is suspect.
Recommendations for Resolution:
To resolve these concerns, the models and documentation would need to be revised as follows: • Change V_1 to reflect an SI value of 1.0 when cover is between 60 and 80% emergent vegetation, as discussed in the model discussion or as the scientific literature supports for any given marsh ecosystem type. • Change V_3 so that a marsh with 100% emergent cover and no interspersion cannot receive an SI value of 1.0 • Change V_2 – this variable only takes an SI value of 1.0 at 100% cover of SAV in areas of open water. This is unreasonable, and it is unlikely that open water will ever have the optimal conditions. Further research is necessary and the SI optimum should be justified using the scientific literature, noting that a goal-oriented SI of 1.0 for 100% cover is still possible.

ATTACHMENT C

PAV03B - Freshwater Emergent Wetland

Impact Sample Point (PAV03B) WVA Wetland Model	Date	GIS Coordinates	Variable 1 (Percent of wetland area covered by emergent vegetation)	Variable 2 (Percent of open water area covered by aquatic vegetation)	Variable 3 (Marsh edge and interspersion) %	Variable 4 (Percent of open water area < 1.5 feet deep in relation to marsh surface)	Variable 5 (Salinity)	Variable 6 (Aquatic organism access)	Dominant Plant Species
1 (dry)	27-Apr	29°51'50.01"N 93°56'30.01"W	25	0	Class 5	0	NA	0	Texas star, dewberry, bushy bluestem, deep-rooted sedge, chinese tallow, rattlebox
2 (dry)	27-Apr	29°51'52.00"N 93°56'28.96"W	25	0	Class 5	0	NA	0	Deep-rooted sedge, solidago, dewberry
3 (drainage ditch)	27-Apr	29°51'57.45"N 93°56'19.46"W	50	10	Class 5	10	0.0	0	Cyperus, deep-rooted sedge, cattail, black needle rush, chinese tallow
4 (soft-stem bullrush)	27-Apr	29°51'56.27"N 93°56'21.39"W	75	0	Class 5	0	NA	0	soft-stem bulrush, deep-rooted sedge, eastern black willow, rattlebox
5 (soft-stem bullrush)	27-Apr	29°51'55.3314"N 93°56'21.6954	100	0	Class 5	0	NA	0	black willow, chinese tallow, soft-stem bulrush, deep-rooted sedge

PAV03B - Woodland, Historically Coastal Prairie

Impact Sample Point (PAV03B) WVA Model	Date	GIS Coordinates	Variable 1 (Percent of wetland area covered by emergent vegetation)	Variable 2 (Percent of open water area covered by aquatic vegetation)	Variable 3 (Marsh edge and interspersion) %	Variable 4 (Percent of open water area < 1.5 feet deep in relation to marsh surface)	Variable 5 (Salinity)	Variable 6 (Aquatic organism access)	Dominant Plant Species
6.5	27-Apr	29°51'59.51"N 93°56'19.59"W	1	0	Class 5	0	NA	0	hackberry, dewberry, poison ivy, live oak

PAV03C - Freshwater Emergent Wetland

Impact Sample Point (PAV03B) WVA Wetland Model	Date	GIS Coordinates	Variable 1 (Percent of wetland area covered by emergent vegetation)	Variable 2 (Percent of open water area covered by aquatic vegetation)	Variable 3 (Marsh edge and interspersion) %	Variable 4 (Percent of open water area < 1.5 feet deep in relation to marsh surface)	Variable 5 (Salinity)	Variable 6 (Aquatic organism access)	Dominant Plant Species
PAV03C 01	14-Mar	29°50'48.37"N 93°57'16.99"W	75	0	Class 5	0	0	0	Cattail, water willow, smartweed

Mitigation Sites

Mitigation Site Sample Area WVA Wetland Model	Date	GIS Coordinates	Variable 1 (Percent of wetland area covered by emergent vegetation)	Variable 2 (Percent of open water area covered by aquatic vegetation)	Variable 3 (Marsh edge and interspesion) %	Variable 4 (Percent of open water area < 1.5 feet deep in relation to marsh surface)	Variable 5 (Salinity)	Variable 6 (Aquatic organism access)	Dominant Plant Species
J.D. Murphee - Brackish	8-Jun	29°48'27"N 94°2'19"W	15	10	Class 4	0	Unknown	100% - pipe	cattail, Spartina patens, bullrush, phragmites

Notes	Observers
BLRA adjacent plans could be copied from Wharton into a BA. Clear trees adjacent to wetland to mitigate for loss of BLRA habitat.	Justyss Watson, Jan Culbertson, Brandon Ford, Mike Morgan, Mike Rezsutek, Charrish Stevens
	Justyss Watson, Jan Culbertson, Brandon Ford, Mike Morgan, Mike Rezsutek, Charrish Stevens
Drainage ditch	Justyss Watson, Jan Culbertson, Brandon Ford, Mike Morgan, Mike Rezsutek, Charrish Stevens
dry area, on-site mitigation, scrape laydown area into freshwater marsh just to catch the water	Justyss Watson, Jan Culbertson, Brandon Ford, Mike Morgan, Mike Rezsutek, Charrish Stevens
come back in and plant soft-stem bullrush, invasive species management, enough water to get it wet/seasonal flooding	Justyss Watson, Jan Culbertson, Brandon Ford, Mike Morgan, Mike Rezsutek, Charrish Stevens

Notes	Observers
	Justyss Watson, Jan Culbertson, Brandon Ford, Mike Morgan, Mike Rezsutek, Charrish Stevens

Notes	Observers
90% cattail with some water willow and smartweed	Justyss Watson and Danny Allen

Notes	Observers
21" deep closer to wetland edge, would require some fill for emergent wetland planting, ~28" to 30" towards 29°48'22"N 94°02'20"W - same throughout middle of site. There are 2 pipe to keep saltwater out. Left open to keep out salvinia at Blind Lake and J.D. Murphee siphon, site goes to intercoastal	Justyss Watson

Future Without Project - PAV03B - Disturbed Coastal Prairie

Model	Habitat Type	Metric	Existing Condition/TY 0	TY 1	TY5	TY 10	TY 25	TY 50	Measurement
Marsh WVA	Wetland	Variable 1 (Percent of wetland area covered by emergent vegetation)	25	25	25	20	15	5	%
	Wetland	Variable 2 (Percent of open water area covered by aquatic vegetation)	0	0	0	0	0	0	%
	Wetland	Variable 3 (Marsh edge and interspersion)	Class 5	Class 5	Class 5	Class 5	Class 5	Class 5	**Class 1 Class 2 Class 3 Class 4 Class 5**
		Variable 4 (Percent of open water area < 1.5 feet deep in relation to marsh surface)	0	0	0	0	0	0	%
	Wetland								
	Wetland	Variable 5 (Salinity)	NA	NA	NA	NA	NA	NA	ppt
	Wetland	Variable 6 (Aquatic organism access)	0	0	0	0	0	0	**0.8 Rock Weir set 1ft below marsh level, w/boat bay 0.6 Rock weir with boat bay 0.6 Rock weir set at >= 1 ft BML**

Future Without Project - PAV03B - Cattail Wetland

Model	Habitat Type	Metric	Existing Condition/TY 0	TY 1	TY5	TY 10	TY 25	TY 50	Measurement
Marsh WVA	Wetland	Variable 1 (Percent of wetland area covered by emergent vegetation)	75	75	75	70	65	55	%
	Wetland	Variable 2 (Percent of open water area covered by aquatic vegetation)	3	3	3	3	3	3	%
	Wetland	Variable 3 (Marsh edge and interspersion)	Class 5	Class 5	Class 5	Class 5	Class 5	Class 5	**Class 1 Class 2 Class 3 Class 4 Class 5**
	Wetland	Variable 4 (Percent of open water area < 1.5 feet deep in relation to marsh surface)	3	3	3	3	3	3	%
	Wetland	Variable 5 (Salinity)	0	0	0	0	0	0	ppt
	Wetland	Variable 6 (Aquatic organism access)	0	0	0	0	0	0	**1.0 Open System 0.8 Rock Weir set 1ft below marsh level, w/boat bay 0.6 Rock weir with boat bay 0.6 Rock weir set at >= 1 ft BML 0.6 Slotted weir with boat bay 0.5 Open culverts 0.5 Weir with boat bay 0.5 weir set at >= 1 ft BML 0.4 Slotted weir 0.35 Flap-gated variable crest weir 0.3 Variable crest weir 0.25 Flap-gated culvert 0.2 Flap-gated culvert 0.15 Rock weir 0.1 Fixed crest weir 0.0001 Solid plug**

Future Without Project - PAV03C - Degraded Cattail Wetland

Model	Habitat Type	Metric	Existing Condition/TY 0	TY 1	TY5	TY 10	TY 25	TY 50	Measurement
Marsh WVA	Wetland	Variable 1 (Percent of wetland area covered by emergent vegetation)	75	75	75	70	65	55	%
	Wetland	Variable 2 (Percent of open water area covered by aquatic vegetation)	0	0	0	0	0	0	%
	Wetland	Variable 3 (Marsh edge and interspersion)	Class 5	Class 5	Class 5	Class 5	Class 5	Class 5	**Class 1 Class 2 Class 3 Class 4 Class 5**
	Wetland	Variable 4 (Percent of open water area < 1.5 feet deep in relation to marsh surface)	0	0	0	0	0	0	%
	Wetland	Variable 5 (Salinity)	0	0	0	0	0	0	ppt

	Wetland	Variable 6 (Aquatic organism access)	0	0	0	0	0	0	**1.0 Open System 0.8 Rock Weir set 1ft below marsh level, w/boat bay 0.6 Rock weir with boat bay 0.6 Rock weir set at >= 1 ft BML 0.6 Slotted weir with boat bay 0.5 Open culverts 0.5 Weir with boat bay 0.5 weir set at >= 1 ft BML 0.4 Slotted weir 0.35 Flap-gated variable crest weir 0.3 Variable crest weir 0.25 Flap-gated culvert 0.2 Flap-gated culvert 0.15 Rock weir 0.1 Fixed crest weir 0.0001 Solid plug**

Future Without Project - PAV03B Disturbed Woodland Historically Coastal Prairie

Model	Habitat Type	Metric	Existing Condition/TY 0	TY 1	TY5	TY 10	TY 25	TY 50	Measurement
WVA	Wetland	Variable 1 (Percent of wetland area covered by emergent vegetation)	1	1	1	1	1	1	**%**
	Wetland	Variable 2 (Percent of open water area covered by aquatic vegetation)	0	0	0	0	0	0	**%**
	Wetland	Variable 3 (Marsh edge and interspersion)	Class 5	Class 5	Class 5	Class 5	Class 5	Class 5	**Class 1 Class 2 Class 3 Class 4 Class 5**
	Wetland	Variable 4 (Percent of open water area < 1.5 feet deep in relation to marsh surface)	0	0	0	0	0	0	**%**
	Wetland	Variable 5 (Salinity)	NA	NA	NA	NA	NA	NA	**ppt**
	Wetland	Variable 6 (Aquatic organism access)	0	0	0	0	0	0	**1.0 Open System 0.8 Rock Weir set 1ft below marsh level, w/boat bay 0.6 Rock weir with boat bay 0.6 Rock weir set at >= 1 ft BML 0.6 Slotted weir with boat bay 0.5 Open culverts 0.5 Weir with boat bay 0.5 weir set at >= 1 ft BML 0.4 Slotted weir 0.35 Flap-gated variable crest weir 0.3 Variable crest weir 0.25 Flap-gated culvert 0.2 Flap-gated culvert 0.15 Rock weir 0.1 Fixed crest weir 0.0001 Solid plug**

Future With Project - Dry Wetland

Model	Habitat Type	Metric	Existing Condition/TY 0	TY 1	TY5	TY 10	TY 25	TY 50	Measurement
Marsh WVA	Wetland	Variable 1 (Percent of wetland area covered by emergent vegetation)	No Value	No Value	No Value	No Value	No Value	No Value	**%**
	Wetland	Variable 2 (Percent of open water area covered by aquatic vegetation)	No Value	No Value	No Value	No Value	No Value	No Value	**%**
	Wetland	Variable 3 (Marsh edge and interspersion)	No Value	No Value	No Value	No Value	No Value	No Value	**Class 1** **Class 2** **Class 3** **Class 4** **Class 5**
	Wetland	Variable 4 (Percent of open water area < 1.5 feet deep in relation to marsh surface)	No Value	No Value	No Value	No Value	No Value	No Value	**%**
	Wetland	Variable 5 (Salinity)	No Value	No Value	No Value	No Value	No Value	No Value	**ppt**
	Wetland	Variable 6 (Aquatic organism access)	No Value	No Value	No Value	No Value	No Value	No Value	**0.8 Rock Weir set 1ft below marsh level, w/boat bay** **0.6 Rock weir with boat bay** **0.6 Rock weir set at >= 1 ft BML**

Future With Project - Staging Area Wetlands

Model	Habitat Type	Metric	Existing Condition/TY 0	TY 1	TY5	TY 10	TY 25	TY 50	Measurement
Marsh WVA	Wetland	Variable 1 (Percent of wetland area covered by emergent vegetation)	No Value	No Value	No Value	No Value	No Value	No Value	**%**
	Wetland	Variable 2 (Percent of open water area covered by aquatic vegetation)	No Value	No Value	No Value	No Value	No Value	No Value	**%**
	Wetland	Variable 3 (Marsh edge and interspersion)	No Value	No Value	No Value	No Value	No Value	No Value	**Class 1** **Class 2** **Class 3** **Class 4** **Class 5**
	Wetland	Variable 4 (Percent of open water area < 1.5 feet deep in relation to marsh surface)	No Value	No Value	No Value	No Value	No Value	No Value	**%**
	Wetland	Variable 5 (Salinity)	No Value	No Value	No Value	No Value	No Value	No Value	**ppt**
	Wetland	Variable 6 (Aquatic organism access)	No Value	No Value	No Value	No Value	No Value	No Value	**1.0 Open System** **0.8 Rock Weir set 1ft below marsh level, w/boat bay** **0.6 Rock weir with boat bay** **0.6 Rock weir set at >= 1 ft BML** **0.6 Slotted weir with boat bay** **0.5 Open culverts** **0.5 Weir with boat bay** **0.5 weir set at >= 1 ft BML** **0.4 Slotted weir** **0.35 Flap-gated variable crest weir** **0.3 Variable crest weir** **0.25 Flap-gated culvert** **0.2 Flap-gated culvert** **0.15 Rock weir** **0.1 Fixed crest weir** **0.0001 Solid plug**

Future With Project - Staging Area Wetlands

Model	Habitat Type	Metric	Existing Condition/TY 0	TY 1	TY5	TY 10	TY 25	TY 50	Measurement
Marsh WVA	Wetland	Variable 1 (Percent of wetland area covered by emergent vegetation)	No Value	No Value	No Value	No Value	No Value	No Value	**%**
	Wetland	Variable 2 (Percent of open water area covered by aquatic vegetation)	No Value	No Value	No Value	No Value	No Value	No Value	**%**
	Wetland	Variable 3 (Marsh edge and interspersion)	No Value	No Value	No Value	No Value	No Value	No Value	**Class 1** **Class 2** **Class 3** **Class 4** **Class 5**
	Wetland	Variable 4 (Percent of open water area < 1.5 feet deep in relation to marsh surface)	No Value	No Value	No Value	No Value	No Value	No Value	**%**
	Wetland	Variable 5 (Salinity)	No Value	No Value	No Value	No Value	No Value	No Value	**ppt**

	Wetland	Variable 6 (Aquatic organism access)	No Value	No Value	No Value	No Value	No Value	No Value	**1.0 Open System 0.8 Rock Weir set 1ft below marsh level, w/boat bay 0.6 Rock weir with boat bay 0.6 Rock weir set at >= 1 ft BML 0.6 Slotted weir with boat bay 0.5 Open culverts 0.5 Weir with boat bay 0.5 weir set at >= 1 ft BML 0.4 Slotted weir 0.35 Flap-gated variable crest weir 0.3 Variable crest weir 0.25 Flap-gated culvert 0.2 Flap-gated culvert 0.15 Rock weir 0.1 Fixed crest weir 0.0001 Solid plug**

Future With Project - Disturbed Woodland Historically Coastal Prairie

Model	Habitat Type	Metric	Existing Condition/TY 0	TY 1	TY5	TY 10	TY 25	TY 50	Measurement
WVA	Wetland	Variable 1 (Percent of wetland area covered by emergent vegetation)	No Value	No Value	No Value	No Value	No Value	No Value	**%**
	Wetland	Variable 2 (Percent of open water area covered by aquatic vegetation)	No Value	No Value	No Value	No Value	No Value	No Value	**%**
	Wetland	Variable 3 (Marsh edge and interspersion)	No Value	No Value	No Value	No Value	No Value	No Value	**Class 1 Class 2 Class 3 Class 4 Class 5**
	Wetland	Variable 4 (Percent of open water area < 1.5 feet deep in relation to marsh surface)	No Value	No Value	No Value	No Value	No Value	No Value	**%**
	Wetland	Variable 5 (Salinity)	No Value	No Value	No Value	No Value	No Value	No Value	**ppt**
	Wetland	Variable 6 (Aquatic organism access)	No Value	No Value	No Value	No Value	No Value	No Value	**1.0 Open System 0.8 Rock Weir set 1ft below marsh level, w/boat bay 0.6 Rock weir with boat bay 0.6 Rock weir set at >= 1 ft BML 0.6 Slotted weir with boat bay 0.5 Open culverts 0.5 Weir with boat bay 0.5 weir set at >= 1 ft BML 0.4 Slotted weir 0.35 Flap-gated variable crest weir 0.3 Variable crest weir 0.25 Flap-gated culvert 0.2 Flap-gated culvert 0.15 Rock weir 0.1 Fixed crest weir 0.0001 Solid plug**

Future Without Project - J.D. Murphee

Model	Habitat Type	Metric	Existing Condition/TY 0	TY 1	TY5	TY 10	TY 25	TY 50	Measurement
Marsh WVA	Wetland	Variable 1 (Percent of wetland area covered by emergent vegetation)	15	15	10	5	0	0	**%**
	Wetland	Variable 2 (Percent of open water area covered by aquatic vegetation)	10	10	8	6	3	1	**%**
	Wetland	Variable 3 (Marsh edge and interspesion) GIS calculation	Class 4				Class 5	Class 5	**Class 1 Class 2 Class 3 Class 4 Class 5**
		Variable 4 (Percent of open water area < 1.5 feet deep in relation to marsh surface)	0	0	0	0	0	0	**%**
	Wetland								
	Wetland	Variable 5 (Salinity)	1	1	1	1	1	1	**ppt**
	Wetland	Variable 6 (Aquatic organism access)	1	1.0	1.0	1.0	1.0	1.0	**1.0 Open System 0.8 Rock Weir set 1ft below marsh level, w/boat bay 0.6 Rock weir with boat bay 0.6 Rock weir set at >= 1 ft BML 0.6 Slotted weir with boat bay 0.5 Open culverts 0.5 Weir with boat bay 0.5 weir set at >= 1 ft BML 0.4 Slotted weir 0.35 Flap-gated variable crest weir 0.3 Variable crest weir 0.25 Flap-gated culvert 0.2 Flap-gated culvert 0.15 Rock weir 0.1 Fixed crest weir 0.0001 Solid plug**

Future With Project - J.D. Murphee									
Model	**Habitat Type**	**Metric**	**Existing Condition/TY 0**	**TY 1**	**TY5**	**TY 10**	**TY 25**	**TY 50**	**Measurement**
Marsh WVA	Wetland	Variable 1 (Percent of wetland area covered by emergent vegetation)	15	85	82	80	77	75	**%**
	Wetland	Variable 2 (Percent of open water area covered by aquatic vegetation)	10	50	60	55	52	50	**%**
	Wetland	Variable 3 (Marsh edge and interspesion) GIS calculation	Class 4	Class 2	Class 2	Class 2	Class 2	Class 2	**Class 1** **Class 2** **Class 3** **Class 4** **Class 5**
	Wetland	Variable 4 (Percent of open water area < 1.5 feet deep in relation to marsh surface)	0	100	100	95	87	80	**%**
	Wetland	Variable 5 (Salinity)	1	1	1	1	1	1	**ppt**
	Wetland	Variable 6 (Aquatic organism access)	1.0	1.0	1.0	1.0	1.0	1.0	**1.0 Open System** **0.8 Rock Weir set 1ft below marsh level, w/boat bay** **0.6 Rock weir with boat bay** **0.6 Rock weir set at >= 1 ft BML** **0.6 Slotted weir with boat bay** **0.5 Open culverts** **0.5 Weir with boat bay** **0.5 weir set at >= 1 ft BML** **0.4 Slotted weir** **0.35 Flap-gated variable crest weir** **0.3 Variable crest weir** **0.25 Flap-gated culvert** **0.2 Flap-gated culvert** **0.15 Rock weir** **0.1 Fixed crest weir** **0.0001 Solid plug**

Mitigation Measures

Dammed off at Big Hill Bayou and Taylor's Bayou, unnaturally static throughout year. Doesn't move up and down as much as it used to. Goal - elevation of soils of +1.2 NAD88. Elevation surveys to verify. If 28" deep, would need to bring up the soil to that point or 30".

Native species plantings - Open water (widgeon grass, water lily)

Tend towards fresh throughout the year. Bring in saltwater on occasion to kill invasive aquatic plants. Previous BU work - TPWD can't bring in material. Actual construction needs to be done by USACE/DD7. TPWD provides space, benefits TPWD as well as mitigation needs. Once established, it stays. Only problem is if it is done incorrectly - impact from wind driven waves. Prescribed burns if needed by TPWD

Future Without-Project - PAV03B

Location	Cover Type	Target Year	Acres	Species	V1	V2	V3	V4	V5	V6	HSI	HUs	AAHUs	
Disturbed Coastal Prairie		0	4	WVA - Fresh	25	0	Class 5	0	0	0.0001	0.5	2		
		1	4	WVA - Fresh	25	0	Class 5	0	0	0.0001	0.5	2	2	
		5	4	WVA - Fresh	25	0	Class 5	0	0	0.0001	0.5	2	7	
		10	4	WVA - Fresh	20	0	Class 5	0	0	0.0001	0.4	2	9	
		25	4	WVA - Fresh	15	0	Class 5	0	0	0.0001	0.4	1	24	
		50	4	WVA - Fresh	5	0	Class 5	0	0	0.0001	0.3	1	32	1

Location	Cover Type	Target Year	Acres	Species	V1	V2	V3	V4	V5	V6	HSI	HUs	AAHUs	
Cattail Wetland		0	1	WVA - Fresh	75	3	Class 5	3	0	0.0001	0.8	1		
		1	1	WVA - Fresh	75	3	Class 5	3	0	0.0001	0.8	1	1	
		5	1	WVA - Fresh	75	3	Class 5	3	0	0.0001	0.8	1	3	
		10	1	WVA - Fresh	70	3	Class 5	3	0	0.0001	0.8	1	4	
		25	1	WVA - Fresh	65	3	Class 5	3	0	0.0001	0.8	1	11	
		50	1	WVA - Fresh	55	3	Class 5	3	0	0.0001	0.7	1	19	1

Location	Cover Type	Target Year	Acres	Species	V1	V2	V3	V4	V5	V6	HSI	HUs	AAHUs	
Disturbed Woodland/Coastal Prairie		0	2	WVA - Fresh	1	0	Class 5	0	0	0.0001	0.2	0		
		1	2	WVA - Fresh	1	0	Class 5	0	0	0.0001	0.2	0	0	
		5	2	WVA - Fresh	1	0	Class 5	0	0	0.0001	0.2	0	2	
		10	2	WVA - Fresh	1	0	Class 5	0	0	0.0001	0.2	0	2	
		25	2	WVA - Fresh	1	0	Class 5	0	0	0.0001	0.2	0	7	
		50	2	WVA - Fresh	5	0	Class 5	0	0	0.0001	0.2	0	12	0

Future Without-Project - PAV03C

Location	Cover Type	Target Year	Acres	Species	V1	V2	V3	V4	V5	V6	HSI	HUs	AAHUs	
Cattail Wetland		0	1	WVA - Fresh	75	3	Class 5	3	0	0.0001	0.8	1		
		1	1	WVA - Fresh	75	3	Class 5	3	0	0.0001	0.8	1	1	
		5	1	WVA - Fresh	75	3	Class 5	3	0	0.0001	0.8	1	3	
		10	1	WVA - Fresh	70	3	Class 5	3	0	0.0001	0.8	1	4	
		25	1	WVA - Fresh	65	3	Class 5	3	0	0.0001	0.8	1	11	
		50	1	WVA - Fresh	55	3	Class 5	3	0	0.0001	0.7	1	19	1

Future Without-Project - J.D. Murphee

Location	Cover Type	Target Year	Acres	Species	V1	V2	V3	V4	V5	V6	HSI	HUs	AAHUs	
J.D. Murphee	Emergent Wetland	0	70	WVA - Fresh	15	10	Class 4	0	1	1.00	0.4	30		
		1	70	WVA - Fresh	15	10	Class 4	0	1	1.00	0.4	30	30	
		5	70	WVA - Fresh	10	8	Class 4	0	1	1.00	0.4	26	112	
		10	70	WVA - Fresh	5	6	Class 4	0	1	1.00	0.3	21	117	
		25	70	WVA - Fresh	0	3	Class 5	0	1	1.00	0.2	16	278	
		50	70	WVA - Fresh	0	1	Class 5	0	1	1.00	0.2	16	403	19

Future With-Project - J.D. Murphee

Location	Cover Type	Target Year	Acres	Species	V1	V2	V3	V4	V5	V6	HSI	HUs	AAHUs	
J.D. Murphee	Emergent Wetland	0	70	WVA - Fresh	15	10	Class 4	0	1	1.00	0.4	30		
		1	70	WVA - Fresh	85	50	Class2	100	1	1.00	0.9	65	48	
		5	70	WVA - Fresh	82	60	Class 2	100	1	1.00	1.0	67	265	
		10	70	WVA - Fresh	80	55	Class 2	95	1	1.00	1.0	69	341	
		25	70	WVA - Fresh	77	52	Class 2	87	1	1.00	1.0	69	1040	
		50	70	WVA - Fresh	75	50	Class 2	80	1	1.00	1.0	69	1733	69

ATTACHMENT D

Mitigation Site – J.D. Murphee

J.D. Murphee

J.D. Murphee

J.D. Murphee

J.D. Murphee

ATTACHMENT E

Riverine Herbaceous/Shrub HGM Interim (FCI formulas)

Temporary Storage & Detention of Storage Water:

$[\{V_{dur} \times V_{freq}\}1/2 \times \{V_{topo} + \{V_{herb} + V_{mid}/2\}/2]\ 1/2$

Maintain Plant and Animal Community:

$\{V_{mid} + V_{herb} + V_{connect}\}/3$

Removal & Sequestrian of Elements & Compounds:

$[[V_{wood} + V_{freq} + V_{dur} + [\{V_{topo} + V_{herb} + V_{mid}\}/3] + [\{V_{detritus} + V_{redox} + V_{sorpt}\}/3]]/5$

V_{dur}

V_{freq}

V_{topo}

V_{wood}

V_{mid}

V_{herb}

$V_{connect}$

$V_{detritus}$

V_{redox}

V_{sorpt}

* The Riverine model is designed to be used to produce an assessment of the potential function of wetlands that share a surface hydrologic connection (at least periodically during anticipated high flows) with a riverine system {i.e. it is limited to wetlands located in the floodplain and/or floodway}. This model is to be used for a rapid non-controversial estimate of the potential impacts to herbaceous riparian wetlands and to see if the proposed mitigation will adequately address the wetland functions that are being impacted.

Riverine Herbaceous/Shrub HGM Interim

The techniques used to determine which functional capacity index (FCI) will be used for each variable rare typically based on standard techniques described in detail in the 1987 Corps Wetland Delineation Manual, the NRCS 3rd Edition to the National Food Security Act Manual (NFSAM) and/or the "A Regional Guidebook for Application of Hydrogeomorphic Assessments to Riverine Low Gradient Wetlands (Ainslie et al. 1997). These sources will hereafter be referred to as the 87 WDM, NFSAM, and the Kentucky Riverine Guidebook, respectively.

Documentation should be made for each variable as to which method, indicator, plot size was used for each variable. The number of sample plots is related to the variability of the site. Significantly different timber age classes or species types should be sampled separately. One of two sample plots might be sufficiently in a small uniform site, whereas, numerous sample plots would be required for a large diverse site. The following is a general definition and guidance on the methodology for each variable.

V_{dur}**: Duration of Flooding:** Indicators as described in the Wetland Hydrology Section of the 87 WDM (paragraphs 46-49) will be utilized to estimate duration of flooding. NOTE: unlike the criteria for hydrology for wetland delineation, growing season is not a factor in the variable. Those indicators associated with saturation should not be used.

V_{freq}**: Frequency of Flooding:** Indicators as described in the Wetland Hydrology Section of the 87 WDM (paragraphs 46-49) will be utilized to estimate frequency of flooding. Utilization of the county soil survey is a particularly good tool. NOTE: unlike the criteria for hydrology for wetland delineation, growing season is not a factor in the variable.

V_{topo}**: Topography:** To determine percent for these criteria, visual estimate will be conducted. Those areas with significant topographic features will be shown on a reference map, briefly described (i.e ridge/slough, mounds, undulations, channels/burn, etc.) and measured to determine acreage. Percent of site containing topographic features can then be determined.

V_{wood}**: Woody vegetation:** Percentage of the WAA that is covered by woody vegetation will be determined by the use of recent aerial photography. Field verification is needed to ensure land use changes have not occurred. Size and density of woody vegetation impedes water flow. For example; a few large trees in a pasture would NOT constitute "covered with woody vegetations" nor would 1 year old seedlings. It should also be noted that an area clear cut with stumps, sprouts and shrubs removed would NOT constituted "woody vegetation" and the functions should be assessed using a herbaceous model.

V_{mid}**: Midstory (Shrubs/saplings/woody vines):** The midstory layer is the layer of botanical specie located between the herbaceous and forest/tree canopy. This would included shrubs, saplings, smaller trees, small trees, and large woody vines. A measure is taken at each plot and/or a visual estimate is performed at each sample location(s).

V_{herb}**: : Herbeceous layer:** Herbaceous layers are made at each data location/plot as is described it in the 87 WDM. It is recommended that 2-5 sub plots be taken at each location to account for vegetative variability.

$V_{detritus}$**: Detritus:** This variable is a measure of the percentage of areas with detritus at the soil surface. Plowed areas or areas “washed” by high velocity flood water should not be considered as areas having detritus. Determination of an A (with organic) or O horizon should be determined for the entire site by on site field information.   For this variable, the A (with organic) must have a Munsell value of 4 or less. Refer to the Kentucky Riverine Model for additional details regarding this variable.

V_{redox}**: Redoximorphic process:** This variable is an indicator of periodic aerobic and anaerobic process within the top 10-12 inches of the soil surface. Redox features should be document for each sample plot/location and any other soil investigation conducted on the site. At least 50%of the must meet this criteria to be a 1 in the sub index.

V_{sorpt}**: Sorptive Soil Properties:** This variable is a general indicator of the potential that the soil has in regards to it’s absorptive properties. This information can be obtained by the use of the county soil survey in conjunction with the field data.

$V_{connect}$**: Connectivity to other habitat types:** This variable concentration on the geo-location of the WAA in relationship to other habitat type within 600 feet from the perimeter of the WAA.

Variables for HGM (Interim) Herbaceous/Shrub Riverine

V_{dur}: The % of the WAA that is flooded and/or ponded due to the hydrology (i.e. flooding overbank flow) of the nearby waterway

Criteria	Variable Sub index
In an average year at 80% of the WAA either floods and/or ponds for at least 14 consecutive days	1.00
In an average year at 80% of the WAA either floods and/or ponds for at least 7 consecutive days	0.75
In an average year at 50-79% of the WAA either floods and/or ponds for at least 7 consecutive days	0.50
In an average year at 25-50% of the WAA either floods and/or ponds for at lease 7 consecutive days	0.25
In an average year all or portions of the WAA either floods and/or ponds for at least 1-7 consecutive days	0.10
The area is NOT subject to flooding	0.00

V_{freq}: The frequency that the WAA is flooded and/or ponded by nearby waterway .

Criteria	Variable Sub index
Floods or pond annually 5 out of 5 years (floodway)	1.00
Floods or ponds 3 or 4 out of 5 years (elevation data reveals in floodway and mapped w/n 100 yr floodplain)	0.75
Floods or ponds 2 out of 5 years (100- year floodplain)	0.50
Floods or ponds less than 2 out of 5 years (100-500 yr floodplain grey w/out elevations)	0.25
The area is not subject to flooding or ponding (500 yr floodplain)	0.00

V_{topo}: The roughness associated with the WAA

Criteria	Variable Sub Index
Greater than 30% of the WAA is represented by dips, hummocks, channel sloughs and/or other topographic features	1.00
15 - 30% of the WAA is represented by dips, hummocks, channel sloughs and/or other topographic features	0.70
Less than 15% of the WAA is represented by dips, hummocks, channel sloughs and/or other topographic features	0.40
Smooth, flat, or very gentle undulating with little or no topographic features	0.10

V_{wood}: Percentage of the WAA that is covered by woody vegetation

Criteria	Variable Sun Index
Greater than 90% of the WAA is covered with woody vegetation	1.00
67 to 90 % of the WAA is covered with woody vegetation	0.75
34 to 66% of the WAA is covered with woody vegetation	0.50
11 to 33% of the WAA is covered with woody vegetation	0.25
0-10% if the WAA is covered with woody vegetation	0.10

V**mid:** The average/mean coverage of the midstory (shrub/sapling) layer in the WAA

Criteria	Variable Sub Index
Midstory coverage of the WAA is more than 75%	**1.00**
Midstory coverage of the WAA is between 50-75 %	**0.75**
Midstory coverage of the WAA is between 25-50%	**0.50**
Midstory coverage of the WAA is between 1-25%	**0.25**
Midstory coverage of the WAA is equal to or less than1%	**0.10**

V**herb:** The average/mean coverage of the WAA by the herbaceous layer

Criteria	Variable Sub Index
Herbaceous cover in the WAA averages greater than 75%	**1.00**
Herbaceous cover in the WAA averages between 50-75%	**0.75**
Herbaceous cover in the WAA averages between 25-50%	**0.50**
Herbaceous cover in the WAA average is between 1-25%	**0.25**
Herbaceous cover in the WAA is equal to or less than 1% (barren soil or all shrub)	**0.10**

V**connect:** the number of habitat types within a 600' of the parameter of the WAA

(Habitat to be counted has to be at a minimum 5% of the size of the WAA)

Habitat Types:

Forested	Shrub/Sapling
Herbaceous/Prairie/Abandoned Ag field	Active Agricultural Field
Open water	Wetland
Mudflat	Lawn

Criteria:	Variable Sub Index
Wetland plus four habitats and/or surrounded by forested	**1.00**
Wetland plus two or more habitat type (other than forested) OR three or more habitat types	**0.75**
Wetland plus one other habitat types or two other habitat types	**0.50**
One other habitat types other than urban habitat	**0.25**
Surround by urban (homes, lawn, concrete, etc.)	**0.10**

V**detritus**: The amount of the detritus on the WAA

(A horizon has to have a value of 4 or less)

Criteria	Variable Sub Index
Greater than 85% of the area possesses an O or A horizon	**1.00**
From 11-84% of the area possesses an O or A horizon	**0.50**
Less than 10% of the area possesses an O or A horizon	**0.30**
Site is plowed	**0.10**

V**redox:** The amount of the WAA that exhibits redox features an indication of the chemical exchange

Criteria	Variable Sub Index
Redox concentrations represent at least 20% of the pedon within the top 4 inches of the soil surface, or feature masked due to parent material but conditions are conducive to redoximorphic processes. (many mottles)	**1.0**
Redox features less than 20%	**0.1**

V**sorpt:** The absorptive properties of the soils in the WAA

Criteria	Variable Sub Index
The WAA is dominated by montmorillonitic clayey soils (clay, clay loams, silty clay loams) or soils with high organic (2/1, 2/2, or 3/1)	**1.00**
WAA is dominated by loamy (silt loams, very fine sandy loams, loam) or non-montmorillonitic clays	**0.50**
The WAA is dominated by sandy soils (sands, loamy fine sands, loamy sands)	**0.10**

Riverine Herb/Shrub HGM (Interim) Worksheet

WAA #

Variable	Subindex
$V_{\mathbf{dur}}$	
$V_{\mathbf{freq}}$	
$V_{\mathbf{topo}}$	
$V_{\mathbf{wood}}$	
$V_{\mathbf{mid}}$	
$V_{\mathbf{herb}}$	
$V_{\mathbf{detritus}}$	
$V_{\mathbf{redox}}$	
$V_{\mathbf{sorpt}}$	
$V_{\mathbf{connect}}$	

WAA #

Variable	Subindex
$V_{\mathbf{dur}}$	
$V_{\mathbf{freq}}$	
$V_{\mathbf{topo}}$	
$V_{\mathbf{wood}}$	
$V_{\mathbf{mid}}$	
$V_{\mathbf{herb}}$	
$V_{\mathbf{detritus}}$	
$V_{\mathbf{redox}}$	
$V_{\mathbf{sorpt}}$	
$V_{\mathbf{connect}}$	

WAA #

Variable	Subindex
$V_{\mathbf{dur}}$	
$V_{\mathbf{freq}}$	
$V_{\mathbf{topo}}$	
$V_{\mathbf{wood}}$	
$V_{\mathbf{mid}}$	
$V_{\mathbf{herb}}$	
$V_{\mathbf{detritus}}$	
$V_{\mathbf{redox}}$	
$V_{\mathbf{sorpt}}$	
$V_{\mathbf{connect}}$	

Riverine Herb/Shrub (Interim HGM) Worksheet
Functional Capacity Index (FCI)

<u>Temporary Storage & Dentention of Storage Water:</u>

[{V_{dur} x $V_{freq\}1/2}$ x {V_{topo} + {V_{herb} + $V_{mid/2\}}$ }/2]1/2

[{___ x ___} ½ x {___ + {____ + _____/2}/2]1/2 = FCI

[{___ x ___} ½ x {___ + {____ + ____/2}/2]1/2 = FCI

<u>Maintain Plant and Animal Communities:</u>

{V_{mid} + V_{herb} + $V_{connect\}}$/3

{____ + ____ + ____}/3 = FCI

{____ + ____ + ____}/3 = FCI

<u>Removal & Sequestrian of Elements & Compounds:</u>

[[V_{wood} + V_{freq} + V_{dur} + [{V_{topo} + V_{herb} + V_{mid} }/3] + [{$V_{detritus}$ + V_{redox} + V_{sorpt} }/3]]/5

[[____ + ____ + ____ +[{____ + ____ + ____}/3] + [{___ + ____ + ____}/3]]/5 = FCI

[[____ + ____ + ____ +[{____ + ____ + ____}/3] + [{___ + ____ + ____}/3]]/5 = FCI

Functional Capacity Units (FCU); FCI x wetland acres per WAA…

WAA #	Pre-project FCUs	Post Project FCUs
Temp Storage of Water		
Maintain Plant & Animal		
Removal of Elements		

Riverine Herb/Shrub (Interim) HGM Worksheet
Functional Capacity Index (FCI)

Mitigation

Temporary Storage & Dentention of Storage Water:
$[\{V_{\mathbf{dur}}\ X\ \ V_{\mathbf{freq}\}1/2}\ X\ \{V_{\mathbf{topo}} + \{V_{\mathbf{herb}} + V_{\mathbf{mid/2}\}}\ \}/2]\ ½$

Pre: [{___ x ___} ½ x {___ + { _____ + ___/2}}/2]1/2 = FCI

Post: [{___ x ___} ½ x {___ + { _____ + ____/2}}/2]1/2 = FCI

Maintain Plant and Animal Communities:

$\{V_{\mathbf{mid}} + V_{\mathbf{herb}} + V_{\mathbf{connect}\}}/3$

Pre: {_____ + _____ + _____}/3 = FCI

Post: {_____ + _____ + _____}/3 = FCI

Removal & Sequestrian of Elements & Compounds:

$[[V_{\mathbf{wood}} + V_{\mathbf{freq}} + V_{\mathbf{dur}} + [\{V_{\mathbf{topo}} + V_{\mathbf{herb}} + V_{\mathbf{mid}}\ \}/3] + [\{V_{\mathbf{detritus}} + V_{\mathbf{redox}} + V_{\mathbf{sorpt}}\ \}/3]]/5$

Pre:
[[_____ + _____ + _____ +[{_____ + _____ + _____}/3] + [{___ + _____ + _____}/3]]/5 = FCI

Post:
[[_____ + _____ + _____ +[{_____ + _____ + _____}/3] + [{___ + _____ + _____}/3]]/5 = FCI

Mitigation

Functional Capacity Units (FCU); FCI x wetland acres per WAA…

WAA #	Pre-project	Post 1 yr	Post 5 yr	Post 10 yr
Temporary Storage				
Maintain Plant & Animal				
Sequestrian of Elements				

Riverine Herb/Shrub (Interim) HGM Worksheet
Functional Capacity Unit (FCU)
Impact(s) sheet

Potential Functional Capacity impacts
{i.e. WAA 1 FCU biota loss (bl) + WAA 2 bl + WAA 3 bl + WAA 4 bl = net FCU loss}

Temporary Storage & Detention of Storage Water:

Maintain Plant & Animal Communities:

Removal & Sequestrian of Elements & Compounds:

* **Net FCU loss is calculated by deducting the post project FCU from the pre-project FCU per function capacity. Different functional capacity index should NEVER be summarized.**