Mississippi Valley Division,
Regional Planning and Environment Division South

Morganza to the Gulf, Louisiana, Hurricane and Storm Damage Risk Reduction Project SEIS

Appendix D – Wetland Value Assessment Models and Assumptions

December 2025

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Part 1: Overarching PIS Morganza to the Gulf Direct Construction Impacts to Swamp and BLH

Morganza to the Gulf
Wetland Value Assessment (WVA) Overarching Project Information Sheet (OPIS)
May-2025

1. Introduction

1.1 Project Background

The authorized Morganza to the Gulf (MTG) project is a hurricane and storm damage risk reduction project involving a 98-mile alignment of earthen levees, floodgates, environmental water control structures, road/railroad gates, and fronting protection for existing pump stations. The purpose of the project is to reduce the risk of damage caused by hurricane storm surges. The project is needed because of the increasing susceptibility of coastal communities to storm surge due to wetland loss, sea level change, and subsidence.

The study area includes communities in the southeast Louisiana parishes of Ascension, Assumption, Jefferson, Lafourche, St. Charles, St. James, and St. John the Baptist (Figure 1). The study area is bounded on the north and east by the Mississippi River Levee, on the west by Bayou Lafourche, and on the south it extends slightly past U.S. Highway 90. The study area covers approximately 1,924 square miles and is characterized by low, flat terrain with wetlands, numerous navigation channels, drainage canals, and natural bayous that drain into Lake Salvador and eventually into the Gulf. The study area is a diverse ecosystem inhabited by a variety of species of birds, mammals, reptiles, and amphibians, as well as fresh, brackish, and saltwater fish.

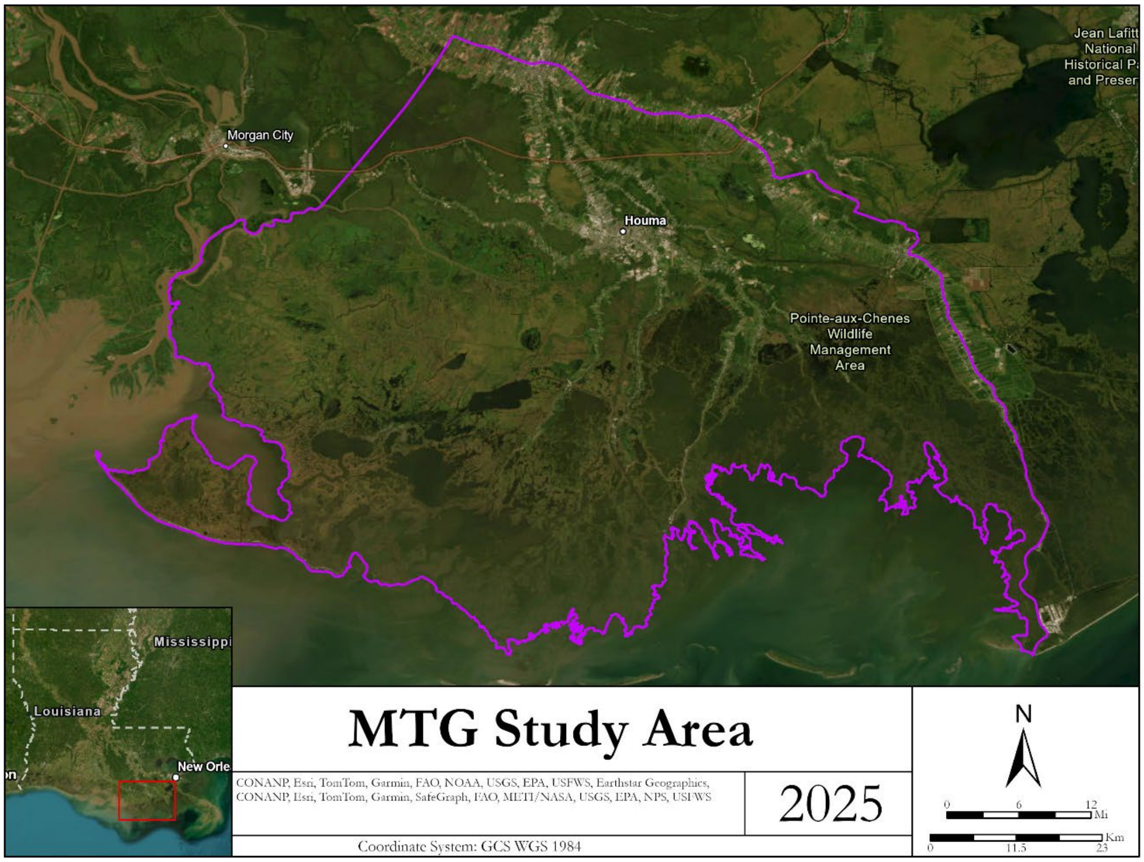

Figure 1: MTG Study Area

1.2 WVA Background

To quantify impacts to wetland habitats over project life, the most current versions of the Civil Works Wetland Value Assessment (WVA) models (Wetland Value Assessment Bottomland Hardwoods Community Model for Civil Works (Version 1.2)) and Wetland Value Assessment Swamp Community Model for Civil Works (Version 2.0)) were used. Further information on these models may be obtained from the USACE, New Orleans District, RPEDS (https://ecolibrary.planusace.us/ (use the search term “WVA”)).

Each model consists of 1) a list of variables (V) 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 Index) and different variable values, and 3) a mathematical formula that combines the Suitability Index for each variable into a single value for wetland habitat quality. That single value is referred to as the Habitat Suitability Index, or HSI. The bottomland hardwood (BLH) WVA models consist of 7 variables: 1) Tree Species Composition, 2) Stand maturity, 3) Understory/Midstory, 4) Hydrology, 5) Size of Contiguous Forested Area, 6) Suitability and Traversability of Surrounding Land Uses, 7) Disturbance. The swamp WVA models consist of 7 variables: 1) Stand structure, 2) Stand maturity, 3) Water regime, 4) Mean high salinity during the growing season, 5) Size of Contiguous Forested Area, 6) Suitability and Traversability of Surrounding Land Uses, 7) Disturbance.

The WVA models compare habitat values across the Project's life for three different conditions: existing, Future Without Project (FWOP), and Future With Project (FWP). Target years (TYs) are designated based on project implementation and anticipated future changes for each future condition. The TY0 represents the pre-project condition and is the same for both the FWP and FWOP condition. The TY0 could be the existing condition as measured in the field or it could be forecasted from field measurements.

1.3 Impacts to Forested Habitat

Construction of Morganza to the Gulf levee and associated structures will result in removal of 333 acres of bottomland hardwood and 178 acres of swamp habitat.

Table 1. Average Annual Habitat Units by reach and structure.

Reach		Habitat	AAHU	Existing Wetland Habitat Acres
Barrier_642	Floodside	BLH	-3.8	**6**
Barrier_642	Protected side	BLH	-11.4	**17**
Barrier_642	Floodside	Swamp	-21.4	**29**
Barrier_642	Protected side	Swamp	-4.1	**7**
Barrier_648	Floodside	BLH	-29.2	**81**
Barrier_648	Protected side	BLH	-10.9	**21**
Barrier_640	Floodside	BLH	-15.1	**29**
Barrier_640	Protected side	BLH	-7.9	**13**
Barrier_640	Floodside	Swamp	-22.7	**42**
Barrier_640	Protected side	Swamp	-2.2	**4**
Barrier_Structures_Swamp		Swamp	-0.5	**1**
Barrier_Structures_640		BLH	0.0	**0**
Barrier_Structures_642		BLH	-1.5	**2**
Barrier_Strucures_648		BLH	-0.4	**1**
B_BLH		BLH	-2.2	**8**
B_Structures_BLH		BLH	-0.1	**0**
E_BLH		BLH	-4.0	**9**
F_BLH		BLH	-4.4	**9**
G_BLH		BLH	-0.02	**0.16**
G_Structures_BLH		BLH	-0.4	**2**
H_6_BLH	Protected side	BLH	-7.5	**19**
H_Structures_BLH		BLH	-0.9	**2**

I_BLH		BLH	-0.2	**1**
I_Structures_BLH		BLH	-0.9	**3**
J_BLH		BLH	-0.1	**1**
L2L	Floodside	Swamp	-67.2	**90**
L2L_159_BLH		BLH	-29.5	**72**
L2L_160_BLH		BLH	-20.7	**34**
L2L_Strucures_BLH		BLH	-0.3	**0.7**
L2L_Haul_Route		BLH	-0.1	**0.1**
LCN_506_Swamp		Swamp	-2.3	**4**
LCN_BLH		BLH	-0.2	**1**
Total Direct BLH		BLH	**-151.7**	**333.4**
Total Direct Swamp		Swamp	**-120.4**	**177.8**
Total Forested Direct		Both	**-272.0**	**511.2**

2. Approach

2.1 Field Data Collection

Data from forested plots for Swamp and BLH were collected within a 3-month period (July 15 – September 26, 2024). Approximately 1/10-acre plots were established using a meter tape. The center and edges of each plot were marked with flagging. The circular plots were divided into quarters to aid in data gathering. General descriptions and observations regarding hydrology and adjacent disturbances or land use were recorded for each site. Percent cover data was collected (using ocular estimation) for overstory, midstory, and understory. Within the canopy, % cover was recorded for hard-mast, non-mast, soft-mast, and cypress categories. Species comprising the midstory and understory were recorded. Diameter at breast height (DBH) was collected using a DBH tape for all trees that were greater than ~1.0 inches DBH; smaller trees were counted. The presence of large (6-8 inches DBH) snags, small (<6 inches DBH) snags, and future snags was recorded. If site conditions suggested that a large number of small trees was evidence of site stress, as opposed to background recruitment (for example, many small trunks branching from one individual), it was recorded in the notes.

2.2 Data Processing

Several standard protocols were applied while completing data entry:

- For trees with 2 trunks, the average DBH of both trunks was used
- For trees with more than 2 trunks, the average DBH of the 2 largest trunks was used and the remaining were disregarded
- If trees with DBH <1.0 inch were marked as stress induced production of multiple, small trunks from one individual, they were not included in the data
- Willow and tallow were entered as maple since they are fast growing
- Trees with DBH <1.0 inch were entered as 0.5 inches

“In-growth” spreadsheets (a tool developed specifically to perform growth projections) were used to predict tree growth for individual trees from plots. The spreadsheet projects individual tree DBH and field site basal area changes over time. Background mortality specifics within the habitat type is also applied at the plot level (Chapman et al., 2008). The in-growth sheet for swamp divides species into cypress and other, while the BLH in-growth sheet has individualized growth rates for maple, cypress, oak species, sugarberry, elm, ash, and other.

Outputs from each plot’s in-growth spreadsheets including tree composition (BLH V1), stand structure (swamp V1), stand maturity (swamp and BLH V2), and understory/midstory (BLH V3) for each plot were developed individually then combined in the appropriate WVAs by area. See sections on Variables 1, 2, and 3 below for more detail.

WVAs were completed for the USACE low, intermediate, and high sea level change scenarios. In most cases, variable assignments and methods were the same for high and low as they were for the intermediate. In cases where they were adjusted, it is noted for that specific variable. In cases where BLH and swamp field data was not collected for a particular WVA, data was used from Reach Barrier (see Table 2) and the growth rates were adjusted for target years using a determination of when, according to light detection and ranging (LiDAR) data and RSLC curves (see 2.5.2), portions of the BLH habitat would be submerged. That analysis was performed for each reach, even if field data was used from a different reach.

2.3 Habitat Classification

Habitat types within the planned levee footprint (and associated structures) were classified as developed, bottomland hardwood, swamp, fresh/Intermediate (f/I) marsh, brackish marsh, saline marsh, water, and non-wetland habitat. Field data from WVA sampling events were used to inform classification. For more detail, see Appendix 1, Morganza to the Gulf Habitat Delineation Methodology.

Morganza to the Gulf Project habitat delineations were accomplished in collaboration with the United States Fish and Wildlife Services using ArcGIS Pro Geographic Information Systems (GIS) software version 3.3.2 - Supervised Classification method. Digital 2023 aerial imagery from U.S. Department of Agriculture’s (USDA) National Aerial Imagery Program (NAIP) one-meter spatial resolution UTM NAD83 Zone 15 projection were the source imagery for the analysis. Representative spectral signatures for each habitat type were identified and captured to create the desired sample classes of water, marsh, bottomland hardwood (BLH) and non-wetland. Supervised Classification tool was run for each reach to categorize the construction footprints into the desired classes. Due to the inconsistency in color and textures of imagery across the reaches, the resulting classes needed manual refinement, mainly between existing levee/earthen roads and marsh environments. Polygon editing tools were used to heads up digitize and split and/or refine the lines between habitats. In addition to knowledge of aerial imagery spectral signatures, ground truthing sites were used to confirm and refine the habitat delineations. Project biologists were consulted during the mapping process to review draft assigned habitats and for a full review after final edits and acre calculations were complete. The 2023 habitat delineations were overlaid with the 2021 USGS vegetation types (https://www.usgs.gov/data/vegetation-types-coastal-louisiana-2021-ver-20-april-2023) to give the salinity modifiers to the habitat data.

2.4 WVA Organization

2.4.1 Spatial Extent

Multiple plots were established to represent habitat evaluated by individual WVAs. Area represented by a WVA was divided by reach and then by additional boundaries; reaches were divided by the Coastal Master Plan (CMP) Integrated Compartment model (ICM) polygons. The ICM is a planning-level model that was developed to aid decision-making in support of the CMP (Reed & White, 2023). Because ICM model compartments were used to generate some components of WVA variables, those boundaries were used to separate area further into areas represented by separate WVAs. Areas where an ICM was divided by an existing hydrological barrier, such as the existing non-federal levee, were divided further into protected versus unprotected, since it was assumed that those features may have resulted in potentially different hydrological conditions at baseline (TY 0). The sites organized by reach, habitat, ICM, and protected vs unprotected (where applicable) are below in Table 2.

For small areas of BLH and/or Swamp within reaches B, E, G, H, I, J, K, and water control structure areas, plots were not established. In those cases, data from other reaches were used for V1 – V3; however, V4-V7 were determined for each individual WVA using data from the actual impact area (ICM), according to the methods described in section 3.3, 3.5 and 3.6. Sea level change analysis for those WVAs was performed and applied to V1-V3. Reaches and the plots used to represent the associated WVAs are in Table 2.

Table 2. WVA boundaries and field plots used to represent the habitat therein.

Reach	ICM	Protected versus Floodside	Swamp Sites	BLH Sites
Barrier	642	Protected	102, 99	100, 105
		Floodside	98	100, 105
	648	Protected		95, 107
		Floodside		97, 96, 94, 92
	640	Protected	87, 109, 137b	138
		Floodside	87, 109, 137b	108, 89, 88
Reach B	866			*108, 89, 88
Reach E	464			*108, 89, 88
Reach G	743			*108, 89, 88
Reach H	753			*108, 89, 88
Reach I	703			*108, 89, 88
Reach J	512			*108, 89, 88
Reach K				*108, 89, 88

Reach LCN	506		1	7, 14, 18, 20
L2L 159	159		10, 25, 27, 28	7, 14, 18, 20
L2L 160	160			9, 11, 15, 19
Barrier Structure	642			100, 105
Barrier Structure	648			97, 96, 94, 92
Barrier Structure	640		87, 109, 137b	108, 89, 88
Reach B Structures	866			*108, 89, 88
Reach G Structures	473			*108, 89, 88
Reach H Structures	753			*108, 89, 88
Reach I Structures	511/512			*108, 89, 88
Reach J Structures	509			*108, 89, 88
Reach L Structures	721			*108, 89, 88
L2L Structures	159			7,14,18,20

*Represents instances where plot data from other reaches was used in a WVA for another reach. Site specific information for was still applied to calculate variable projections.

2.4.1 Target Year (TY) Selection

According to USACE, project construction would begin in 2025, therefore, TY0 (baseline year) would be 2024, and the end of the project life is TY60 in 2084. Additional target years (15, 30, and 45) were added to capture potential changes in habitat condition due to sea level change over the project life.

2.5 Relative Sea Level Change

2.5.1 Assumptions

An inherent assumption used to determine future impacts to BLH with Relative Sea Level Change (RSLC) is that persistent flooding of a BLH site will cause the BLH to convert to another habitat type resulting in loss of BLH acres in the lower elevation persistently flooded zones. Swamp habitat, which is more tolerant to flooding, can persist longer than BLH during extended periods of deeper flooding. Therefore, sea level change (SLC) assumptions were applied broadly to swamp WVAs.

SLC equations from the USACE Engineering Regulation (ER) 1100-2-8162 were used for all three scenarios (low, intermediate, and high) in the RSLC spreadsheet for BLH habitat. This report focuses on the intermediate scenario. The equation for intermediate RSLC, which was used for the WVA analysis, is below. See ER 1100-2-8162 for more information.

$$E(t) = 0.0017t + bt^2$$

where *E(t)* is the eustatic sea level change, in meters, as a function of *t*. The Eustatic sea level change for the medium sea level change is -1.7 mm/year. *b* is a constant for the modified National Research Council Curve I, which is 2.71 x 10^{-5}.

2.5.2 BLH Area Projection

Light detection and ranging (LiDAR) data was obtained for the BLH areas to determine the average annual baseline elevation, which was assumed to be equivalent to the forest floor. The RSLC spreadsheet uses LiDAR data in combination with the RSLC to determine future BLH acres in a coastal WVA. A reduction in BLH acres assumes some acres are lost to persistent flooding and have likely converted to open water or marsh. LiDAR data was not obtained for Swamp sites due to the limitations of the data and ability to broadly apply RSLC assumptions to swamp. Swamp habitat is perpetually inundated with turbid waters, making LiDAR data inaccurate in these areas due to the inability of light to reach the swamp floor and accurately determine the elevation.

Another important assumption is that average annual baseline water elevation is equal to the forest floor in the lowest elevation increment of existing BLH. This value comes from the average elevation of the lowest increment for which data exists. If <1 to 2% of the area is at this lowest elevation, the average elevation of the next highest increment is used. This value is an input value and may be set differently by the user if site specific conditions suggest otherwise. Should the user have no specific conditions or water level data to support changing this assumption, it is recommended that the user follow the above-mentioned assumption/protocol. For this project, the lowest occurring BLH elevation was selected, regardless of the % area.

The spreadsheet requires LiDAR data or other elevation data at 0.25-foot increments. It also requires that RSLC information be accessed and projected water elevation be entered. LiDAR data was acquired from the Louisiana Statewide LiDAR Atlas. The low, intermediate, and high RSLC curves were used for each of the respective WVA scenarios for BLH. RSLC was calculated using the Marsh Impact Mitigation (MIMs) 3.11 spreadsheet. The main inputs into the MIMs spreadsheet are land loss, subsidence, and accretion. Using the total acreage of the evaluation area, the LiDAR spreadsheet calculates an average area per pixel to calculate acreage by elevation increments. Additionally, average annual salinity (ppt) is entered. If it is sufficiently high, it decreases the BLH mortality threshold.

The spreadsheet provides users with future BLH acreages at TY1 (same as TY0), TY16, TY32, TY47 and TY62. The TYs 16, 32, 47 and 62, divide the project life into 4 nearly equal duration time periods so that RSLC BLH acreage impacts may be determined at intervals over the 60-yr project life.

The spreadsheet outputs total project acres for FWOP and FWP. These acreage values are entered into the WVA spreadsheet. The spreadsheet also outputs percent of remaining acres experiencing inundation sufficient enough to cause reduced DBH growth. These percentages are used in the DBH-growth spreadsheet to reduce DBH growth rate.

The freshwater inundation BLH mortality threshold of 1.0 ft is higher than expected in order to capture the lag between the time the mortality begins occurring and when the functional BLH is sufficiently degraded to no longer be considered BLH. Note that the BLH mortality inundation threshold is reduced to 0.4 ft when average annual salinity >= 2.0 ppt given that brackish water is more toxic to BLH tree species than freshwater.

The LiDAR for each WVA was pulled within the footprint of each reach, except for Reach Barrier. Due to the size and hydrology of Reach Barrier, the WVAs for this reach were split into the three ICMs that encompass the reach footprint. For each of the Barrier ICMs, LiDAR for the entire footprint of the ICM was used, as the extent of contiguous BLH habitat outside of the levee footprint was significant within the ICM.

3. BLH/Swamp WVA Variable General Assumptions

In the FWP condition, all variables in future years are assigned the lowest possible value to represent the removal of habitat with construction. Therefore, only the FWOP variable assignments are discussed in detail. In instances where methods for variable assignment are similar or the same for swamp and BLH (V3 (Swamp)/V4 (BLH), V5-V7), those methods are described once.

3.1 Swamp Variable V1 - Stand structure

Most swamp tree species do not produce hard mast; consequently, wildlife foods predominantly consist of soft mast, other edible seeds, invertebrates, and vegetation. Because most swamp tree species produce some soft mast or other edible seeds, the actual tree species composition is not usually a limiting factor. More limiting is the presence of stand structure to provide resting, foraging, breeding, nesting, and nursery habitat and the medium for invertebrate production. This medium can exist as herbaceous vegetation, scrub-shrub/midstory cover, or overstory canopy and preferably as a combination of all three. This variable assigns the lowest suitability to sites with a limited amount of all three stand structure components, the highest suitability to sites with a significant amount of all three stand structure components, and mid-range suitability to various combinations when one or two stand structure components are present. A mature stand dominated by overstory trees also receives the highest suitability rating.

Stand structure variable components (% overstory, midstory, and herbaceous vegetation) per plot were averaged for each WVA baseline conditions (TY 0).

<u>FWOP</u>

Site descriptions and data were used to evaluate whether or not there was evidence of any recruitment of swamp tree species. Because there was evidence of small cypress seedlings and saplings recorded at many plots that span the project area, it was assumed that there was some potential for regeneration across impacted swamp habitat. Therefore, V1 was held constant through TY60 in future without project, except in the case of high RSLC, where class was dropped by one in TY 60.

3.2 Swamp Variable V2 - Stand maturity

Species specific growth equations were used to project tree growth in the in-growth spreadsheets. Growth rates used in the calculations are based on forested habitat data from CRMS data (Coastal Protection and Restoration Authority (CPRA) of Louisiana. 2023. Coastwide Reference Monitoring System. Coastal Information Management System (CIMS) database. https://cims.coastal.la.gov.). Data were specific to trees within the coastal zone within

Terrebonne Basin, where impacts from flooding and sea level change would be expected. Average DBH and basal area for each plot were calculated and then averaged (for DBH) or summed (for number of trees and basal area) for each WVA.

FWOP

Based on an assumption that ~2.0 feet of inundation is a threshold for when negative impacts to swamp accelerate, and the knowledge that this is projected to generally occur between 30-45 years (see V3 discussion below), a 30% reduction in growth rate was assigned at TY 45 for all WVAs in the low, intermediate and high RSLC scenario.

3.3 Swamp Variable V3 - Water Regime - Flooding Duration and Water Exchange / BLH Variable V4 –Hydrology

The same general information is used to calculate the SIs for Swamp V3 and BLH V4. These variables are somewhat interchangeably referred to as water regime or hydrology, as they consider the flooding duration and amount of water flow or exchange in forested wetlands using eight categories. For swamp the optimal water regime is assumed to be seasonal (compared to temporary for BLH) flooding with abundant and consistent riverine/tidal input and water flow-through (SI=1.0). WVA field observations and CRMS data from sites nearest the swamp or BLH WVA sites were used to consider hydrology variable assignment. Most recent land elevation (2021, NAVD88) and water surface elevation data (mean 2020 – 2024, ft NAVD88) were retrieved for the forested CRMS sites in Terrebonne basin (Coastal Protection and Restoration Authority (CPRA) of Louisiana. 2023. Coastwide Reference Monitoring System. Coastal Information Management System (CIMS) database. https://cims.coastal.la.gov.) Sea level change, calculated according to USACE Engineering Regulation (ER) 1100-2-8162, using data from Gauge 76320: GIWW at Houma: Jan 1959 to Nov 2008, was applied to CRMS elevation data and WSE to approximate general timing of inundation. Forested CRMS sites supporting swamp species were nearly 100% inundated by TY30, and if not, it is assumed they would be by TY45.

Table 3: Swamp Variable V3 / BLH Variable V4 Flood Duration and Flow/Exchange Matrix

		Flow/Exchange			
		High	Moderate	Low	None
Flooding Duration	Temporary	1.00	0.85	0.70	0.50
	Seasonal	0.85	0.75	0.65	0.40
	Semi-Permanent	0.75	0.65	0.45	0.25
	Permanent/Dewatered	0.65	0.45	0.30	0.10

FWOP

Flow Exchange

For all WVAs, assignment of flow/exchange was made based on broad assumptions regarding existing hydrological barriers. Condition for habitat behind existing structure (protected) was assumed to be low flow, while that on floodside was assumed to be moderate. This was carried through all TYs.

Duration

Field observations suggested that hydrology varied by plot. Some forested plots were noted as dry while others had up to 2.5 ft of water over ground on site during data collection. Site descriptions were used to infer current and future flood duration for BLH. It was assumed for BLH that flooding would become semi-permanent or permanent around TY 30 or 45. Notes on water level, as well as condition of vegetation (flood-stressed, healthy, etc), were used to project which year that transition would occur. It was assumed that areas with stressed vegetation would be less tolerant to projected increased flood duration, which was captured by assuming earlier transition to the lower SI value longer flooding duration. Then, assignments for all plots within an area were considered while choosing the most representative for the reach/WVA overall. Site data from the Barrier Reach was used in cases where field data was not collected for a particular reach, the growth rates were adjusted for target years using a determination of when, according to lidar data and RSLC curves (see 2.5.2), portions of the BLH habitat would be submerged. That analysis was performed for each reach, even if field data was used from a different reach.

For swamp, it was assumed that plots were permanently inundated by TY30 or TY45 based on forested CRMS sites supporting swamp species and RSLC analyses explained in the first paragraph of this section.

For swamp and BLH, in the low sea level change scenario, the existing condition was held through project years and for the high scenario, the change in flooding duration was moved earlier by 1 target year.

3.4 Swamp Variable 4 - Mean High Salinity During the Growing Season

Information from the Louisiana 2023 CMP Data Access Portal (https://mpdap.coastal.la.gov/dataset/salinity#map=12.57/29.95051/-93.21243&geography=extraction_point&aggregate=mean&time=annual&year=52&scenario=A&selected=QAQC2101-QAQC2127&chart=2-52) was used to determine the average annual salinity projections during the growing season for all TYs based on the CMP ICM. The model provides a 52-year projection that begins in 2019. Projected annual mean salinity for CRMS station(s) near the project area were downloaded and charted. A linear regression was performed on the data, and the resulting values from the regression were used for the appropriate target years. Professional judgement was used when selecting data and applying regressions to individual WVAs, and some modifications were made (e.g., identifying and removing outliers).

3.5 BLH Variable V1 – Tree Species Composition

Wildlife species that utilize bottomland hardwoods depend heavily on mast, other edible seeds, and tree buds as primary sources of food. The basic assumptions for this variable are: 1) more production of mast (hard and/or soft) and other edible seeds is better than less production, and 2) because of its availability during late fall and winter and its high energy content, hard mast is more critical than soft mast, other edible seeds, and buds. Table 4 shows the class values based on tree species.

Table 4. BLH Variable V1 Tree Species Association Class descriptions.

Class 1	Less than 25% of overstory canopy consists of mast or other edible-seed producing trees or more than 50% of soft mast present but no hard mast.
Class 2	25% to 50% of overstory canopy consists of mast or other edible-seed producing trees, but hard mast producers constitute less than 10% of the canopy
Class 3	25% to 50% of overstory canopy consists of mast or other edible-seed producing trees, and hard mast producers constitute more than 10% of the canopy.
Class 4	Greater than 50% of overstory canopy consists of mast or other edible-seed producing trees, but hard mast producers constitute less than 20% of the canopy
Class 5	Greater than 50% of overstory canopy consists of mast or other edible-seed producing trees, and hard mast producers constitute more than 20% of the canopy

FWOP

In general, BLH plots are higher in elevation than most of the swamp plots and are less likely to become as inundated in the FWOP. LiDAR data were used to determine which BLH areas became submerged in future TYs to such an extent that BLH would no longer be present; this was then used to change the number of acres of BLH in future TYs. While potential shifts in habitat are captured by reducing the number of BLH acres in future without TYs, V1 was also reduced to Class 1 in all future TYs when BLH acres go to 0. For reaches that did not have specific field site data, Barrier Reach field site data were used as a proxy for existing vegetation conditions (Table 2). The growth rates were adjusted for target years using a determination of when, according to LiDAR data and RSLC curves (see 2.5.2), portions of the BLH habitat would be submerged. That analysis was performed for each reach, even if field data was used from a different reach.

3.6 BLH Variable V2 - Stand maturity

DBH measurements for each site were entered into the WVA in-growth spreadsheets and then averaged for input into the WVA model. The BLH sites were typically much higher in elevation than the swamp sites and permanently flooded conditions were not observed.

FWOP

The procedure for V2 is the same as described for swamp, however, growth reduction factors were applied based on individual plot elevations as compared to projected high, medium, and low RSLC impacts to BLH habitat (using LIDAR elevation data). RSLC projections were applied to project area elevations, and the percent of area falling within particular elevation ranges where stress, but not mortality would be anticipated was used to reduce growth rates within the in-growth spreadsheets. The data were then combined as described in section 2.5.

For reaches that did not have specific field site data, Barrier Reach field site data were used as a proxy for existing vegetation conditions (Table 2). The growth rates were adjusted for target years using a determination of when, according to LiDAR data and RSLC curves (see 2.5.2), portions of the BLH habitat would be submerged. Growth rate adjustments were performed for each reach, even if field data was used from a different reach.

3.7 BLH Variable V3 – Understory / midstory

Understory and midstory data were collected from all site visits for baseline estimates.

FWOP

There were two considerations when making assumptions about future understory/midstory percent cover. The first is based on canopy closure. If the canopy was predicted to decrease light availability to the midstory and understory levels, then percent coverage was assumed to decrease. Similarly, if it was predicted to increase light availability, percent cover was assumed to increase. The second consideration was flooding inundation. The FWOP percent cover for understory and midstory were decreased slightly based on where a transition to less favorable hydrology (V4) was assigned.

3.8 BLH / Swamp Variable V5 – Size of contiguous forested area

Although edge and diversity, which are dominant features of small forested tracts, are important for certain wildlife species, it is important to understand four concepts: 1) species which thrive in edge habitat are highly mobile and presently occur in substantial numbers, 2) because of forest fragmentation and ongoing timber harvesting by man, edge and diversity are quite available, 3) most species found in “edge” habitat are “generalists” in habitat use and are quite capable of existing in larger tracts, and 4) those species in greatest need of conservation are “specialists” in habitat use and require large forested tracts. Therefore, the basic assumption for this variable is that larger forested tracts are less common and offer higher quality habitat than smaller tracts. For this model, tracts greater than 500 acres in size are considered large enough to warrant being considered optimal.

Habitat classifications (see section 2.2) and recent imagery were used in ESRI’s ArcGIS PRO 2.3 software to estimate the sizes of contiguous forested areas for each feature within the project footprint (levees and structures). The boundary of contiguous forested area is not bound in anyway by the project footprint. A weighted average by proportion of impact area for each contiguous forest size category was calculated to determine their Suitability Index (SI) for the FWOP baseline. These SIs were then entered directly into the WVA spreadsheets. The same SI was applied for both the swamp and BLH WVAs, because swamp and BLH were considered together as a large contiguous forest. In the FWP, the project footprint changed to non-forested habitat (TY1-60). The FWP SI values were classified as Class 1 with a SI of 0.20 for TY1-TY60. The only assumed difference between FWOP and FWP was the development of the project footprint.

3.9 BLH / Swamp Variable V6 – Suitability and traversability of surrounding land uses

The 2023 National Landcover Database (NLCD) was used to categorize land use within the vicinity of each Project feature. Half mile buffers were created around each individual BLH patch for each levee reach. The percentage of each land use type within the 0.5-mile buffers of a reach was used to calculate a weighted average of land use by SI. The weighted average SIs were directly entered into the WVA spreadsheets. The same SI was applied for both the swamp and BLH WVAs, because swamp and BLH were considered together as a large contiguous forest.

In the FWP (TY1), it is assumed that MTG would be constructed. The MTG footprint was considered to be Developed, Low Intensity, because the Mississippi River levee in the NCLD was indicated as such. All land within the MTG footprint was changed from the NCLD classification to Developed, Low Intensity for TY1 and TY60. Similar to V5, the only assumed difference between FWOP and FWP was the construction of the MTG levee. In the FWP, the project footprint land use classification was changed to 100% development, and the FWP SI values were set to zero for TY1-TY60.

3.10 BLH / Swamp Variable V7 – Disturbance

The effect of disturbance is measured by the distance to the disturbance, and the type of disturbance. Creation of separate 50-foot and 500-foot buffers around individual BLH patches was performed within the project areas and distances to disturbance classes were calculated for each impact area. The 2023 NLCD data and available Satellite imagery were used to classify the disturbance type such as highways, industrial areas, waterways, agriculture, homes, etc.

The waterways occurring within the buffer were individually assessed for disturbance level. The NLCD classifies all water ways as Open Water, which equates to an insignificant disturbance level. Many waterways in the vicinity of the project area are used for navigation at varying frequencies. Disturbance levels were assigned to individual waterways depending on assumed amounts of traffic. See specific reach PISs for disturbance classification of individual water ways.

Disturbance type/distance zone areas were digitized and acreages were calculated. Using the percentage of each zone and its Suitability Index (SI), weighted average SIs were calculated for each disturbance type and distance combination. The resulting weighted SIs were directly input into WVA spreadsheets. The SI was assumed to remain unchanged throughout target years in the FWOP (TY0-60). In the FWP, the FWP SI values were set to zero and the habitat acreage within each impact area was assumed to go to zero at construction (TY1-60).

4. WVA Variables by feature for Swamp

4.1 Barrier – 640 Floodside, Protected Side, and ECS Culverts

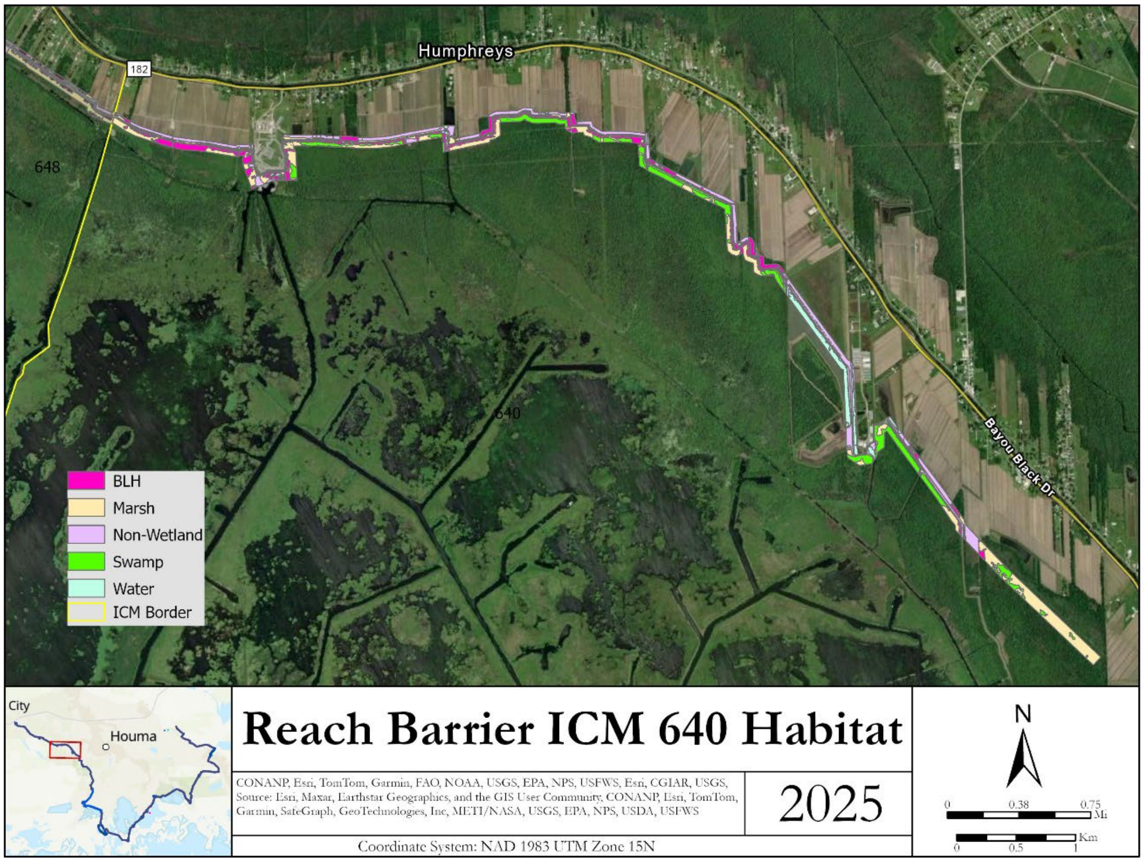

Figure 2: Reach Barrier ICM 640 Habitat Floodside and Protected Side

4.1.1 Variable V1 – Stand Structure

Reach	ICM		Target Year	% Overstory	% Scrub-shrub	% Herbaceous
Barrier 640 FS and PS SWAMP	640	FWOP	0	50.0	26.7	97.0
			1	50.0	26.7	97.0
			15	50.0	26.7	97.0
			30	50.0	26.7	97.0
			45	50.0	26.7	97.0
			60	50.0	26.7	97.0
		FWP	0	50.0	26.7	97.0
			1	0.0	0.0	0.0
			60	0.0	0.0	0.0
ECS Barrier 6 Culverts	640	FWOP	0	50.0	30.0	97.0
			1	50.0	30.0	97.0
			15	50.0	30.0	97.0
			30	50.0	30.0	97.0
			45	50.0	30.0	97.0
			60	50.0	30.0	97.0
		FWP	0	50.0	30.0	97.0
			1	0.0	0.0	0.0
			60	0.0	0.0	0.0

4.1.2 Variable V2 – Stand Maturity

Reach	ICM		Target Year	Cypress dbh	Cypress BA	Tupelo dbh	Tupelo BA
Barrier 640 FS and ECS Culverts SWAMP	640	FWOP	0	8.96	52.79	10.51	1.97
			1	8.96	52.79	10.51	1.97
			15	9.08	69.93	7.51	3.27
			30	9.07	95.59	8.36	2.95
			45	9.18	126.62	0.00	0.00
			60	9.52	160.60	0.00	0.00
		FWP	0	8.96	52.79	10.51	1.97
			1	0.10	0.10	0.10	0.10
			60	0.10	0.10	0.10	0.10
Barrier 640 PS SWAMP	640	FWOP	0	8.96	52.79	10.51	5.91
			1	8.96	52.79	10.51	5.91
			15	9.08	69.93	7.51	9.81
			30	9.07	95.59	8.36	8.86
			45	9.18	126.62	0.00	0.00
			60	9.52	160.60	0.00	0.00
		FWP	0	8.96	52.79	10.51	5.91
			1	0.10	0.10	0.10	0.10
			60	0.10	0.10	0.10	0.10

4.1.3 Variable V3 – Water Regime

Reach	ICM		Target Year	Flow Exchange	Flood/duration
Barrier 640 FS and PS SWAMP	640	FWOP	0	Low	Semi-permanent
Barrier 640 FS and PS SWAMP	640	FWOP	1	Low	Semi-permanent
Barrier 640 FS and PS SWAMP	640	FWOP	15	Low	Semi-permanent
Barrier 640 FS and PS SWAMP	640	FWOP	30	Low	Semi-permanent
Barrier 640 FS and PS SWAMP	640	FWOP	45	Low	Permanent
Barrier 640 FS and PS SWAMP	640	FWOP	60	Low	Permanent
Barrier 640 FS and PS SWAMP	640	FWP	0	Low	Semi-permanent
Barrier 640 FS and PS SWAMP	640	FWP	1	None	Permanent
Barrier 640 FS and PS SWAMP	640	FWP	60	None	Permanent
ECS Barrier 6 Culverts	640	FWOP	0	Moderate	Semi-permanent
ECS Barrier 6 Culverts	640	FWOP	1	Moderate	Semi-permanent
ECS Barrier 6 Culverts	640	FWOP	15	Moderate	Semi-permanent
ECS Barrier 6 Culverts	640	FWOP	30	Moderate	Semi-permanent
ECS Barrier 6 Culverts	640	FWOP	45	Moderate	Permanent
ECS Barrier 6 Culverts	640	FWOP	60	Moderate	Permanent
ECS Barrier 6 Culverts	640	FWP	0	Moderate	Semi-permanent
ECS Barrier 6 Culverts	640	FWP	1	None	Permanent
ECS Barrier 6 Culverts	640	FWP	60	None	Permanent

4.1.4 Variable V4 – Mean High Salinity During the Growing Season

Reach	ICM		Target Year	PPT
Barrier 640 FS, PS, and ECS Culverts SWAMP	640	FWOP	0	0.03
Barrier 640 FS, PS, and ECS Culverts SWAMP	640	FWOP	1	0.00
Barrier 640 FS, PS, and ECS Culverts SWAMP	640	FWOP	15	0.11
Barrier 640 FS, PS, and ECS Culverts SWAMP	640	FWOP	30	0.22
Barrier 640 FS, PS, and ECS Culverts SWAMP	640	FWOP	45	0.33
Barrier 640 FS, PS, and ECS Culverts SWAMP	640	FWOP	60	0.44
Barrier 640 FS, PS, and ECS Culverts SWAMP	640	FWP	0	0.03
Barrier 640 FS, PS, and ECS Culverts SWAMP	640	FWP	1	32.00
Barrier 640 FS, PS, and ECS Culverts SWAMP	640	FWP	60	32.00

4.1.5 Variable V5 – Size of Contiguous Forested Area

Reach	ICM		Target Year	Class
Barrier 640 FS, PS, and ECS Culverts SWAMP	640	FWOP	0	5
			1	5
			15	5
			30	5
			45	5
			60	5
		FWP	0	5
			1	1
			60	1

4.1.6 Variable V6 – Suitability and Traversability of Surrounding Land Uses

Reach	ICM		Target Year	Forest/marsh	Abandoned Ag	Pasture/Hay	Active Ag	Develop
Barrier 640 FS, PS, and ECS Culverts SWAMP	640	FWOP	0	52.81	0.19	7.46	23.99	15.56
			1	52.81	0.19	7.46	23.99	15.56
			15	52.81	0.19	7.46	23.99	15.56
			30	52.81	0.19	7.46	23.99	15.56
			45	50.81	0.19	7.46	23.99	17.56
			60	50.81	0.19	7.46	23.99	17.56
		FWP	0	52.81	0.19	7.46	23.99	15.56
			1	0.00	0.00	0.00	0.00	100.00
			60	0.00	0.00	0.00	0.00	100.00

4.1.7 Variable V7 – Disturbance

Reach	ICM		Target Year	Type
Barrier 640 FS, PS, and ECS Culverts SWAMP	640	FWOP	0	0.81
			1	0.81
			15	0.81
			30	0.81
			45	0.81
			60	0.81
		FWP	0	0.81
			1	0.01
			60	0.01

4.2 Barrier – 642 Floodside and Protected Side

The inclusion of the western most section of the project footprint is an assumed difference for Reach Barrier ICM 642. This section, located west of Bayou Black, is in ICM 751 but is included with ICM 642 as hydrology is assumed to be similar.

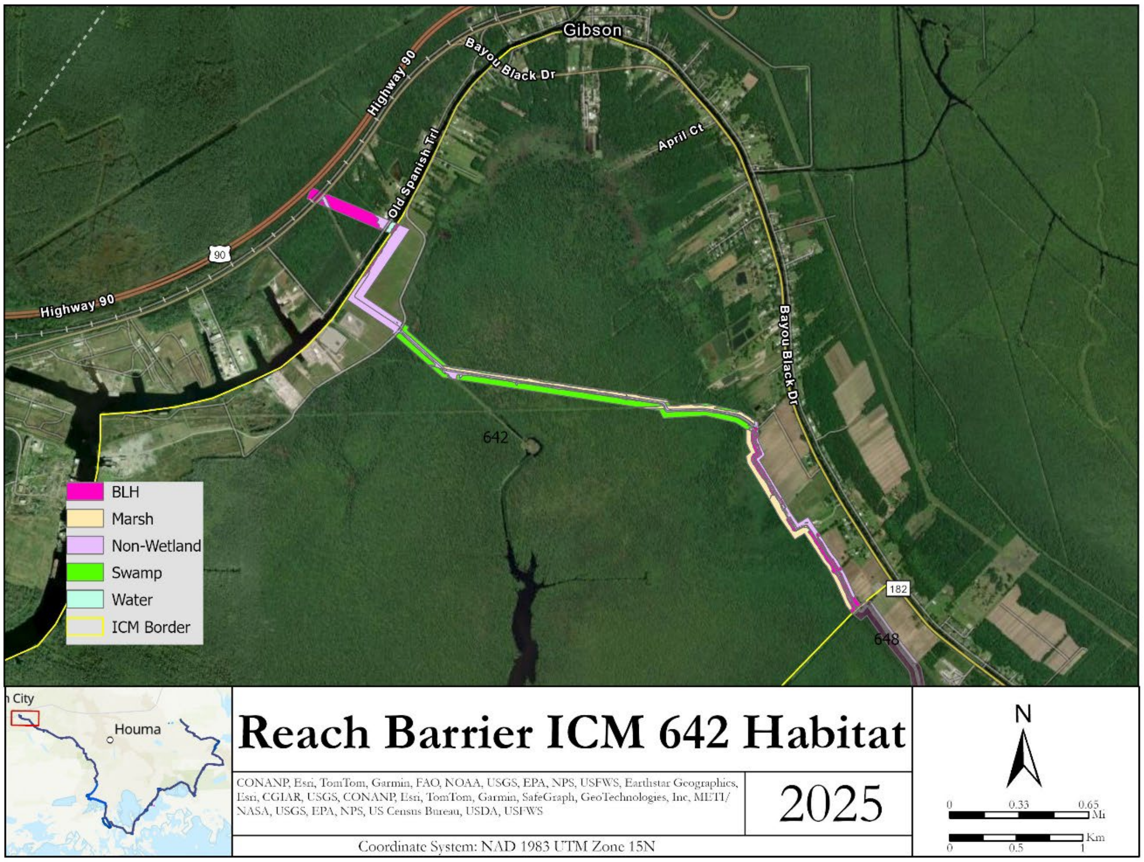

Figure 3: Reach Barrier ICM 642 Habitat Flood side and Protected Side

4.2.1 Variable V1 – Stand Structure

Reach	ICM		Target Year	% Overstory	% Scrub-shrub	% Herbaceous
Barrier 642 FS SWAMP	642	FWOP	0	85.0	8.0	18.0
			1	85.0	8.0	18.0
			15	85.0	13.0	23.0
			30	85.0	13.0	23.0
			45	85.0	13.0	23.0
			60	85.0	13.0	23.0
		FWP	0	85.0	8.0	18.0
			1	0.0	0.0	0.0
			60	0.0	0.0	0.0
Barrier 642 PS SWAMP	642	FWOP	0	47.5	8.5	50.0
			1	47.5	8.5	50.0
			15	48.0	9.0	50.0
			30	48.0	9.0	50.0
			45	48.0	9.0	50.0
			60	48.0	9.0	50.0
		FWP	0	47.5	8.5	50.0
			1	0.0	0.0	0.0
			60	0.0	0.0	0.0

4.2.2 Variable V2 – Stand Maturity

Reach	ICM		Target Year	Cypress dbh	Cypress BA	Tupelo dbh	Tupelo BA
Barrier 642 FS SWAMP	642	FWOP	0	19.55	41.79	14.38	188.40
			1	19.55	41.79	14.38	188.40
			15	12.29	51.47	14.94	167.15
			30	12.25	58.13	15.55	145.71
			45	11.17	68.80	0.00	0.00
			60	11.50	78.00	0.00	0.00
		FWP	0	19.55	41.79	14.38	188.40
			1	0.10	0.10	0.10	0.10
			60	0.10	0.10	0.10	0.10
Barrier 642 PS SWAMP	642	FWOP	0	11.25	71.12	13.43	60.52
			1	11.25	71.12	13.43	60.52
			15	11.69	80.65	14.49	53.56
			30	12.88	89.45	15.63	46.60
			45	13.75	99.58	0.00	0.00
			60	15.03	109.15	0.00	0.00
		FWP	0	11.25	71.12	13.43	60.52
			1	0.10	0.10	0.10	0.10
			60	0.10	0.10	0.10	0.10

4.2.3 Variable V3 – Water Regime

Reach	ICM		Target Year	Flow Exchange	Flood/duration
Barrier 642 FS SWAMP	642	FWOP	0	Moderate	Seasonal
			1	Moderate	Seasonal
			15	Moderate	Seasonal
			30	Moderate	Seasonal
			45	Moderate	Semi-permanent
			60	Moderate	Semi-permanent
		FWP	0	Moderate	Seasonal
			1	None	Permanent
			60	None	Permanent
Barrier 642 PS SWAMP	642	FWOP	0	Low	Semi-permanent
			1	Low	Semi-permanent
			15	Low	Semi-permanent
			30	Low	Permanent
			45	Low	Permanent
			60	Low	Permanent
		FWP	0	Low	Semi-permanent
			1	None	Permanent
			60	None	Permanent

4.2.4 Variable V4 – Mean High Salinity During the Growing Season

Reach	ICM		Target Year	PPT
Barrier 642 FS and PS SWAMP	642	FWOP	0	0.03
			1	0.04
			15	0.13
			30	0.24
			45	0.34
			60	0.45
		FWP	0	0.03
			1	32.00
			60	32.00

4.2.5 Variable V5 – Size of Contiguous Forested Area

Reach	ICM		Target Year	Class
Barrier 642 FS and PS SWAMP	642	FWOP	0	5
			1	5
			15	5
			30	5
			45	5
			60	5
		FWP	0	5
			1	1
			60	1

4.2.6 Variable V6 – Suitability and Traversability of Surrounding Land Uses

Reach	ICM		Target Year	Forest/marsh	Abandoned Ag	Pasture/Hay	Active Ag	Develop
Barrier 642 FS and PS SWAMP	642	FWOP	0	78.67	0.09	2.22	7.73	11.29
			1	78.67	0.09	2.22	7.73	11.29
			15	78.67	0.09	2.22	7.73	11.29
			30	78.67	0.09	2.22	7.73	11.29
			45	76.67	0.09	2.22	7.73	13.29
			60	76.67	0.09	2.22	7.73	13.29
		FWP	0	78.67	0.09	2.22	7.73	11.29
			1	0.00	0.00	0.00	0.00	100.00
			60	0.00	0.00	0.00	0.00	100.00

4.2.7 Variable V7 – Disturbance

Reach	ICM		Target Year	Type
Barrier 642 FS and PS SWAMP	642	FWOP	0	0.89
			1	0.89
			15	0.89
			30	0.89
			45	0.89
			60	0.89
		FWP	0	0.89
			1	0.01
			60	0.01

4.3 Lockport to Larose 159

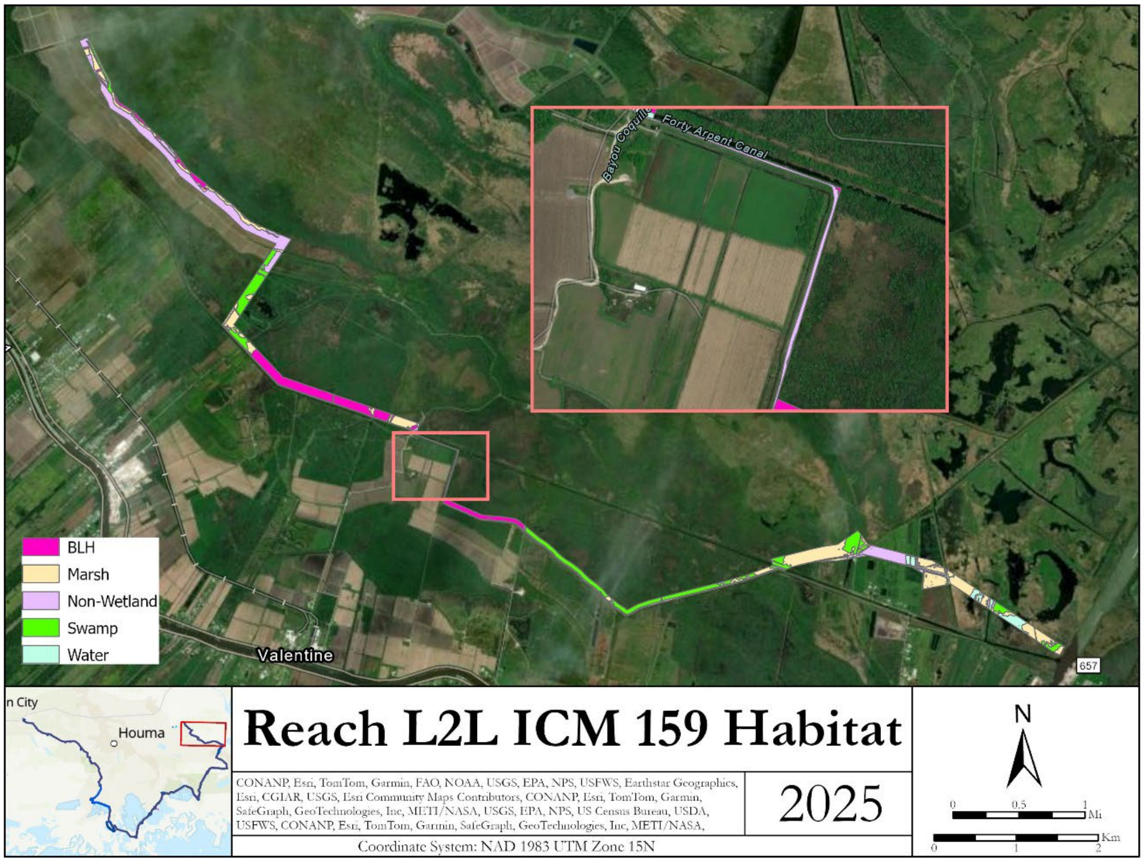

Figure 4: Reach L2L ICM 159 Habitat Floodside and Protected Side

4.3.1 Variable V1 – Stand Structure

Reach	ICM		Target Year	% Overstory	% Scrub-shrub	% Herbaceous
L2L 159 SWAMP	159	FWOP	0	57.0	35.0	51.0
			1	57.0	35.0	51.0
			15	57.0	35.0	51.0
			30	57.0	35.0	51.0
			45	57.0	35.0	51.0
			60	57.0	35.0	51.0
		FWP	0	57.0	35.0	51.0
			1	0.0	0.0	0.0
			60	0.0	0.0	0.0

4.3.2 Variable V2 – Stand Maturity

Reach	ICM		Target Year	Cypress dbh	Cypress BA	Tupelo dbh	Tupelo BA
L2L 159 SWAMP	159	FWOP	0	11.27	26.71	9.43	31.10
			1	11.27	26.71	9.43	31.10
			15	12.53	36.94	9.24	32.70
			30	13.11	50.50	9.42	32.92
			45	15.74	61.25	6.85	1.04
			60	17.87	72.10	7.29	1.79
		FWP	0	11.27	26.71	9.43	31.10
			1	6.00	0.10	6.00	0.00
			60	6.00	0.10	6.00	0.00

4.3.3 Variable V3 – Water Regime

Reach	ICM		Target Year	Flow Exchange	Flood/duration
L2L 159 SWAMP	159	FWOP	0	Moderate	Seasonal
			1	Moderate	Seasonal
			15	Moderate	Seasonal
			30	Moderate	Seasonal
			45	Moderate	Semi-permanent
			60	Moderate	Semi-permanent
		FWP	0	Moderate	Seasonal
			1	None	Permanent
			60	None	Permanent

4.3.4 Variable V4 – Mean High Salinity During the Growing Season

Reach	ICM		Target Year	PPT
L2L 159 SWAMP	159	FWOP	0	0.58
			1	0.59
			15	0.73
			30	0.88
			45	1.00
			60	1.20
		FWP	0	0.58
			1	33.00
			60	33.00

4.3.5 Variable V5 – Size of Contiguous Forested Area

Reach	ICM		Target Year	Class
L2L 159 SWAMP	159	FWOP	0	5
			1	5
			15	5
			30	5
			45	5
			60	5
		FWP	0	5
			1	1
			60	1

4.3.6 Variable V6 – Suitability and Traversability of Surrounding Land Uses

Reach	ICM		Target Year	Forest/ marsh	Abandoned Ag	Pasture/ Hay	Active Ag	Develop
L2L 159 SWAMP	159	FWOP	0	69.05	0.00	13.20	16.30	1.45
			1	69.05	0.00	13.20	16.30	1.45
			15	69.05	0.00	13.20	16.30	1.45
			30	69.05	0.00	13.20	16.30	1.45
			45	67.05	0.00	13.20	16.30	3.45
			60	67.05	0.00	13.20	16.30	3.45
		FWP	0	69.05	0.00	13.20	16.30	1.45
			1	0.00	0.00	0.00	0.00	100.0
			60	0.00	0.00	0.00	0.00	100.0

4.3.7 Variable V7 – Disturbance

Reach	ICM		Target Year	Type
L2L 159 SWAMP	159	FWOP	0	0.96
			1	0.96
			15	0.96
			30	0.96
			45	0.96
			60	0.96
		FWP	0	0.96
			1	0.01
			60	0.01

4.4 Reach LCN

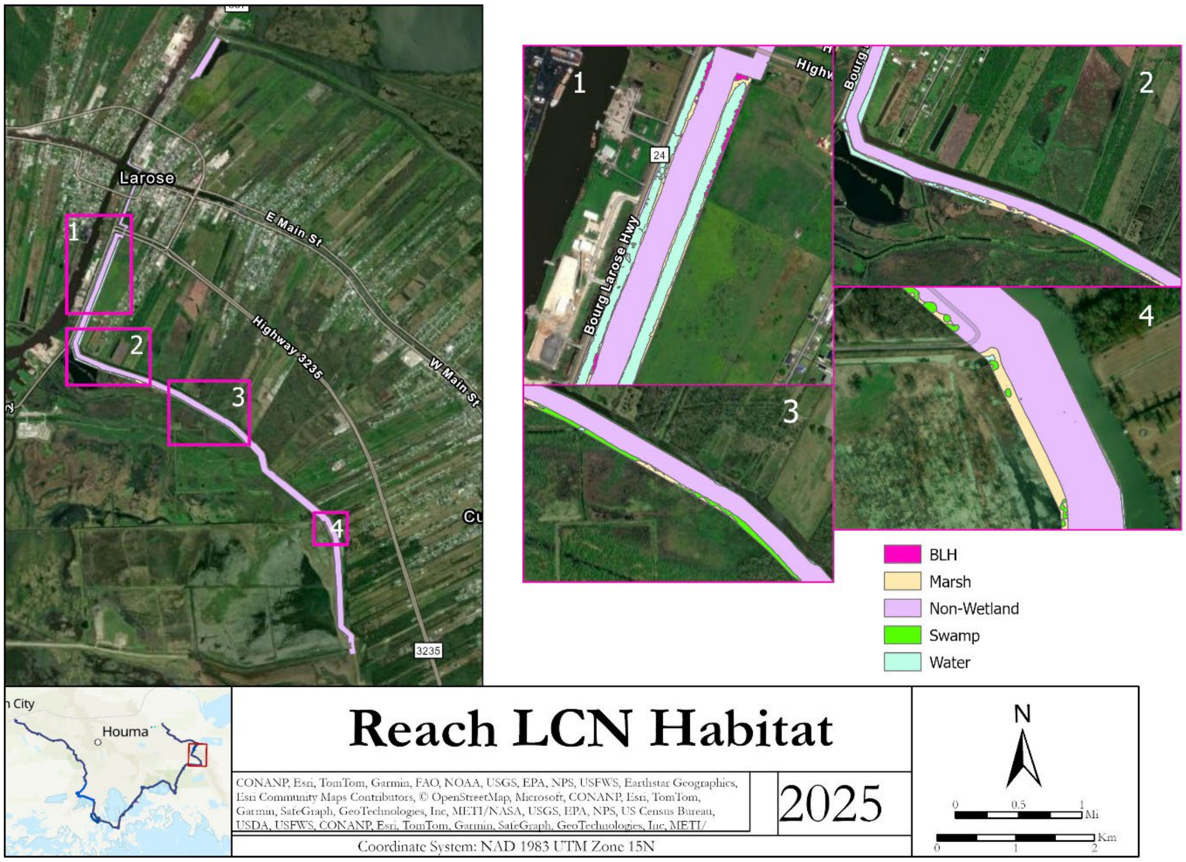

Figure 5: Reach LCN Habitat Floodside and Protected Side

4.4.1 Variable V1 – Stand Structure

Reach	ICM		Target Year	% Overstory	% Scrub-shrub	% Herbaceous
LCN SWAMP	506	FWOP	0	57.0	48.0	51.0
			1	57.0	48.0	51.0
			15	57.0	48.0	51.0
			30	57.0	48.0	51.0
			45	57.0	48.0	51.0
			60	57.0	48.0	51.0
		FWP	0	57.0	48.0	51.0
			1	0.0	0.0	0.0
			60	0.0	0.0	0.0

4.4.2 Variable V2 – Stand Maturity

Reach	ICM		Target Year	Cypress dbh	Cypress BA	Tupelo dbh	Tupelo BA
LCN SWAMP	506	FWOP	0	9.70	32.31	0.00	0.00
			1	9.70	32.31	0.00	0.00
			15	10.17	39.10	0.00	0.00
			30	11.29	44.60	0.00	0.00
			45	12.30	49.06	0.00	0.00
			60	13.17	52.16	0.00	0.00
		FWP	0	9.70	32.31	0.00	0.00
			1	6.00	0.10	6.00	0.00
			60	6.00	0.10	6.00	0.00

4.4.3 Variable V3 – Water Regime

Reach	ICM		Target Year	Flow Exchange	Flood/duration
LCN SWAMP	506	FWOP	0	Moderate	Seasonal
			1	Moderate	Seasonal
			15	Moderate	Seasonal
			30	Moderate	Seasonal
			45	Moderate	Semi-Permanent
			60	Moderate	Semi-Permanent
		FWP	0	Moderate	Seasonal
			1	None	Permanent
			60	None	Permanent

4.4.4 Variable V4 – Mean High Salinity During the Growing Season

Reach	ICM		Target Year	PPT
LCN SWAMP	506	FWOP	0	1.00
			1	1.00
			15	1.30
			30	1.50
			45	1.80
			60	2.00
		FWP	0	1.00
			1	33.00
			60	33.00

The only difference from the standard assumptions in the LCN Swamp WVA pertained to salinity in the growing season. The high salinity levels observed at Reach LCN during TY0 were considered unrepresentative of current conditions that support a healthy swamp ecosystem. Due to this inconsistency, salinity was brought back to 1.0 ppt and then projected according to the regression

4.4.5 Variable V5 – Size of Contiguous Forested Area

Reach	ICM		Target Year	Class
LCN SWAMP	506	FWOP	0	1
			1	1
			15	1
			30	1
			45	1
			60	1
		FWP	0	1
			1	1
			60	1

4.4.6 Variable V6 – Suitability and Traversability of Surrounding Land Uses

Reach	ICM		Target Year	Forest/marsh	Abandoned Ag	Pasture/Hay	Active Ag	Develop
LCN SWAMP	506	FWOP	0	49.92	0.08	13.17	6.61	30.22
			1	49.92	0.08	13.17	6.61	30.22
			15	49.92	0.08	13.17	6.61	30.22
			30	49.92	0.08	13.17	6.61	30.22
			45	47.92	0.08	13.17	6.61	32.22
			60	47.92	0.08	13.17	6.61	32.22
		FWP	0	49.92	0.08	13.17	6.61	30.22
			1	0.00	0.00	0.00	0.00	100.0
			60	0.00	0.00	0.00	0.00	100.0

4.4.7 Variable V7 – Disturbance

Reach	ICM		Target Year	Type
LCN SWAMP		FWOP	0	0.75
			1	0.75
			15	0.75
			30	0.75
			45	0.75
			60	0.75
		FWP	0	0.75
			1	0.01
			60	0.01

5. WVA Variable by reach for BLH

5.1 Barrier – ICM 640 FS, PS, and Hanson Canal

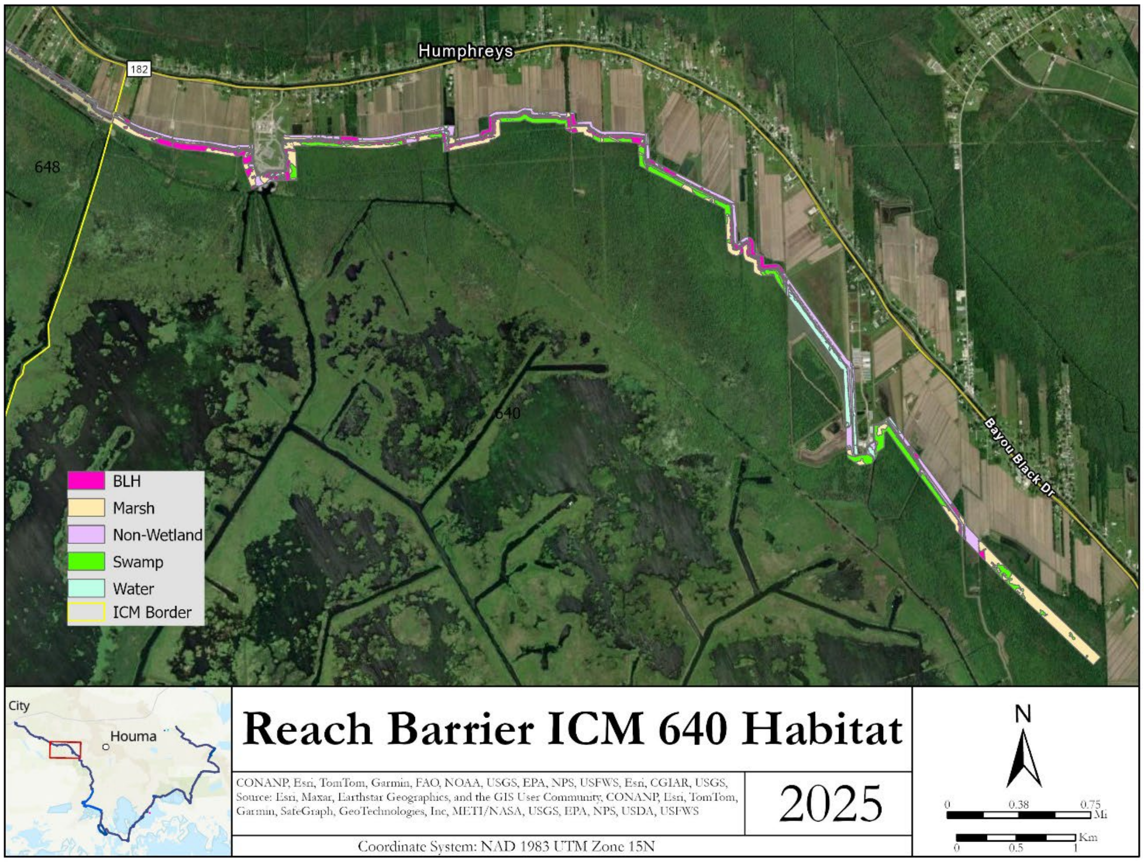

Figure 6: Reach Barrier ICM 640 Habitat Floodside and Protected Side

5.1.1 Variable V1 – Tree Species Composition

Reach	ICM		Target Year	Class
Barrier 640 FS and Hanson Canal BLH	640	FWOP	0	4
			1	4
			15	4
			30	4
			45	4
			60	4
		FWP	0	4
			1	1
			60	1
Barrier 640 PS BLH	640	FWOP	0	4
			1	4
			15	4
			30	4
			45	4
			60	4
		FWP	0	4
			1	1
			60	1

5.1.2 Variable V2 – Stand Maturity

Reach	ICM		Target Year	DBH
Barrier 640 FS and Hanson Canal BLH	640	FWOP	0	10.00
			1	10.00
			15	9.48
			30	8.42
			45	8.61
			60	10.09
		FWP	0	10.00
			1	6.00
			60	6.00
Barrier 640 PS BLH	640	FWOP	0	11.95
			1	11.95
			15	12.92
			30	12.66
			45	14.00
			60	11.27
		FWP	0	11.95
			1	6.00
			60	6.00

5.1.3 Variable V3 – Understory/Midstory

Reach	ICM		Target Year	% Understory	% Midstory
Barrier 640 FS and Hanson Canal BLH	640	FWOP	0	80	24
			1	80	24
			15	60	35
			30	50	35
			45	35	30
			60	15	20
		FWP	0	80	24
			1	100	0
			60	100	0
Barrier 640 PS BLH	640	FWOP	0	5	20
			1	10	25
			15	25	35
			30	20	30
			45	15	20
			60	5	10
		FWP	0	5	20
			1	100	0
			60	100	0

5.1.4 Variable V4 – Hydrology

Reach	ICM		Target Year	Flow Exchange	Flood Duration
Barrier 640 FS and Hanson Canal BLH	640	FWOP	0	Moderate	Seasonal
			1	Moderate	Seasonal
			15	Moderate	Seasonal
			30	Moderate	Semi-Permanent
			45	Moderate	Semi-Permanent
			60	Moderate	Semi-Permanent
		FWP	0	Moderate	Seasonal
			1	None	Permanent
			60	None	Permanent
Barrier 640 PS BLH	640	FWOP	0	Low	Seasonal
			1	Low	Seasonal
			15	Low	Seasonal
			30	Low	Semi-Permanent
			45	Low	Semi-Permanent
			60	Low	Semi-Permanent
		FWP	0	Low	Seasonal
			1	None	Permanent
			60	None	Permanent

5.1.5 Variable V5 – Size of Contiguous Forested Area

Reach	ICM		Target Year	Class
Barrier 640 FS and Hanson Canal BLH	640	FWOP	0	5
			1	5
			15	5
			30	5
			45	5
			60	5
		FWP	0	5
			1	1
			60	1
Barrier 640 PS BLH	640	FWOP	0	3
			1	3
			15	3
			30	3
			45	3
			60	3
		FWP	0	3
			1	1
			60	1

5.1.6 Variable V6 – Suitability and Traversability of Surrounding Land Uses

Reach	ICM		Target Year	Forest/marsh	Abandoned Ag	Pasture/Hay	Active Ag	Develop
Barrier 640 FS, PS, and Hansons Canal BLH	640	FWOP	0	52.81	0.19	7.46	23.99	15.56
			1	52.81	0.19	7.46	23.99	15.56
			15	52.81	0.19	7.46	23.99	15.56
			30	52.81	0.19	7.46	23.99	15.56
			45	50.81	0.19	7.46	23.99	17.56
			60	50.81	0.19	7.46	23.99	17.56
		FWP	0	52.81	0.19	7.46	23.99	15.56
			1	0.00	0.00	0.00	0.00	100.00
			60	0.00	0.00	0.00	0.00	100.00

5.1.7 Variable V7 – Disturbance

Reach	ICM		Target Year	SI Value
Barrier 640 FS, PS, and Hansons Canal BLH	640	FWOP	0	0.81
			1	0.81
			15	0.81
			30	0.81
			45	0.81
			60	0.81
		FWP	0	0.81
			1	0.01
			60	0.01

5.2 Barrier – 642 Protected Side, Flood Side, and Bayou Black Barge FG BLH

The inclusion of the western most section of the project footprint is an assumed difference for Reach Barrier ICM 642. This section, located west of Bayou Black, is in ICM 751 but is included with ICM 642 as hydrology is assumed to be similar.

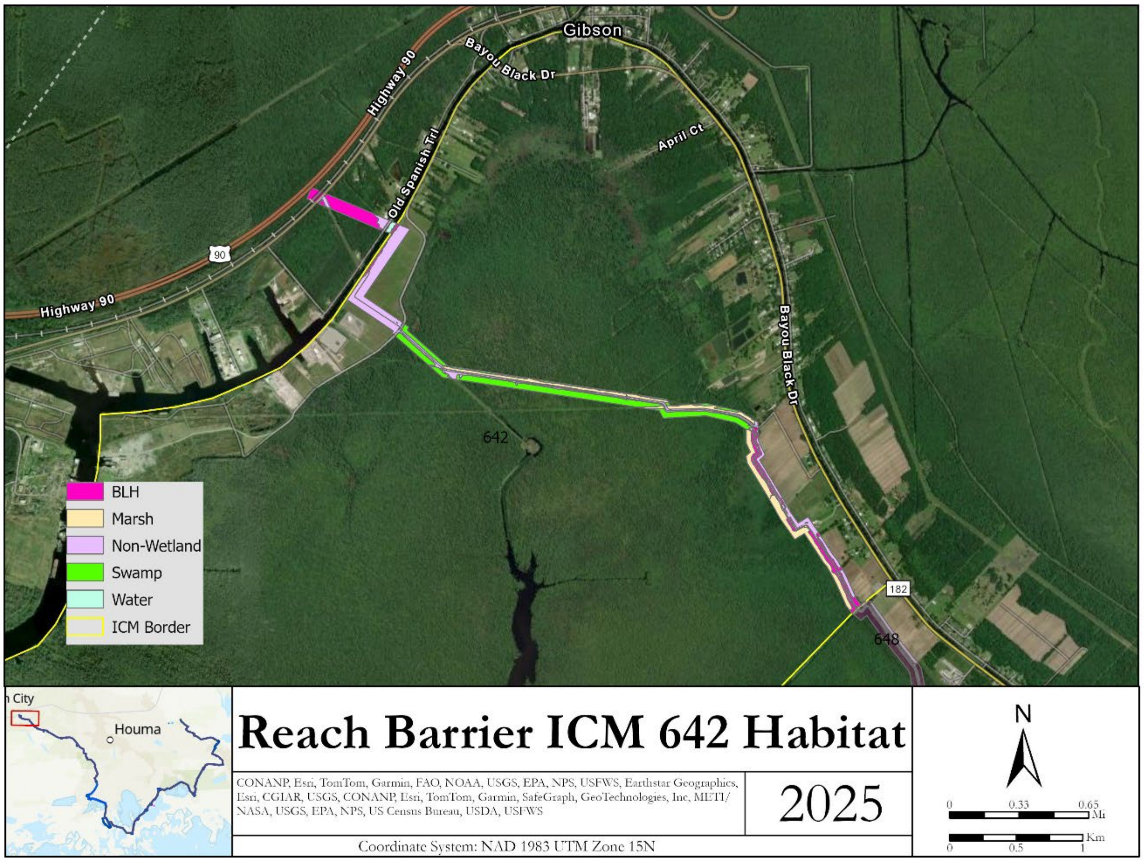

Figure 7: Reach Barrier ICM 642 Habitat Floodside and Protected Side

5.2.1 Variable V1 – Tree Species Composition

Reach	ICM		Target Year	Class
Barrier 642 FS and Bayou Black Barge FG BLH	642	FWOP	0	5
			1	5
			15	5
			30	5
			45	5
			60	5
		FWP	0	5
			1	1
			60	1
Barrier 642 PS BLH	642	FWOP	0	5
			1	5
			15	5
			30	5
			45	5
			60	5
		FWP	0	5
			1	1
			60	1

5.2.2 Variable V2 – Stand Maturity

Reach	ICM		Target Year	DBH
Barrier 642 FS and Bayou Black Barge FG BLH	642	FWOP	0	14.13
			1	14.13
			15	11.83
			30	8.42
			45	11.19
			60	13.89
		FWP	0	14.13
			1	6.00
			60	6.00
Barrier 642 PS BLH	642	FWOP	0	14.13
			1	14.13
			15	11.83
			30	8.42
			45	11.19
			60	13.89
		FWP	0	14.13
			1	6.00
			60	6.00

5.2.3 Variable V3 – Understory/Midstory

Reach	ICM		Target Year	% Understory	% Midstory
Barrier 642 FS and Bayou Black Barge FG BLH	642	FWOP	0	85	60
			1	85	60
			15	60	45
			30	50	35
			45	40	25
			60	30	15
		FWP	0	85	60
			1	100	0
			60	100	0
Barrier 642 PS BLH	642	FWOP	0	85	60
			1	85	60
			15	60	45
			30	50	35
			45	40	25
			60	30	15
		FWP	0	85	60
			1	100	0
			60	100	0

5.2.4 *Variable V4 – Hydrology*

Reach	ICM		Target Year	Flow Exchange	Flood Duration
Barrier 642 FS and Bayou Black Barge FG BLH	642	FWOP	0	Moderate	Seasonal
			1	Moderate	Seasonal
			15	Moderate	Seasonal
			30	Moderate	Seasonal
			45	Moderate	Semi-Permanent
			60	Moderate	Semi-Permanent
		FWP	0	Moderate	Seasonal
			1	None	Permanent
			60	None	Permanent
Barrier 642 PS BLH	642	FWOP	0	Low	Seasonal
			1	Low	Seasonal
			15	Low	Seasonal
			30	Low	Seasonal
			45	Low	Semi-Permanent
			60	Low	Semi-Permanent
		FWP	0	Low	Seasonal
			1	None	Permanent
			60	None	Permanent

5.2.5 Variable V5 – Size of Contiguous Forested Area

Reach	ICM		Target Year	Class
Barrier 642 FS, and Bayou Black Barge FG BLH	642	FWOP	0	5
			1	5
			15	5
			30	5
			45	5
			60	5
		FWP	0	5
			1	1
			60	1
Barrier 642 PS BLH	642	FWOP	0	5
			1	5
			15	5
			30	5
			45	5
			60	5
		FWP	0	5
			1	1
			60	1

5.2.6 Variable V6 – Suitability and Traversability of Surrounding Land Uses

Reach	ICM		Target Year	Forest/marsh	Abandoned Ag	Pasture/Hay	Active Ag	Develop
Barrier 642 FS, PS, and Bayou Black Barge FG BLH	642	FWOP	0	78.67	0.09	2.22	7.73	11.29
			1	78.67	0.09	2.22	7.73	11.29
			15	78.67	0.09	2.22	7.73	11.29
			30	78.67	0.09	2.22	7.73	11.29
			45	76.67	0.09	2.22	7.73	13.29
			60	76.67	0.09	2.22	7.73	13.29
		FWP	0	78.67	0.09	2.22	7.73	11.29
			1	0.00	0.00	0.00	0.00	100.00
			60	0.00	0.00	0.00	0.00	100.00

5.2.7 Variable V7 – Disturbance

Reach	ICM		Target Year	SI Value
Barrier 642 FS, PS, and Bayou Black Barge FG BLH	642	FWOP	0	0.89
			1	0.89
			15	0.89
			30	0.89
			45	0.89
			60	0.89
		FWP	0	0.89
			1	0.01
			60	0.01

Per analysis of land cover data, a weighted average Suitability Index (SI) of applicable distance classes and disturbance types was calculated as 0.89. This SI was assumed to remain unchanged for all FWOP TYs and was assumed to go to 0.01 for FWP TY1-TY60.

5.3 Barrier – 648 Protected Side, Flood Side, Bayou Black Pump, Shell Canal East, and ECSs BLH

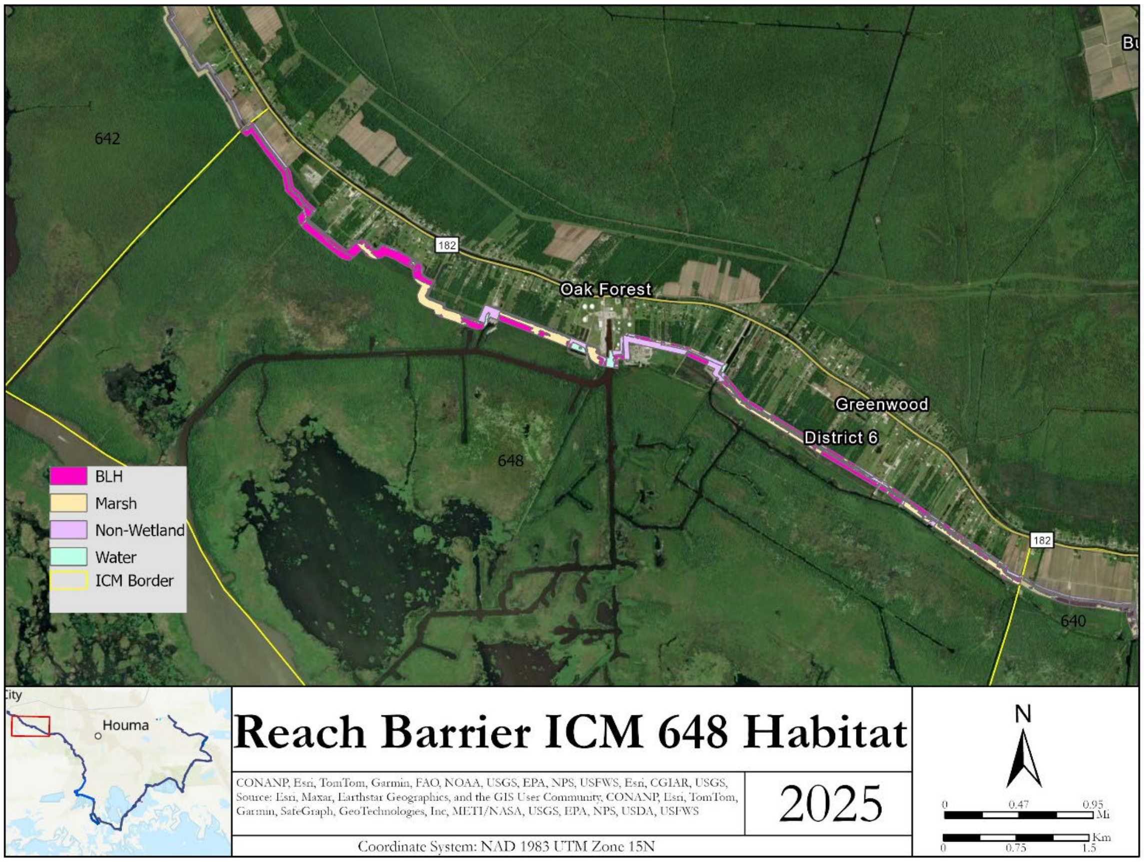

Figure 8: Reach Barrier ICM 648 Habitat Floodside and Protected Side

5.3.1 Variable V1 – Tree Species Composition

Reach	ICM		Target Year	Class
Barrier 648 FS, Bayou Black Pump, Shell Canal East, and ECSs BLH	648	FWOP	0	1
			1	1
			15	1
			30	1
			45	1
			60	1
		FWP	0	1
			1	1
			60	1
Barrier 648 PS BLH	648	FWOP	0	4
			1	4
			15	4
			30	4
			45	4
			60	4
		FWP	0	4
			1	1
			60	1

5.3.2 Variable V2 – Stand Maturity

Reach	ICM		Target Year	DBH
Barrier 648 FS, Bayou Black Pump, Shell Canal East, and ECSs BLH	648	FWOP	0	9.77
			1	9.77
			15	9.55
			30	9.11
			45	9.75
			60	10.39
		FWP	0	9.77
			1	6.00
			60	6.00
Barrier 648 PS BLH	648	FWOP	0	9.06
			1	9.06
			15	9.86
			30	9.80
			45	11.47
			60	13.16
		FWP	0	9.06
			1	6.00
			60	6.00

5.3.3 Variable V3 – Understory/Midstory

Reach	ICM		Target Year	% Understory	% Midstory
Barrier 648 FS, Bayou Black Pump, Shell Canal East, and ECSs BLH	648	FWOP	0	70	35
			1	70	35
			15	60	30
			30	40	20
			45	30	10
			60	25	10
		FWP	0	70	35
			1	100	0
			60	100	0
Barrier 648 PS BLH	648	FWOP	0	49	41
			1	49	41
			15	49	41
			30	45	30
			45	30	35
			60	15	20
		FWP	0	49	41
			1	100	0
			60	100	0

5.3.4 Variable V4 – Hydrology

Reach	ICM		Target Year	Flow Exchange	Flood Duration
Barrier 648 FS, Bayou Black Pump, Shell Canal East, and ECSs BLH	648	FWOP	0	Moderate	Semi-Permanent
			1	Moderate	Semi-Permanent
			15	Moderate	Semi-Permanent
			30	Moderate	Permanent
			45	Moderate	Permanent
			60	Moderate	Permanent
		FWP	0	Moderate	Semi-Permanent
			1	None	Permanent
			60	None	Permanent
Barrier 648 PS BLH	648	FWOP	0	Low	Seasonal
			1	Low	Seasonal
			15	Low	Seasonal
			30	Low	Seasonal
			45	Low	Semi-Permanent
			60	Low	Semi-Permanent
		FWP	0	Low	Seasonal
			1	None	Permanent
			60	None	Permanent

5.3.5 Variable V5 – Size of Contiguous Forested Area

Reach	ICM		Target Year	Class
Barrier 648 FS, Bayou Black Pump, Shell Canal East, and ECSs BLH	648	FWOP	0	5
			1	5
			15	5
			30	5
			45	5
			60	5
		FWP	0	5
			1	1
			60	1
Barrier 648 PS BLH	648	FWOP	0	1
			1	1
			15	1
			30	1
			45	1
			60	1
		FWP	0	1
			1	1
			60	1

5.3.6 Variable V6 – Suitability and Traversability of Surrounding Land Uses

Reach	ICM		Target Year	Forest/marsh	Abandoned Ag	Pasture/Hay	Active Ag	Develop
Barrier 648 FS, PS, and Bayou Black Pump, Shell Canal East, and ECSs BLH	648	FWOP	0	63.38	0.37	10.40	5.15	20.70
			1	63.38	0.37	10.40	5.15	20.70
			15	63.38	0.37	10.40	5.15	20.70
			30	63.38	0.37	10.40	5.15	20.70
			45	61.38	0.37	10.40	5.15	22.70
			60	61.38	0.37	10.40	5.15	22.70
		FWP	0	63.38	0.37	10.40	5.15	20.70
			1	0.00	0.00	0.00	0.00	100.00
			60	0.00	0.00	0.00	0.00	100.00

5.3.7 Variable V7 – Disturbance

Reach	ICM		Target Year	SI Value
Barrier 648 FS, PS, and Bayou Black Pump, Shell Canal East, and ECSs BLH	648	FWOP	0	0.84
			1	0.84
			15	0.84
			30	0.84
			45	0.84
			60	0.84
		FWP	0	0.84
			1	0.01
			60	0.01

5.4 Reach B and Marmande Stoplog

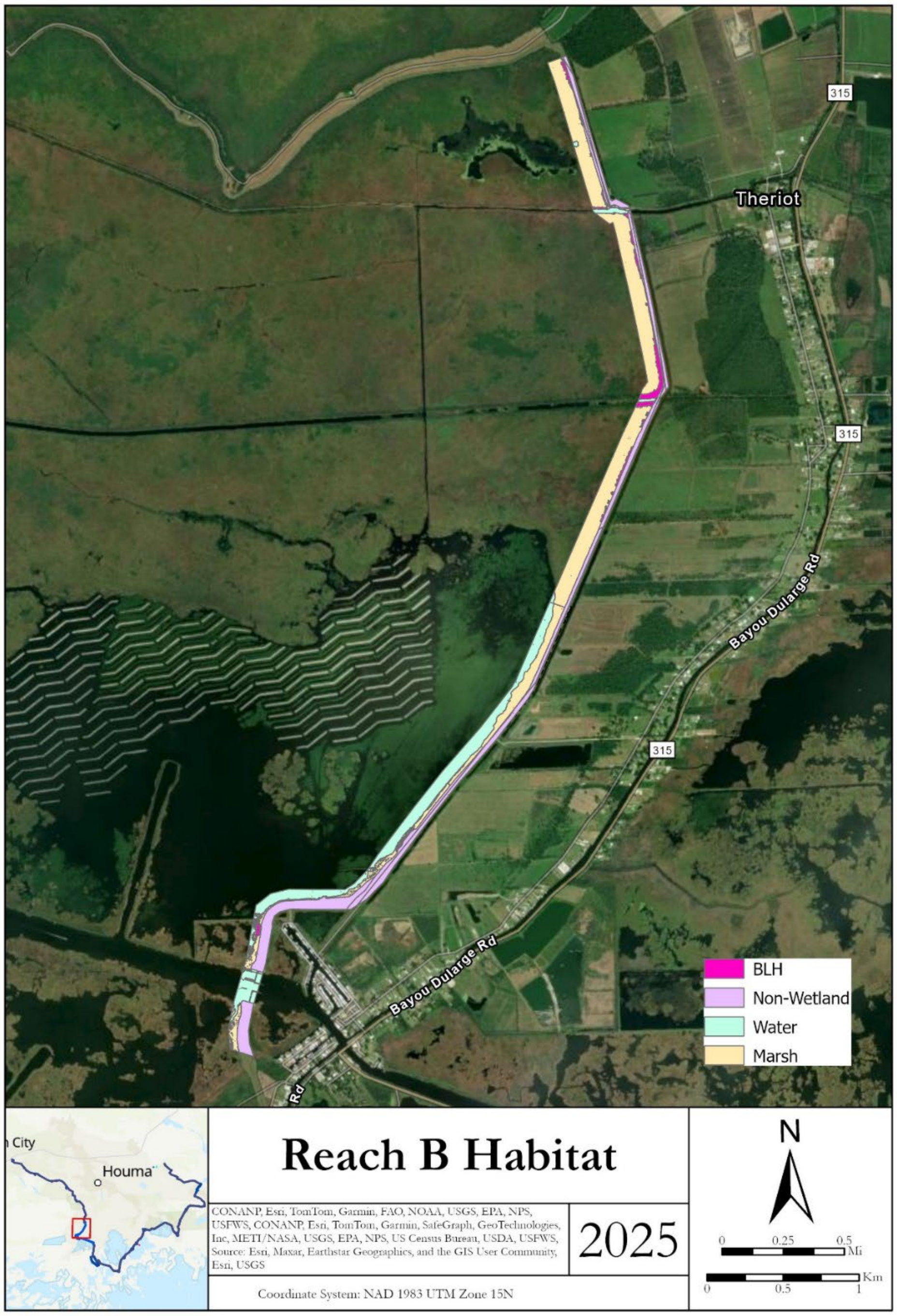

Figure 9: Reach B Habitat

5.4.1 Variable V1 – Tree Species Composition

Reach	ICM		Target Year	Class
B and Marmande Stoplog FG BLH	866	FWOP	0	4
			1	4
			15	4
			30	4
			45	4
			60	4
		FWP	0	4
			1	1
			60	1

5.4.2 Variable V2 – Stand Maturity

Reach	ICM		Target Year	DBH
B and Marmande Stoplog FG BLH	866	FWOP	0	9.90
			1	9.90
			15	9.44
			30	8.44
			45	8.46
			60	8.60
		FWP	0	9.90
			1	6.00
			60	6.00

5.4.3 Variable V3 – Understory/Midstory

Reach	ICM		Target Year	% Understory	% Midstory
B and Marmande Stoplog FG BLH	866	FWOP	0	80	24
			1	80	24
			15	60	35
			30	40	15
			45	25	15
			60	15	10
		FWP	0	80	24
			1	100	0
			60	100	0

5.4.4 Variable V4 – Hydrology

Reach	ICM		Target Year	Flow Exchange	Flood Duration
B and Marmande Stoplog FG BLH	866	FWOP	0	Moderate	Semi-Permanent
			1	Moderate	Semi-Permanent
			15	Moderate	Semi-Permanent
			30	Moderate	Permanent
			45	Moderate	Permanent
			60	Moderate	Permanent
		FWP	0	Moderate	Semi-Permanent
			1	None	Permanent
			60	None	Permanent

5.4.5 Variable V5 – Size of Contiguous Forested Area

Reach	ICM		Target Year	Class
B and Marmande Stoplog FG	866	FWOP	0	2
			1	2
			15	2
			30	2
			45	2
			60	2
		FWP	0	2
			1	1
			60	1

5.4.6 Variable V6 – Suitability and Traversability of Surrounding Land Uses

Reach	ICM		Target Year	Forest/marsh	Abandoned Ag	Pasture/Hay	Active Ag	Develop
B and Marmande Stoplog FG BLH	866	FWOP	0	71.10	0.01	11.45	15.14	2.30
			1	71.10	0.01	11.45	15.14	2.30
			15	71.10	0.01	11.45	15.14	2.30
			30	71.10	0.01	11.45	15.14	2.30
			45	69.10	0.01	11.45	15.14	4.30
			60	69.10	0.01	11.45	15.14	4.30
		FWP	0	71.10	0.01	11.45	15.14	2.30
			1	0.00	0.00	0.00	0.00	100.00
			60	0.00	0.00	0.00	0.00	100.00

5.4.7 Variable V7 – Disturbance

Reach	ICM		Target Year	SI Value
B and Marmande Stoplog FG BLH	866	FWOP	0	0.98
			1	0.98
			15	0.98
			30	0.98
			45	0.98
			60	0.98
		FWP	0	0.98
			1	0.01
			60	0.01

5.5 Reach E

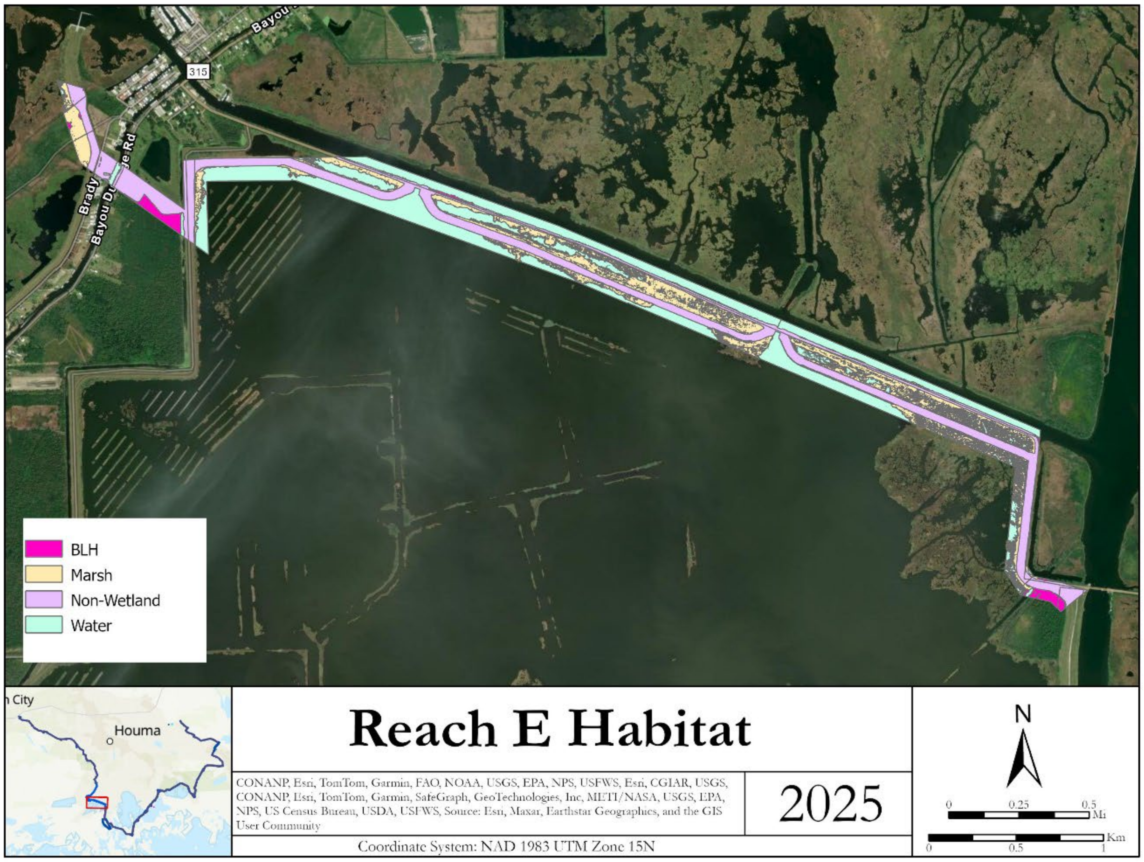

Figure 10: Reach E Habitat

5.5.1 *Variable V1 – Tree Species Composition*

Reach	ICM		Target Year	Class
E	464	FWOP	0	4
			1	4
			15	4
			30	4
			45	4
			60	4
		FWP	0	4
			1	1
			60	1

5.5.2 Variable V2 – Stand Maturity

Reach	ICM		Target Year	DBH
E	464	FWOP	0	9.90
			1	9.90
			15	9.44
			30	8.47
			45	8.59
			60	9.54
		FWP	0	9.90
			1	6.00
			60	6.00

5.5.3 Variable V3 – Understory/Midstory

Reach	ICM		Target Year	% Understory	% Midstory
E	464	FWOP	0	80	24
			1	80	24
			15	60	35
			30	50	35
			45	30	15
			60	20	10
		FWP	0	80	24
			1	100	0
			60	100	0

5.5.4 Variable V4 – Hydrology

Reach	ICM		Target Year	Flow Exchange	Flood Duration
E	464	FWOP	0	Moderate	Semi-Permanent
			1	Moderate	Semi-Permanent
			15	Moderate	Semi-Permanent
			30	Moderate	Semi-Permanent
			45	Moderate	Permanent
			60	Moderate	Permanent
		FWP	0	Moderate	Semi-Permanent
			1	None	Permanent
			60	None	Permanent

5.5.5 Variable V5 – Size of Contiguous Forested Area

Reach	ICM		Target Year	Class
E	464	FWOP	0	4
			1	4
			15	4
			30	4
			45	4
			60	4
		FWP	0	4
			1	1
			60	1

5.5.6 Variable V6 – Suitability and Traversability of Surrounding Land Uses

Reach	ICM		Target Year	Forest/marsh	Abandoned Ag	Pasture/Hay	Active Ag	Develop
E	464	FWOP	0	57.03	0.11	1.04	35.73	6.08
			1	57.03	0.11	1.04	35.73	6.08
			15	57.03	0.11	1.04	35.73	6.08
			30	57.03	0.11	1.04	35.73	6.08
			45	57.03	0.11	1.04	35.73	6.08
			60	55.03	0.11	1.04	35.73	8.08
		FWP	0	57.03	0.11	1.04	35.73	6.08
			1	0.00	0.00	0.00	0.00	100.00
			60	0.00	0.00	0.00	0.00	100.00

5.5.7 Variable V7 – Disturbance

Reach	ICM		Target Year	SI Value
E	464	FWOP	0	0.91
			1	0.91
			15	0.91
			30	0.91
			45	0.91
			60	0.91
		FWP	0	0.91
			1	0.01
			60	0.01

The only assumed differences from the 2023 NLCD was the Houma Navigation Canal Class 1 water way and the Falgout Canal Class 2 water way. The Houma Navigation Canal and the Falgout Canal are classified as Open Water by the 2023 NLCD making both a Class 4 Disturbance Class. It is assumed that the Houma Navigation canal is a Class 1 disturbance class and the Falgout canal is a Class 2 disturbance class using satellite imagery to assess boat travel and access.

5.6 Reach G and Bayou Grand Caillou Barge FG BLH

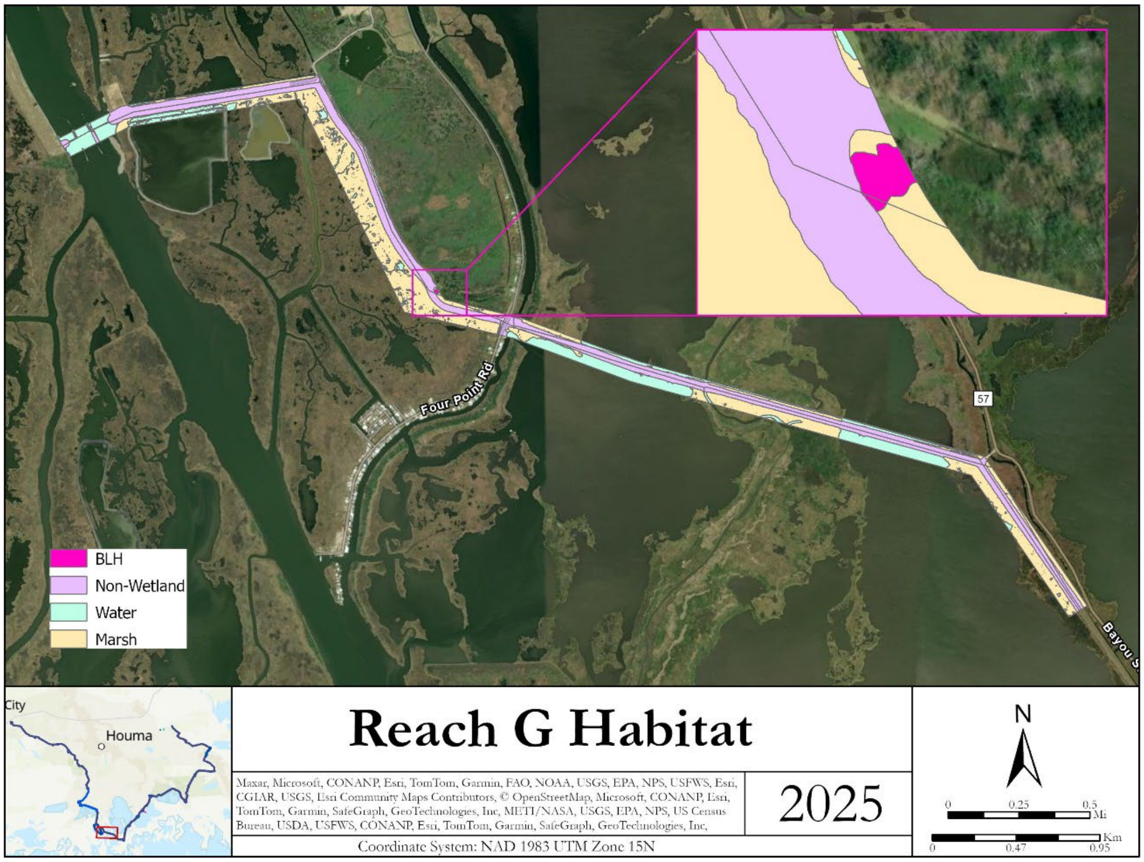

Figure 11: Reach G Habitat

5.6.1 Variable V1 – Tree Species Composition

Reach	ICM		Target Year	Class
G and Bayou Grand Caillou Barge FG BLH	743	FWOP	0	4
			1	4
			15	4
			30	4
			45	4
			60	4
		FWP	0	4
			1	1
			60	1

5.6.2 Variable V2 – Stand Maturity

Reach	ICM		Target Year	DBH
G	743	FWOP	0	9.90
			1	9.90
			15	9.44
			30	9.15
			45	6.00
			60	6.00
		FWP	0	9.90
			1	6.00
			60	6.00
Bayou Grand Caillou Barge FG	743	FWOP	0	9.90
			1	9.90
			15	9.44
			30	6.00
			45	6.00
			60	6.00
		FWP	0	9.90
			1	6.00
			60	6.00

5.6.3 Variable V3 – Understory/Midstory

Reach	ICM		Target Year	% Understory	% Midstory
G and Bayou Grand Caillou Barge FG BLH	743	FWOP	0	80	24
			1	80	24
			15	55	24
			30	25	15
			45	20	10
			60	20.0	10.0
		FWP	0	80.0	24.0
			1	100.0	0.0
			60	100	0

5.6.4 Variable V4 – Hydrology

Reach	ICM		Target Year	Flow Exchange	Flood Duration
G and Bayou Grand Caillou Barge FG BLH	743	FWOP	0	Moderate	Semi-Permanent
			1	Moderate	Semi-Permanent
			15	Moderate	Semi-Permanent
			30	Moderate	Permanent
			45	None	Permanent
			60	None	Permanent
		FWP	0	Moderate	Semi-Permanent
			1	None	Permanent
			60	None	Permanent

5.6.5 Variable V5 – Size of Contiguous Forested Area

Reach	ICM		Target Year	Class
G and Bayou Grand Caillou Barge FG BLH	743	FWOP	0	1
			1	1
			15	1
			30	1
			45	1
			60	1
		FWP	0	1
			1	1
			60	1

5.6.6 Variable V6 – Suitability and Traversability of Surrounding Land Uses

Reach	ICM		Target Year	Forest/marsh	Abandoned Ag	Pasture/Hay	Active Ag	Develop
G and Bayou Grand Caillou Barge FG BLH	743	FWOP	0	78.93	1.32	2.13	9.24	8.39
			1	78.93	1.32	2.13	9.24	8.39
			15	78.93	1.32	2.13	9.24	8.39
			30	78.93	1.32	2.13	9.24	8.39
			45	76.93	1.32	2.13	9.24	10.39
			60	76.93	1.32	2.13	9.24	10.39
		FWP	0	78.93	1.32	2.13	9.24	8.39
			1	0.00	0.00	0.00	0.00	100.00
			60	0.00	0.00	0.00	0.00	100.00

5.6.7 Variable V7 – Disturbance

Reach	ICM		Target Year	SI Value
G and Bayou Grand Caillou Barge FG BLH	743	FWOP	0	1.00
			1	1.00
			15	1.00
			30	1.00
			45	1.00
			60	1.00
		FWP	0	1.00
			1	0.01
			60	0.01

5.7 Reach H, Bayou Petit Caillou Barge FG and Placid Canal Barge FG BLH

Figure 12: Reach H Habitat

5.7.1 Variable V1 – Tree Species Composition

Reach	ICM		Target Year	Class
H, Bayou Petit Caillou Barge FG and Placid Canal Barge FG BLH	753	FWOP	0	4
			1	4
			15	4
			30	4
			45	4
			60	4
		FWP	0	4
			1	1
			60	1

5.7.2 Variable V2 – Stand Maturity

Reach	ICM		Target Year	DBH
H, Bayou Petit Caillou Barge FG and Placid Canal Barge FG BLH	753	FWOP	0	9.90
			1	9.90
			15	9.44
			30	8.48
			45	8.58
			60	9.33
		FWP	0	9.90
			1	6.00
			60	6.00

5.7.3 Variable V3 – Understory/Midstory

Reach	ICM		Target Year	% Understory	% Midstory
H, Bayou Petit Caillou Barge FG and Placid Canal Barge FG BLH	753	FWOP	0	80	24
			1	80	24
			15	60	35
			30	50	35
			45	35	15
			60	20.0	10.0
		FWP	0	80.0	24.0
			1	100.0	0.0
			60	100	0

5.7.4 Variable V4 – Hydrology

Reach	ICM		Target Year	Flow Exchange	Flood Duration
H, Bayou Petit Caillou Barge FG and Placid Canal Barge FG BLH	753	FWOP	0	Moderate	Semi-Permanent
			1	Moderate	Semi-Permanent
			15	Moderate	Semi-Permanent
			30	Moderate	Semi-Permanent
			45	Moderate	Permanent
			60	Moderate	Permanent
		FWP	0	Moderate	Semi-Permanent
			1	None	Permanent
			60	None	Permanent

5.7.5 Variable V5 – Size of Contiguous Forested Area

Reach	ICM		Target Year	Class
H, Bayou Petit Caillou Barge FG and Placid Canal Barge FG BLH	753	FWOP	0	1
			1	1
			15	1
			30	1
			45	1
			60	1
		FWP	0	1
			1	1
			60	1

5.7.6 Variable V6 – Suitability and Traversability of Surrounding Land Uses

Reach	ICM		Target Year	Forest/marsh	Abandoned Ag	Pasture/Hay	Active Ag	Develop
H, Bayou Petit Caillou Barge FG, and Placid Canal Barge FG BLH	753	FWOP	0	58.89	0.12	2.86	30.16	7.97
			1	58.89	0.12	2.86	30.16	7.97
			15	58.89	0.12	2.86	30.16	7.97
			30	58.89	0.12	2.86	30.16	7.97
			45	56.89	0.12	2.86	30.16	9.97
			60	56.89	0.12	2.86	30.16	9.97
		FWP	0	58.89	0.12	2.86	30.16	7.97
			1	0.00	0.00	0.00	0.00	100.00
			60	0.00	0.00	0.00	0.00	100.00

5.7.7 Variable V7 – Disturbance

Reach	ICM		Target Year	SI Value
H, Bayou Petit Caillou Barge FG, and Placid Canal Barge FG BLH	753	FWOP	0	0.76
			1	0.76
			15	0.76
			30	0.76
			45	0.76
			60	0.76
		FWP	0	0.76
			1	0.01
			60	0.01

The only assumed difference from the 2023 NLCD was the Bayou Petite Caillou Class 2 water way. Bayou Petite Caillou is classified as Open Water by the 2023 NLCD making it a Class 4 Disturbance Class. It is assumed that Bayou Petite Caillou is a Class 2 disturbance class using satellite imagery to assess boat travel and access.

5.8 Reach I, Bayou Terrebonne Barge FG, and Humble Canal Barge FG BLH

Figure 13: Reach I Habitat

5.8.1 Variable V1 – Tree Species Composition

Reach	ICM		Target Year	Class
I, Bayou Terr Barge FG, and Humble Canal Barge FG BLH	703	FWOP	0	4
			1	4
			15	4
			30	4
			45	4
			60	4
		FWP	0	4
			1	1
			60	1

5.8.2 Variable V2 – Stand Maturity

Reach	ICM		Target Year	DBH
I, Bayou Terr Barge FG, and Humble Canal Barge FG BLH	703	FWOP	0	9.90
			1	9.90
			15	9.44
			30	8.48
			45	8.54
			60	9.05
		FWP	0	9.90
			1	6.00
			60	6.00

5.8.3 Variable V3 – Understory/Midstory

Reach	ICM		Target Year	% Understory	% Midstory
I, Bayou Terr Barge FG, and Humble Canal Barge FG BLH	703	FWOP	0	80	24
			1	80	24
			15	60	35
			30	50	35
			45	35	15
			60	20.0	10.0
		FWP	0	80.0	24.0
			1	100.0	0.0
			60	100	0

5.8.4 Variable V4 – Hydrology

Reach	ICM		Target Year	Flow Exchange	Flood Duration
I, Bayou Terr Barge FG, and Humble Canal Barge FG BLH	703	FWOP	0	Moderate	Semi-Permanent
			1	Moderate	Semi-Permanent
			15	Moderate	Semi-Permanent
			30	Moderate	Semi-Permanent
			45	Moderate	Permanent
			60	Moderate	Permanent
		FWP	0	Moderate	Semi-Permanent
			1	None	Permanent
			60	None	Permanent

5.8.5 Variable V5 – Size of Contiguous Forested Area

Reach	ICM		Target Year	Class
I, Bayou Terr Barge FG, and Humble Canal Barge FG BLH	703	FWOP	0	1
			1	1
			15	1
			30	1
			45	1
			60	1
		FWP	0	1
			1	1
			60	1

5.8.6 Variable V6 – Suitability and Traversability of Surrounding Land Uses

Reach	ICM		Target Year	Forest/marsh	Abandoned Ag	Pasture/Hay	Active Ag	Develop
I, Bayou Terr Barge FG and Humble Canal Barge FG	703	FWOP	0	51.39	0.00	0.51	43.43	4.67
			1	51.39	0.00	0.51	43.43	4.67
			15	51.39	0.00	0.51	43.43	4.67
			30	51.39	0.00	0.51	43.43	4.67
			45	49.39	0.00	0.51	43.43	6.67
			60	49.39	0.00	0.51	43.43	6.67
		FWP	0	51.39	0.00	0.51	43.43	4.67
			1	0.00	0.00	0.00	0.00	100.00
			60	0.00	0.00	0.00	0.00	100.00

5.8.7 Variable V7 – Disturbance

Reach	ICM		Target Year	SI Value
I, Bayou Terr Barge FG, and Humble Canal Barge FG	703	FWOP	0	0.91
			1	0.91
			15	0.91
			30	0.91
			45	0.91
			60	0.91
		FWP	0	0.91
			1	0.01
			60	0.01

The only assumed difference from the 2023 NLCD was Bayou Terrebonne Class 2 water way. Bayou Terrebonne is classified as Open Water by the 2023 NLCD making it a Class 4 Disturbance Class. It is assumed that Bayou Terrebonne is a Class 2 disturbance class using satellite imagery to assess boat travel and access.

5.9 Reach J

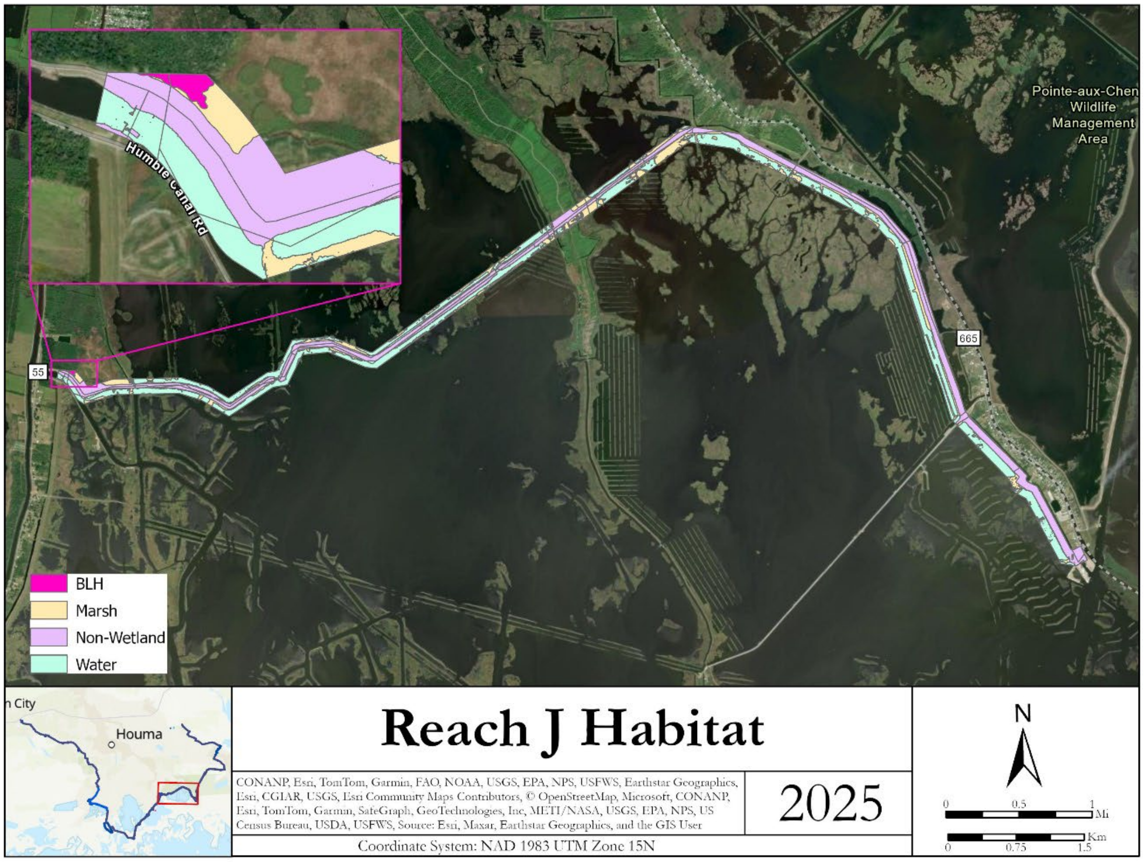

Figure 14: Reach J Habitat

5.9.1 Variable V1 – Tree Species Composition

Reach	ICM		Target Year	Class
J	512	FWOP	0	4
			1	4
			15	4
			30	4
			45	4
			60	4
		FWP	0	4
			1	1
			60	1

5.9.2 Variable V2 – Stand Maturity

Reach	ICM		Target Year	DBH
J	512	FWOP	0	9.90
			1	9.90
			15	9.44
			30	9.35
			45	6.00
			60	6.00
		FWP	0	9.90
			1	6.00
			60	6.00

5.9.3 Variable V3 – Understory/Midstory

Reach	ICM		Target Year	% Understory	% Midstory
J	512	FWOP	0	80	24
			1	80	24
			15	55	30
			30	35	15
			45	35	15
			60	35.0	15.0
		FWP	0	80.0	24.0
			1	100.0	0.0
			60	100.0	0.0

5.9.4 Variable V4 – Hydrology

Reach	ICM		Target Year	Flow Exchange	Flood Duration
J	512	FWOP	0	Low	Semi-Permanent
			1	Low	Semi-Permanent
			15	Low	Semi-Permanent
			30	Low	Semi-Permanent
			45	Low	Permanent
			60	Low	Permanent
		FWP	0	Low	Semi-Permanent
			1	None	Permanent
			60	None	Permanent

5.9.5 Variable V5 – Size of Contiguous Forested Area

Reach	ICM		Target Year	Class
J	512	FWOP	0	3
			1	3
			15	3
			30	3
			45	3
			60	3
		FWP	0	3
			1	1
			60	1

5.9.6 Variable V6 – Suitability and Traversability of Surrounding Land Uses

Reach	ICM		Target Year	Forest/marsh	Abandoned Ag	Pasture/Hay	Active Ag	Develop
J	512	FWOP	0	1.76	0.90	17.04	72.22	8.09
			1	1.76	0.90	17.04	72.22	8.09
			15	1.76	0.90	17.04	72.22	8.09
			30	1.76	0.90	17.04	72.22	8.09
			45	0.76	0.90	17.04	72.22	9.09
			60	0.76	0.90	17.04	72.22	9.09
		FWP	0	1.76	0.90	17.04	72.22	8.09
			1	0.00	0.00	0.00	0.00	100.00
			60	0.00	0.00	0.00	0.00	100.00

5.9.7 Variable V7 – Disturbance

Reach	ICM		Target Year	SI Value
J	512	FWOP	0	0.91
			1	0.91
			15	0.91
			30	0.91
			45	0.91
			60	0.91
		FWP	0	0.91
			1	0.01
			60	0.01

5.10 Reach LCN

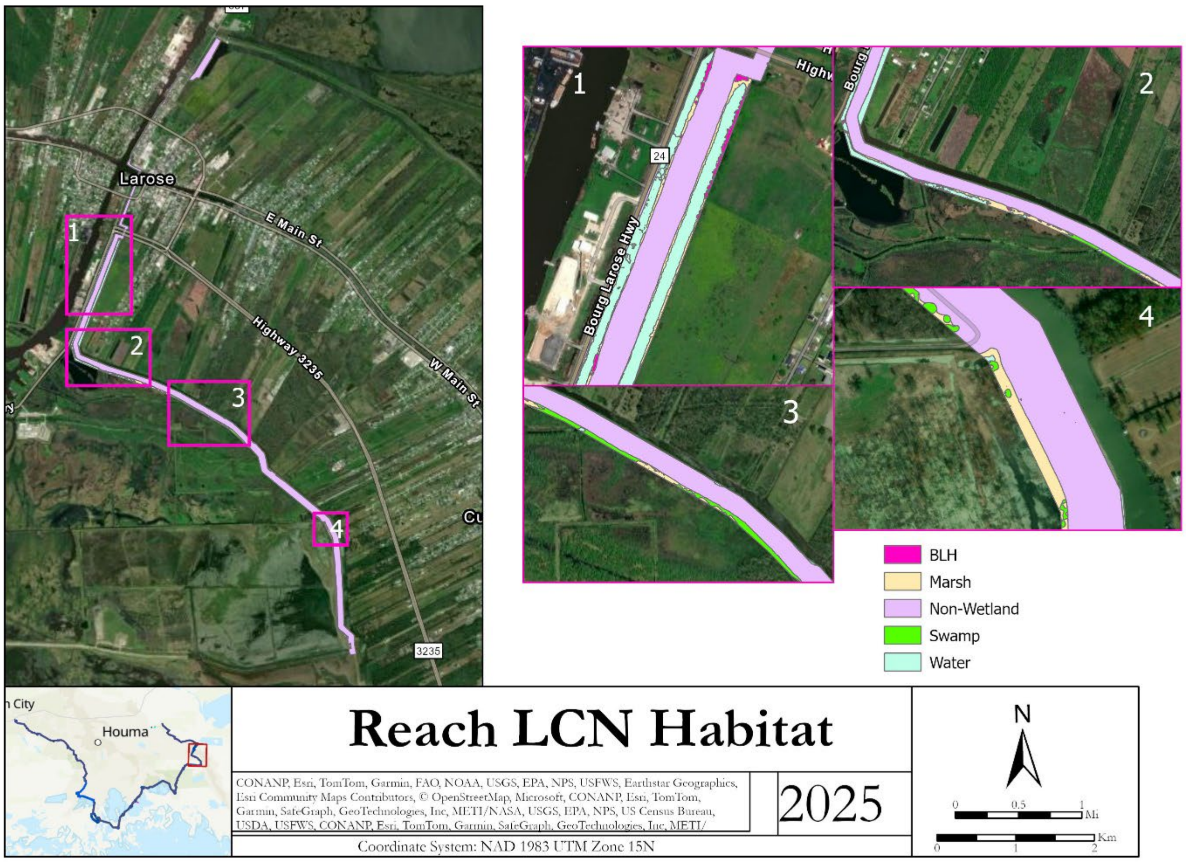

Figure 15: Reach LCN Habitat

5.10.1 Variable V1 – Tree Species Composition

Reach	ICM		Target Year	Class
LCN BLH	506	FWOP	0	1
			1	1
			15	1
			30	1
			45	1
			60	1
		FWP	0	1
			1	1
			60	1

5.10.2 Variable V2 – Stand Maturity

Reach	ICM		Target Year	DBH
LCN BLH	506	FWOP	0	11.54
			1	11.54
			15	10.18
			30	9.95
			45	10.31
			60	11.32
		FWP	0	11.54
			1	6.00
			60	6.00

5.10.3 Variable V3 – Understory/Midstory

Reach	ICM		Target Year	% Understory	% Midstory
LCN BLH	506	FWOP	0	65	54
			1	65	54
			15	45	30
			30	20	15
			45	15	10
			60	15	10
		FWP	0	65	54
			1	100	0
			60	100	0

5.10.4 Variable V4 – Hydrology

Reach	ICM		Target Year	Flow Exchange	Flood Duration
LCN BLH	506	FWOP	0	Moderate	Seasonal
			1	Moderate	Seasonal
			15	Moderate	Seasonal
			30	Moderate	Semi-Permanent
			45	Moderate	Semi-Permanent
			60	Moderate	Semi-Permanent
		FWP	0	Moderate	Seasonal
			1	None	Permanent
			60	None	Permanent

5.10.5 Variable V5 – Size of Contiguous Forested Area

Reach	ICM		Target Year	Class
LCN BLH	506	FWOP	0	1
			1	1
			15	1
			30	1
			45	1
			60	1
		FWP	0	1
			1	1
			60	1

5.10.6 Variable V6 – Suitability and Traversability of Surrounding Land Uses

Reach	ICM		Target Year	Forest/marsh	Abandoned Ag	Pasture/Hay	Active Ag	Develop
LCN BLH	506	FWOP	0	49.92	0.08	13.17	6.61	30.22
			1	49.92	0.08	13.17	6.61	30.22
			15	49.92	0.08	13.17	6.61	30.22
			30	49.92	0.08	13.17	6.61	30.22
			45	47.92	0.08	13.17	6.61	32.22
			60	47.92	0.08	13.17	6.61	32.22
		FWP	0	49.92	0.08	13.17	6.61	30.22
			1	0.00	0.00	0.00	0.00	100.00
			60	0.00	0.00	0.00	0.00	100.00

5.10.7 Variable V7 – Disturbance

Reach	ICM		Target Year	SI Value
LCN BLH	506	FWOP	0	0.75
			1	0.75
			15	0.75
			30	0.75
			45	0.75
			60	0.75
		FWP	0	0.75
			1	0.01
			60	0.01

5.11 Lockport to Larose 159, 160, and GIWW Floodgate E BLH

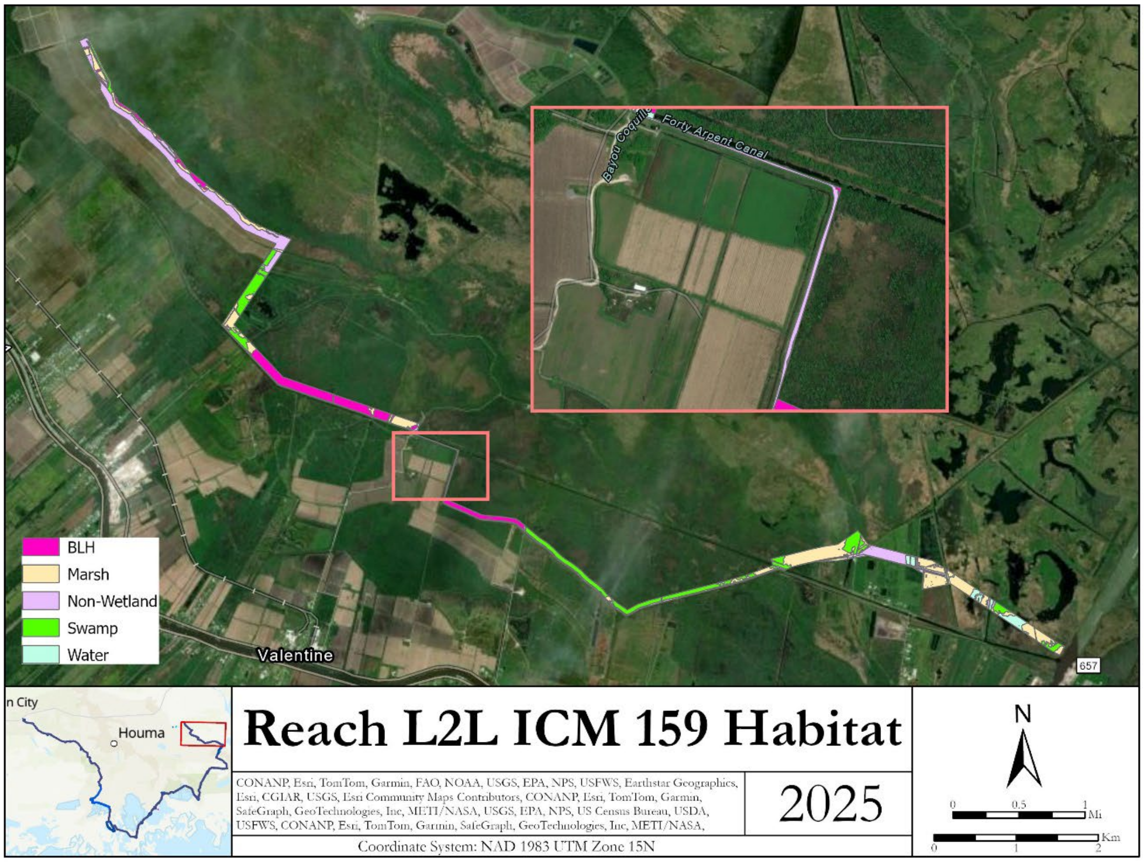

Figure 16: Reach L2L ICM159 Habitat

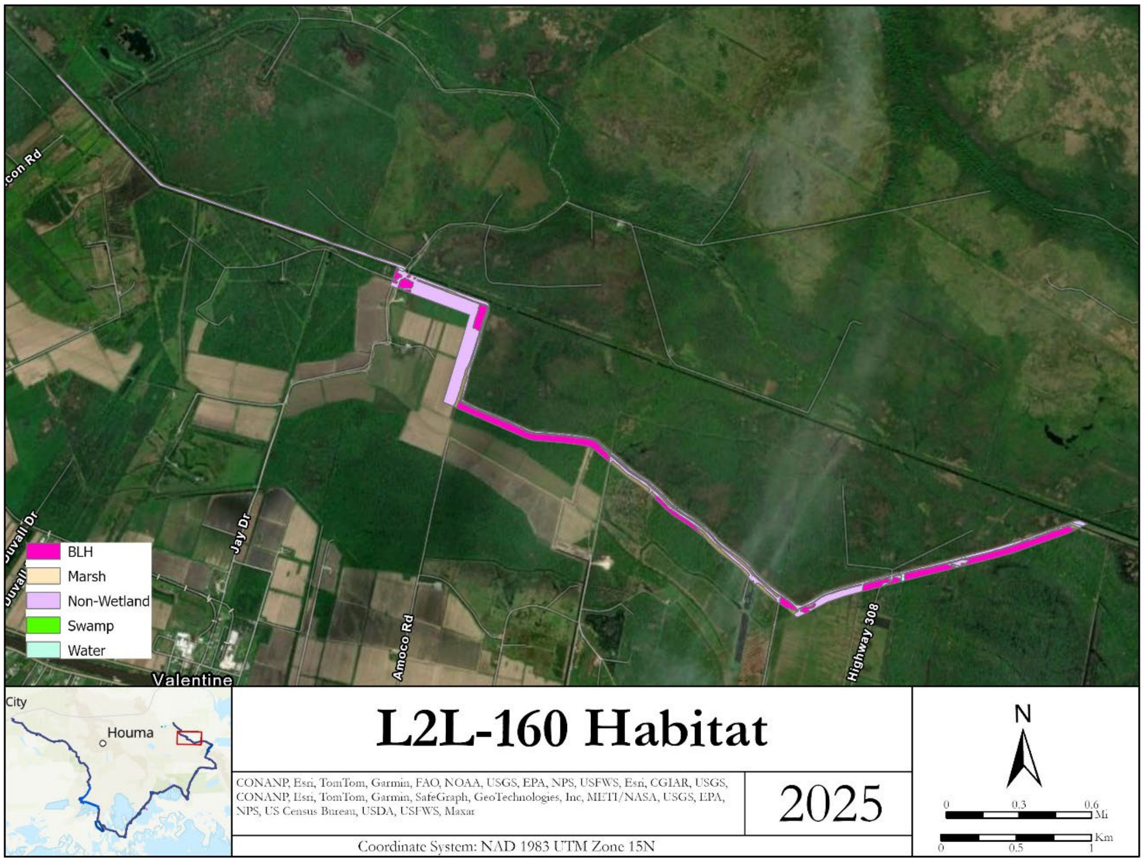

Figure 17: Reach L2L ICM160 Habitat

5.11.1 Variable V1 – Tree Species Composition

Reach	ICM		Target Year	Class
L2L 159 and GIWW Floodgate E BLH	159	FWOP	0	1
			1	1
			15	1
			30	1
			45	1
			60	1
		FWP	0	1
			1	1
			60	1
L2L 160 BLH	160	FWOP	0	5
			1	5
			15	5
			30	5
			45	5
			60	5
		FWP	0	5
			1	1
			60	1

5.11.2 Variable V2 – Stand Maturity

Reach	ICM		Target Year	DBH
L2L 159 and GIWW Floodgate E BLH	159	FWOP	0	11.54
			1	11.54
			15	10.18
			30	10.17
			45	11.05
			60	11.16
		FWP	0	11.54
			1	6.00
			60	6.00
L2L 160 BLH	160	FWOP	0	11.51
			1	11.51
			15	11.11
			30	10.55
			45	12.36
			60	11.94
		FWP	0	11.51
			1	6.00
			60	6.00

5.11.3 Variable V3 – Understory/Midstory

Reach	ICM		Target Year	% Understory	% Midstory
L2L 159 and GIWW Floodgate E BLH	159	FWOP	0	65	54
			1	65	54
			15	60	50
			30	45	35
			45	35	25
			60	20	15
		FWP	0	65	54
			1	100	0
			60	100	0
L2L 160 BLH	160	FWOP	0	65	54
			1	65	54
			15	60	50
			30	45	35
			45	35	25
			60	20	15
		FWP	0	65	54
			1	100	0
			60	100	0

5.11.4 Variable V4 – Hydrology

Reach	ICM		Target Year	Flow Exchange	Flood Duration
L2L 159 and GIWW Floodgate E BLH	159	FWOP	0	Moderate	Seasonal
			1	Moderate	Seasonal
			15	Moderate	Seasonal
			30	Moderate	Seasonal
			45	Moderate	Semi-Permanent
			60	Moderate	Semi-Permanent
		FWP	0	Moderate	Seasonal
			1	None	Permanent
			60	None	Permanent
L2L 160 BLH	160	FWOP	0	Low	Temporary
			1	Low	Temporary
			15	Low	Temporary
			30	Low	Temporary
			45	Low	Seasonal
			60	Low	Seasonal
		FWP	0	Low	Temporary
			1	None	Permanent
			60	None	Permanent

5.11.5 Variable V5 – Size of Contiguous Forested Area

Reach	ICM		Target Year	Class
L2L 159 and GIWW Floodgate E BLH	159	FWOP	0	5
			1	5
			15	5
			30	5
			45	5
			60	5
		FWP	0	5
			1	1
			60	1
L2L 160 BLH	160	FWOP	0	4
			1	4
			15	4
			30	4
			45	4
			60	4
		FWP	0	4
			1	1
			60	1

5.11.6 Variable V6 – Suitability and Traversability of Surrounding Land Uses

Reach	ICM		Target Year	Forest/marsh	Abandoned Ag	Pasture/Hay	Active Ag	Develop
L2L 159 and GIWW Floodgate E BLH	159	FWOP	0	69.05	0.00	13.20	16.30	1.45
			1	69.05	0.00	13.20	16.30	1.45
			15	69.05	0.00	13.20	16.30	1.45
			30	69.05	0.00	13.20	16.30	1.45
			45	67.05	0.00	13.20	16.30	3.45
			60	67.05	0.00	13.20	16.30	3.45
		FWP	0	69.05	0.00	13.20	16.30	1.45
			1	0.00	0.00	0.00	0.00	100.00
			60	0.00	0.00	0.00	0.00	100.00
L2L 160 BLH	160	FWOP	0	81.17	0.00	4.57	13.37	0.89
			1	81.17	0.00	4.57	13.37	0.89
			15	81.17	0.00	4.57	13.37	0.89
			30	81.17	0.00	4.57	13.37	0.89
			45	79.17	0.00	4.57	13.37	2.89
			60	79.17	0.00	4.57	13.37	2.89
		FWP	0	81.17	0.00	4.57	13.37	0.89
			1	0.00	0.00	0.00	0.00	100.00
			60	0.00	0.00	0.00	0.00	100.00

5.11.7 Variable V7 – Disturbance

Reach	ICM		Target Year	SI Value
L2L 159, 159, and GIWW Floodgate E BLH	159	FWOP	0	0.96
			1	0.96
			15	0.96
			30	0.96
			45	0.96
			60	0.96
		FWP	0	0.96
			1	0.01
			60	0.01

Citations

E.L. Chapman, J.Q. Chambers, K.F. Ribbeck, D.B. Baker, M.A. Tobler, H. Zeng, D.A. White. Hurricane Katrina impacts on forest trees of Louisiana's Pearl River basin. 2008. Forest Ecology and Management 256(2008) 883-889.

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Part 2: Morganza to the Gulf DSEIS Wetland Value Assessment - Marsh Direct Project Information Sheet

Morganza to the Gulf, Louisiana, Hurricane and Storm Damage Risk Reduction Project Draft Supplemental Environmental Impact Statement
Draft Marsh Wetland Value Assessment (WVA) Project Information Sheet (PIS)

March-2025

1. Introduction

1.1 Project Background

The authorized Morganza to the Gulf (MTG) project is a hurricane and storm damage risk reduction project involving a 98-mile alignment of earthen levees, floodgates, environmental water control structures, road/railroad gates, and fronting protection for existing pump stations.

The U.S. Army Corps of Engineers (USACE), Mississippi Valley Division (MVD), New Orleans District (CEMVN), has prepared a Supplemental Programmatic Environmental Impact Statement (SPEIS) to evaluate proposed design changes to the authorized MTG project that consider existing levee alignments and minimization of impacts to sensitive habitats that also meet the one percent Annual Exceedance Probability (AEP) Storm Surge Risk Reduction (100-year level of risk reduction). This SPEIS supplements the Revised Programmatic EIS (RPEIS), MTG, Louisiana, which was integrated with the 2013 Final Post Authorization Change Report (PACR), approved in the Chief's Report signed on July 8, 2013. The purpose of the project is to reduce the risk of damage caused by hurricane storm surges. The project is needed because of the increasing susceptibility of coastal communities to storm surge due to wetland loss, sea level rise, and subsidence.

The study area includes communities in the southeast Louisiana parishes of Ascension, Assumption, Jefferson, Lafourche, St. Charles, St. James, and St. John the Baptist (Figure 1). The study area is bounded on the north and east by the Mississippi River Levee, on the west by Bayou Lafourche, and on the south it extends slightly past U.S. Highway 90. The study area covers approximately 1.924 square miles and is characterized by low, flat terrain with wetlands, numerous navigation channels, drainage canals, and natural bayous that drain into Lake Salvador and eventually into the Gulf of Mexico. The study area is a diverse ecosystem inhabited by a variety of species of birds, mammals, reptiles, and amphibians, as well as fresh, brackish, and saltwater fish.

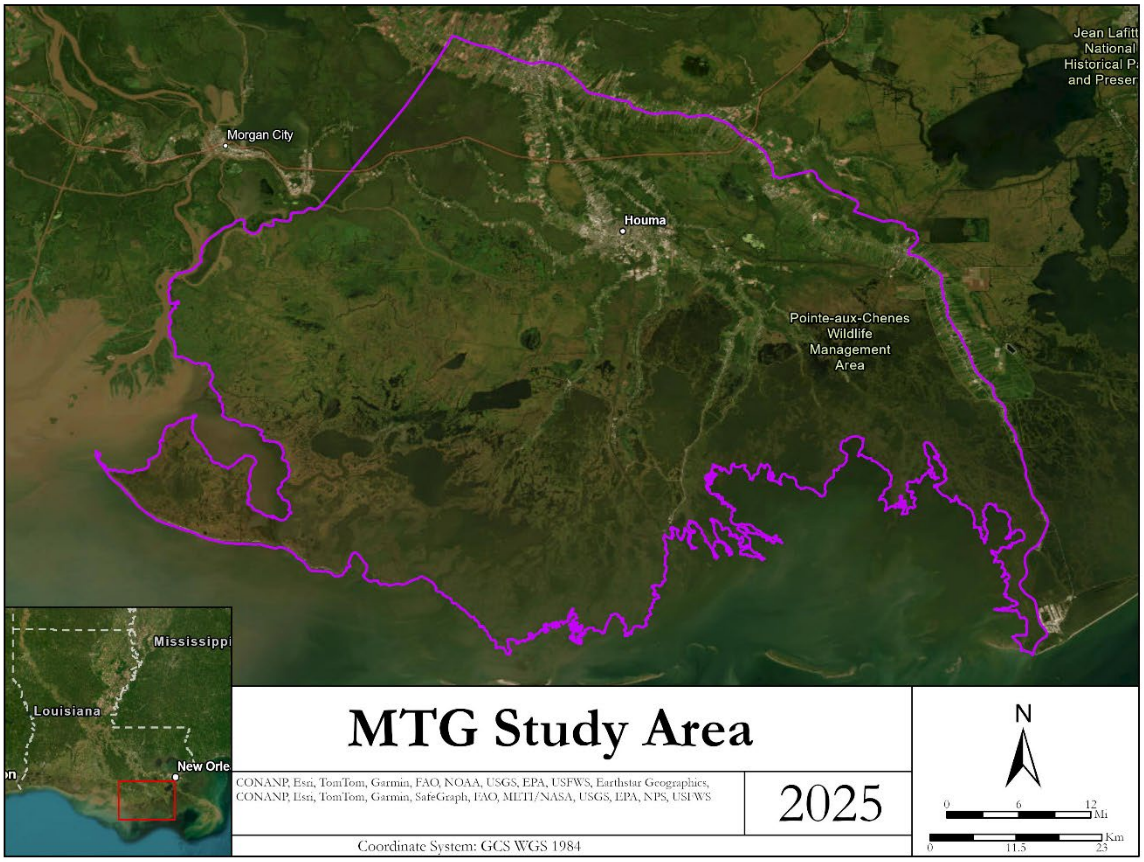

Figure 1: MTG Study Area

1.2 <u>WVA Background</u>

To quantify impacts to wetland habitats over project life, the most current versions of the Civil Works Wetland Value Assessment (WVA) models (Fresh/Intermediate, Brackish, and Saline Marsh Wetland Value Assessment Marsh Community Models for Civil works (Version 2.1)) were used. Further information on these models may be obtained from the USACE, New Orleans District, RPEDS (https://ecolibrary.planusace.us/ (use the search term “WVA”)).

Each model consists of: 1) a list of variables (V) 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 Index) and different variable values; and 3) a mathematical formula that combines the Suitability Index for each variable into a single value for wetland habitat quality. That single value is referred to as the Habitat Suitability Index, or HSI. The Marsh WVA models consist of 6 variables: 1) Percent of wetland area covered by emergent vegetation, 2) Percent of open water area covered by aquatic vegetation, 3) Marsh edge and interspersion, 4) Percent of open water area ≤ 1.5 feet deep in relation to marsh surface, 5) Salinity, 6) Aquatic organism access.

The WVA models compare habitat values for three different conditions, existing, Future Without Project (FWOP), and Future With Project (FWP) across the Project’s life. Target years (TYs) are designated based on project implementation and anticipated future changes for each future condition. The TY0 represents the pre-project condition and is the same for both the FWP and FWOP condition. The TY0 could be the existing condition as measured in the field or it could be forecasted from field measurements.

1.3 Summary

Construction of Morganza to the Gulf levee and associated structures will result in removal of 1,372 acres of fresh/intermediate marsh, 379 acres of brackish marsh, and 2,116 acres of salt marsh habitat.

Table 1: Impacts, habitat, and AAHUs by reach/structure.

Reach		Habitat	AAHU	Existing Wetland Habitat Acres
Barrier 642		Fresh/Int	-14.9	30
Barrier 648		Fresh/Int	-37.3	82
Barrier 640		Fresh/Int	-45.3	108
Barrier Structures Marsh		Fresh/Int	-0.7	2
B1	Floodside	Fresh/Int	-65.9	161
B2	Floodside	Fresh/Int	-1.8	11
B2 Structures Marsh		Fresh/Int	-13.1	73
E1	Floodside	Fresh/Int	-4.0	8
E2*	Floodside	Fresh/Int	0.0	2
E3	Floodside	Fresh/Int	-37.3	244
G1	Floodside	Saline	-40.6	81
G2	Floodside	Saline	-2.8	18
G3	Floodside	Saline	-17.6	39
G4	Protected side	Brackish	-7.2	28
G1 Structures		Saline	-330.8	912
H1	Floodside	Fresh/Int	-0.8	6
H2	Protected side	Fresh/Int	-4.7	13
H3	Protected side	Saline	-22.0	45
H4	Floodside	Saline	-72.8	229
H5	Protected side	Saline	-9.5	43
H4 Structures		Saline	-12.1	48
I1	Floodside	Saline	-22.2	161
I2	Floodside	Saline	-4.9	34
I3	Protected side	Saline	-22.7	100
I Structures		Saline	-9.8	81
J1	Floodside	Fresh/Int	-16.8	141
J2	Floodside	Saline	-15.1	128
J3	Floodside	Saline	-21.6	169
J4	Protected side	Saline	-5.3	46
J5	Protected side	Saline	-9.3	34

J6	Protected side	Saline	0.00	0.02
J4 Structures		Saline	1.1	9
K1	Protected side	Brackish	-34.2	235
K2	Protected side	Brackish	-14.4	116
L1	Protected side	Fresh/Int	-15.2	102
L2	Floodside	Fresh/Int	-7.3	71
L3	Protected side	Fresh/Int	-16.3	86
L4	Floodside	Fresh/Int	-41.5	116
L2 Structures		Fresh/Int	-2.5	20
L2L 159		Fresh/Int	-74.0	151
L2L 160		Fresh/Int	-7.7	19
L2L Structures		Fresh/Int	-6.4	21
L2L Haul Route		Fresh/Int	-0.1	0.2
LCN 506		Fresh/Int	-6.9	36
LCN Structures		Fresh/Int	-1.1	13
Total			**-1021**	**4070**

*All open water, no emergent vegetation present

Approach

1.4 Field Data collection

WVA field data collection took place over a 4-month period (5/10/2024- 9/24/2024). Transects were established across the MTG levee alignment that attempted to capture a representative portion of the project area. A soil rake marked in tenths of feet was used to measure water depth and to document the presence/absence of submerged aquatic vegetation (SAV) approximately every 100 ft. If depths exceeded the length of the rake (4.5 ft), a stadia rod was used, or the depth was noted as greater than 4.5 ft. The dominant species of emergent vegetation were noted at the start and end of each transect to confirm marsh type, and the transect start and end time were recorded for use in water depth correction. Field data were used to represent the TY0 condition for both FWP and FWOP condition.

1.5 Habitat Classification

Habitat types within the planned levee footprint (and associated structures) were classified into developed, bottomland hardwood (BLH), swamp, f/I marsh, brackish/saline marsh, water, agricultural, and other. Field data from WVA sampling events were used to inform classification. See section 3 for habitat maps by reach.

Morganza to the Gulf Project habitat delineations were accomplished using ArcGIS Pro Geographic Information Systems (GIS) software version 3.3.2 - Supervised Classification method. Digital 2023 aerial imagery from U.S. Department of Agriculture's (USDA) National Aerial Imagery Program (NAIP) one-meter spatial resolution UTM NAD83 Zone 15 projection were the source imagery for the analysis. Representative spectral signatures for each habitat type were identified and captured to create the desired sample classes of water, marsh, bottomland hardwood (BLH) and non-wetland. Supervised Classification tool was run for each reach to categorize the construction footprints into the desired classes. Due to the inconsistency in color and textures of imagery across the reaches, the resulting classes needed manual refinement, mainly between existing levee/earthen roads and marsh environments. Polygon editing tools were used to heads up digitize and split and/or refine the lines between habitats. In addition to knowledge of aerial imagery spectral signatures, ground truthing sites were used to confirm and refine the habitat delineations. Project biologists were consulted during the mapping process to review draft assigned habitats and full review after final edits and acre calculations were complete. See section 3 for habitat maps by reach.

1.6 <u>WVA organization</u>

1.6.1 Spatial Extent

Multiple plots were established to represent habitat evaluated by individual WVAs. Area represented by a WVA was divided by reach and then by additional boundaries. Reaches were divided by the Coastal Master Plan (CMP) Integrated Compartment model (ICM) polygons. The ICM is a planning-level model that was developed to aid decision-making in support of the CMP (Reed & White, 2023). ICM compartments are regional divisions used to organize data, modeling, and project evaluation. Each compartment was developed based on Hydrologic Connectivity (Natural and artificial water flow patterns that influence sediment transport and water quality), Geomorphic Features (Physical landscape characteristics such as marshes, ridges, and bayous) and ecological zones (areas with similar vegetation types and habitat). As ICM compartments were used to generate components of WVA variables, these boundaries were incorporated to further refine area representation for separate WVAs. The WVAs organized by reach, sub reach, ICM, protected vs unprotected (where applicable), habitat type, and associated field sites are below in Table 2.

Overall, there are 24 fresh/intermediate, 3 brackish, 18 saline WVAs.

Table 2. WVA boundaries and field plots used to represent the habitat therein.

Reach	Sub Reach	ICM(s)	Protected vs Floodside	Habitat Type	Field Sites
Barrier	Barrier 1	640	Floodside	Fresh/Int	Assumptions made from adjacent BLH/Swamp Sites
	Barrier 2	642			
	Barrier 3	648			
	Barrier Structures	640/642/628			
Reach B	B1	866	Floodside	Fresh/Int	71, 73, 75, 76, 77, 78, 139
	B2	666			69, 70
	B Structures	866/666			Used assumptions from like ICMs
Reach E	E1	666	Floodside	Fresh/Int	71 and 72 used as proxys
	E2	443			68 with 71 and 72 used as proxys
	E3	464			64, 65, 66, 67
	E Structures	443			Used assumptions from E2
Reach G	G1	473	Floodside	Saline	53, 54, 55, 56
	G2	669			52
	G3	462			48, 49, 50
	G4	699	Protected Side	Brackish	51, 119
	G Structures	473		Saline	Used assumptions from G1
Reach H	H1	514	Protected Side	Fresh/Int	42, 45, 56 as proxys
	H2	487			43, 44
	H3	462	Floodside	Saline	42, 45, 46
	H4	753			32, 33, 34, 37, 38, 40, 121, 140
	H5	700	Protected Side		30, 31, 154
	H Structures	753			Used assumptions from H4
Reach I	I1	703	Floodside	Saline	23, 24, 25, 26, 27, 155
	I2	512			22

	I3	511	Protected Side		28, 29
	I Structures	511/512/703			Used assumptions from like ICMs
Reach J	J1	535	Protected Side	Fresh/Int	20, 21, 122, 123
	J2	512	Floodside	Saline	18, 19, 152b
	J3	711			11, 12, 13, 14, 15, 16, 156 new
	J4	509			7, 8, 9, 151 new
	J5	534	Protected Side		17, 152
	J6	713			10, 124, 125, 126
	J Structures	509			Used assumptions from J4
Reach K	K1	714	Protected Side	Brackish	5, 6, 127
	K2	532			4, 128
Reach L	L1	532	Protected Side	Fresh/Int	129
	L2	721	Floodside		3
	L3	539	Protected Side		2, 130, 131
	L4	536	Floodside		1, 132, 133, 134
	L Structures	721			Used assumptions from L2
Reach L2L	L2L 1	159	Floodside	Fresh/Int	L2L:1, 2, 3, 4, 5, 8, 12, 13, 16, 17, 21, 24
	L2L 2	160	Protected Side		Used assumptions from L2L1
	L2L Structures	159			Used assumptions from L2L1
Reach LCN	LCN1	506	Floodside	Fresh/Int	2,4,5
	LCN Structures				Used assumptions from LCN1

1.6.2 Target Year (TY) Structure

Project construction was assumed to begin TY1 in 2025 to streamline analyses across Project features due to uncertainty in funding allocation, overall construction and implementation. The baseline year (TY0) would be 2024, and the end of the project life is target year TY60 in 2084. At TY1, the start of construction, the marsh will be buried and will no longer be considered functional. Therefore, V1, V2, V6 will be set to 0 at TY1 for the FWP condition.

Selection of TYs for each individual marsh WVA was based on projected significant events, such as 0% emergent marsh based on the USGS land-loss projections (see Section 3.1 for details). Each individual marsh WVA includes TY0, TY1, and TY60. All FWP WVAs were limited to these TYs. Some FWOP WVAs included additional TYs. See individual WVAs by feature for details.

2. Marsh WVA Variable General Assumptions

2.1 V1- Percent of wetland area covered by emergent vegetation

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. These habitats serve as a source of detritus and energy for lower trophic organisms that form the basis of the food chain. This variable assigns an SI of 1.0 to emergent vegetation between 60% to 80% and assigns an SI of 0.1 to emergent vegetation of 0%.

TY0 conditions FWOP and FWP:
Current acres of marsh/water within the MTG alignment were classified in ArcGIS Pro based on 2023 USDA imagery. The percent of existing marsh acres in the ICMs within the MTG footprint were calculated and entered as the TY0 (Target year) value for V1 (see V1 subsections in section 3).

TY 1-60 conditions FWOP:
The Marsh Impact Mitigation (MIMs) 3.11 spreadsheet is used to project marsh and water acres and percentages in the Future Without Project (FWOP) and Future With Project (FWP) TYs. The main inputs into the MIMs 3.11 spreadsheet are land loss, SLC, subsidence, and accretion. Every ICM had a unique MIMs 3.11 data sheet, but when field data was not available within an ICM nearby stations were used as a proxy to fill in the missing data. See Table 2 for field data sites associated with each ICM.

Land loss:
Historic acres of land within the Coastal Master Plan (CMP) Integrated Compartment model (ICM) polygons were calculated by USGS (1985-2020). ICM polygons were selected based on proximity to the MTG alignment. Future land loss was predicted using a linear regression of historic land acres measured by USGS. The results of this linear regression were used to populate FWOP V1 values through TY60.

SLC:
Sea level change equations from the USACE Engineering Regulation (ER) 1100-2-8162 are used for all three scenarios in the MIMs 3.11 spreadsheet. The equation for medium SLC, which was used for the WVA analysis, is below. See ER 1100-2-8162 for more information.

$$E(t) = 0.0017t + bt^2$$

where *E(t)* is the eustatic sea level change, in meters, as a function of *t*. The Eustatic sea level change for the medium sea level change is -1.7 mm/year. *b* is a constant for the modified National Research Council Curve I, which is 2.71×10^{-5}.

Accretion data:
CRMS measures vertical accretion by placing a layer of feldspar in the marsh substrate and then measuring the depth of deposited material above the feldspar layer. Original marker horizons were established concurrently with baseline RSET measurements. CRMS stations were sampled regularly, and a new feldspar layer was placed every 2 years, providing multiple accretion data sets. Continual establishment of new feldspar horizons provides a consistent temporal scale for comparison of accretion across CRMS sites. All plots were sampled until they no longer provided accretion data.

Due to the dynamic nature of accretion, the measured values can be highly variable; therefore, accretion rates are determined by linear regressions of the data over time. Full-term data sets, which are calculated from the full data record, provide a more accurate accretion rate when compared to short-term (1.5 to 3 year) data sets.

For this analysis, mean accretion data were obtained from CRMS sites in the vicinity of the MTG alignment (Table 3). Full-term feldspar set series with the greatest historical consistency were selected; these rates were averaged and used as a model input.

Subsidence:

Totals Subsidence (TS) was calculated using the sum of Deep Subsidence (DS) and Shallow Subsidence (SS).

TS=DS+SS(VA-SEC)

DS values were obtained from the Louisiana 2023 CMP Data Access Portal (https://mpdap.coastal.la.gov/dataset/shallow-subsidence#map=12.57/29.95051/-93.21243&geography=extraction_point&time=annual&year=52&scenario=A&selected=QAQC2101-QAQC2127&chart=2-52). SS values were calculated using the following formula (SS= Mean CRMS

Accretion - mean surface elevation change). Surface Elevation Change (SEC) data was obtained from CRMS RSET data. Mean accretion and TS were both used as inputs into the MIMS RSLC tab to estimate the effects of RSLC on the rate of land loss in the project area. See table 3 for a compilation of the data inputs.

Table 3: Accretion and subsidence data used as inputs for RSLC rate.

Reach	CRMS Station	AVG SEC mm	AVG VA mm	SS mm	DS mm	TS mm
B1, B2, E1	398	7.4	16.4	9	7	16
E2, E3	434 307	7.45	10.4	2.95	9.4	12.3
G1-4	369	3.8	9.25	5.45	9.26	14.7
H1, H2	390 392	7.85	9.7	1.8	8.2	10
H3	369	3.8	9.25	5.45	9.26	14.7
H4, H5, I1-3, J1 J2	341	18.2	24.6	6.35	8.73	15.08
J3- J5	3296 338 336	11.4	16.05	4.65	8.16	12.81
J6	416 400	8.7	12.4	3.7	6.9	10.6
K1, K2	416 2852	7.75	12.3	4.55	6.745	11.295
L1	2852	7.5	12.1	4.6	6.54	11.14
L2-4, LCN	386	7.8	14.75	6.95	6.87	13.82
L2L	3054	9.1	11.65	2.55	4.62	7.17
Barrier	5035	4	8.75	4.75	2.96	7.71

2.2 V2- Percent Submerged Aquatic Vegetation (SAV)

SAV plays a crucial role in coastal wetlands by providing foraging and nursery habitat while reducing wave action and turbidity for a variety of fish and wildlife species. This variable assigns an SI of 1.0 to SAV coverage between 56.25% to 100% and assigns an SI of 0.1 to SAV coverage of 0%.

To calculate V2, the number of samples with SAV present was divided by the total number of samples for all transects combined within the WVA area to give the percentage of SAV coverage. That number is used as the TY0 value. The FWOP TY1 value is assumed to be the same as TY0. In most FWOP scenarios much of the marsh habitat ceases to exist by TY60, therefore it is assumed that V2 will also go to 0. In cases where marsh continues to exist in intermediate TYs best professional judgment is used to estimate V2 values. The FWP value for V2 was assumed to be 0 after the beginning of construction (TY1) and would remain at zero for TY60 due to the construction of the levee.

2.3 V3- Interspersion

This variable considers 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 (see WVA model documentation) 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.

Interspersion was estimated for TY0 by visually comparing the project area marsh condition in GIS to the guidance images in the Marsh WVA for Civil Works Manual. When the project contains multiple areas with very different interspersion values, we may report multiple classes with the corresponding percentage of the project area for which they apply. For FWOP TY1 we assume that environmental conditions will not change, and the interspersion values will remain the same. Generally, for FWOP TY60, interspersion values are dropped two classes due to marsh degradation. In cases of Class 3 in TY0 shifting to Class 1 in TY60, this represents carpet marsh is becoming more interspersed.

2.4 V4- Percent Shallow Open Water

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 V4 SI graph for the saline marsh model is similar to the 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.

To calculate V4, water depths were corrected using data from the USGS gauge in Bayou Grand Caillou at Dulac (07381324) to account for variability at the time of sampling due to tides, weather, etc. This gage was selected for use for every reach in correction calculations due to its representative data and central location. To calculate a correction factor, the water level at the start and end of sampling was averaged, and this value was subtracted from the 10-year mean water level. This correction factor was subtracted from all the water depths collected in the field to get the adjusted water depth value. The number of adjusted water depth values that were equal to 1.5 feet or less were divided by the total number of water depth samples. That percentage was recorded in the WVA model as the value of

Shallow Open Water (SOW) for TY0. For subsequent TYs, the amount of RSLC calculated in the MIMs 3.11 (V1 earlier) spreadsheet was applied to the TY0 water depths and the percentage of shallow open water was recalculated. For FWP, FY1-FY60 V4 was assigned a value of 0 due to the construction of the levee.

Due to the lack of open water (except for canals) in the barrier reach, it was assumed that all water in the area would be greater than 1.5 ft.

2.5 <u>V5- Average Annual Salinity</u>

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. 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 reflects 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 dynamic salinity conditions in coastal Louisiana. 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 dynamic salinity conditions in coastal Louisiana. 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.

To calculate V5, information from the Louisiana 2023 CMP Data Access Portal (https://mpdap.coastal.la.gov/dataset/salinity#map=12.57/29.95051/-93.21243&geography=extraction_point&aggregate=mean&time=annual&year=52&scenario=A&selected=QAQC2101-QAQC2127&chart=2-52) was used to estimate the average annual salinity. ICM-Hydro salinity outputs and existing long-term measurements (i.e., nearby CRMS stations) were used to estimate salinity values for a given TY. Linear regressions of ICM-Hydro salinity outputs were created and compared to CRMS station measurements. Adjustments to the linear regressions were made when the ICM-Hydro outputs disagreed with long term measured data.

2.6 V6- Access Value

Access by aquatic organisms, particularly estuarine-dependent fishes and shellfishes, is 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 V6 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.). Optimal conditions are assumed to exist when all of the study area is accessible, and the access points are entirely open and unobstructed.

The V6 Calculator tab in the model was used to assign structure ratings to all impediments to water flow in or out of the WVA area to get a total access value from 1 (open system) to 0.0001 (solid plug; no water flow). Access values for FWP TY1 was assumed to be 0.001 due to ongoing construction. In FWP TY60 construction will be complete, and the access value will correspond to levee and associated environmental control structures.

3. WVA Variables by Feature for Marsh

3.1 Barrier

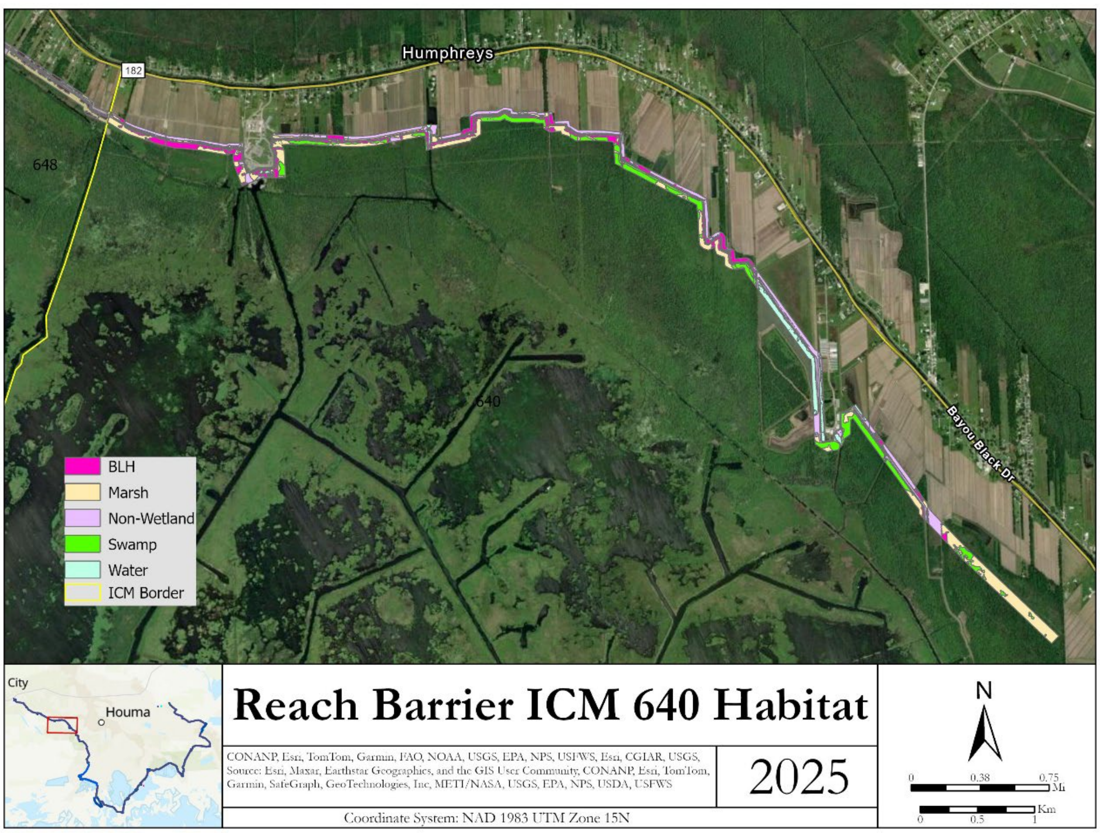

Figure 2: Map of ICM 640 in Reach Barrier

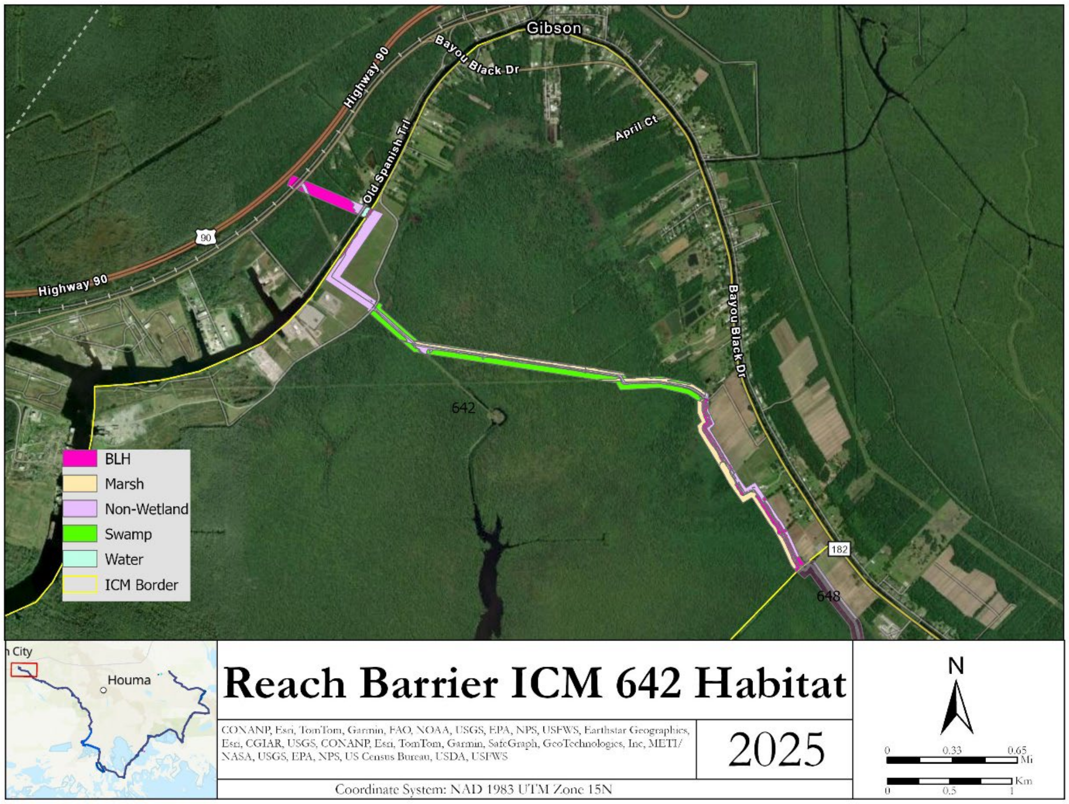

Figure 3: Map of ICM 642 in Reach Barrier

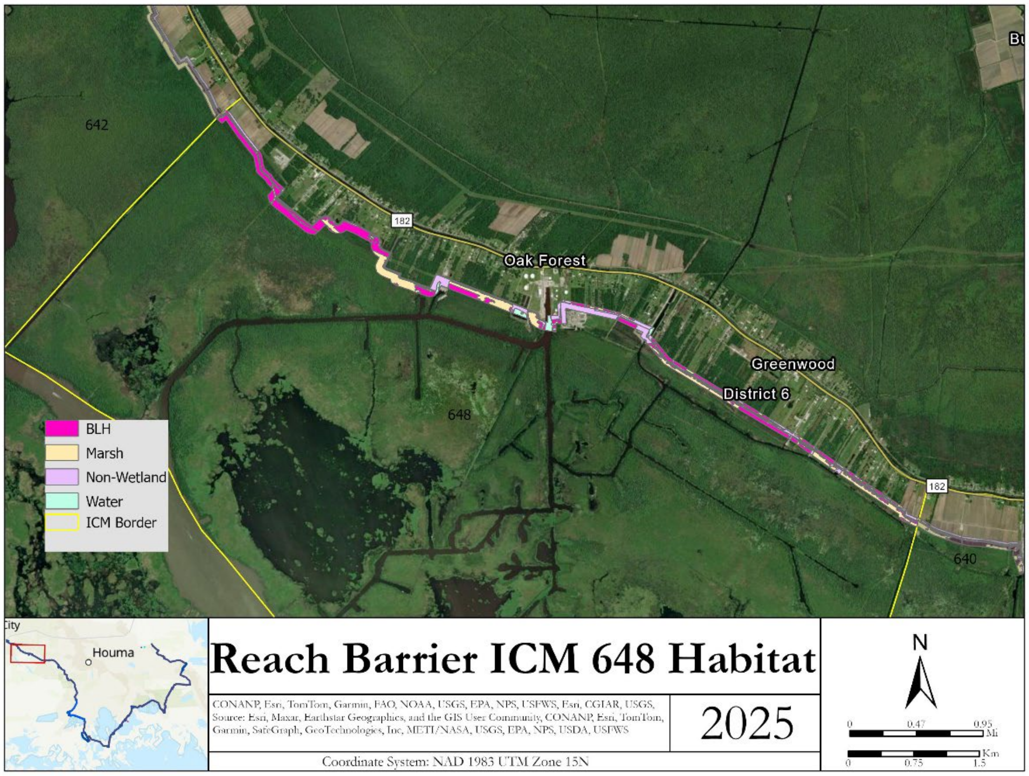

Figure 4: Map of ICM 648 in Reach Barrier

3.1.1 V1-Percent Marsh

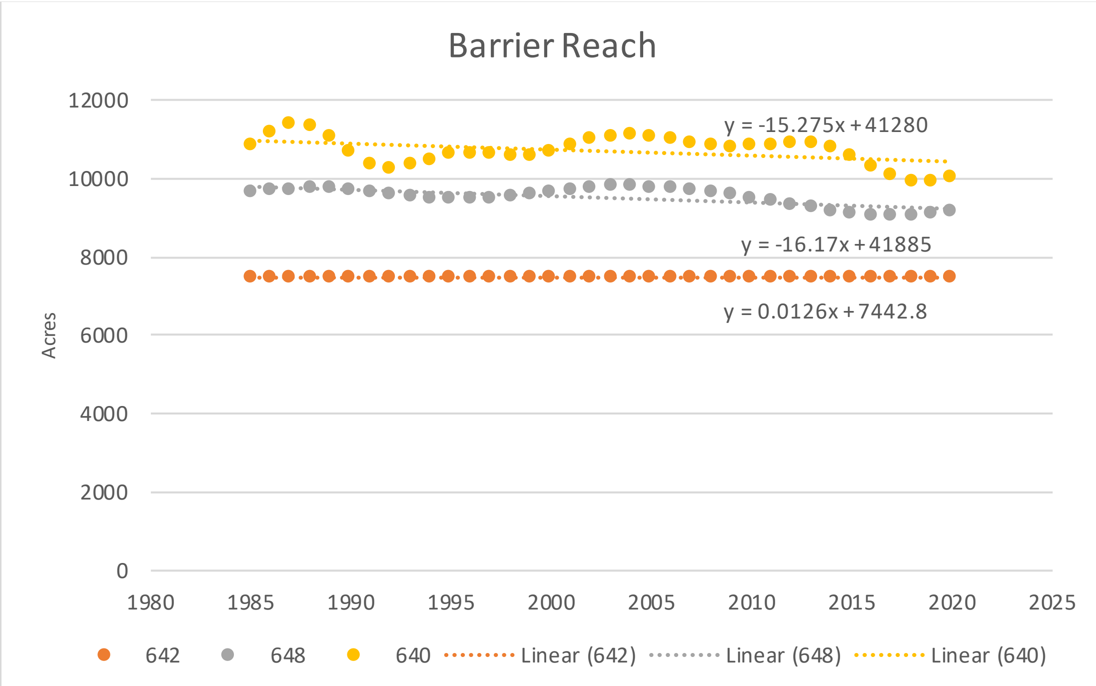

Figure 5: Acres of marsh for ICMs 640, 642, and 648 each year from 1985 to 2020 with regression lines.

Table 4: Marsh percentages under the Intermediate SLC scenario for FWOP and FWP TY 0-60

Reach	ICM		Target Year	% Marsh
Barrier1	642	FWOP	0	93.5
			1	93.5
			60	72.8
		FWP	0	93.5
			1	0
			60	0
Barrier2	648	FWOP	0	86.8
			1	86.5
			60	57.1
		FWP	0	86.8
			1	0
			60	0
Barrier3	640	FWOP	0	75.8
			1	75.5
			60	51.3
		FWP	0	75.8
			1	0
			60	0

Barrier Structures		FWOP	0	68
			1	67
			60	46
		FWP	0	68
			1	0
			60	0

3.1.2 V2- Percent Submerged Aquatic Vegetation (SAV)

For FWOP and FWP all TYs V2 is assumed to be 0 due to the lack of open water and presence of deeper canals

Reach	ICM		Target Year	% SAV
Barrier1	642	FWOP	0	0.0
			1	0.0
			60	0.0
		FWP	0	0.0
			1	0.0
			60	0.0
Barrier2	648	FWOP	0	0.0
			1	0.0
			60	0.0
		FWP	0	0.0
			1	0.0
			60	0.0
Barrier3	640	FWOP	0	0.0
			1	0.0
			60	0.0
		FWP	0	0.0
			1	0.0
			60	0.0
Barrier Structures		FWOP	0	0.0
			1	0.0
			60	0.0
		FWP	0	0.0
			1	0.0
			60	0.0

3.1.2 V3-Interspersion

Reach	ICM		Target Year	% Interspersion
Barrier1	642	FWOP	0	C3-100%
			1	C3-100%
			60	C1-100%
		FWP	0	C3-100%
			1	C5-100%
			60	C5-100%
Barrier2	648	FWOP	0	C3-100%
			1	C3-100%
			60	C1-100%
		FWP	0	C3-100%
			1	C5-100%
			60	C5-100%
Barrier3	640	FWOP	0	C3-100%
			1	C3-100%
			60	C1-100%
		FWP	0	C3-100%
			1	C5-100%
			60	C5-100%
Barrier Structures		FWOP	0	C3-100%
			1	C3-100%
			60	C1-100%
		FWP	0	C3-100%
			1	C5-100%
			60	C5-100%

3.1.3 *V4- Percent Shallow Open Water*

Reach	ICM		Target Year	% <1.5 ft
Barrier1	642	FWOP	0	0.0
			1	0.0
			60	0.0
		FWP	0	0
			1	0.0
			60	0.0
Barrier2	648	FWOP	0	0.0
			1	0.0
			60	0.0
		FWP	0	0
			1	0.0
			60	0.0
Barrier3	640	FWOP	0	0.0
			1	0.0
			60	0.0
		FWP	0	0
			1	0.0
			60	0.0
Barrier Structures		FWOP	0	0.0
			1	0.0
			60	0.0
		FWP	0	0
			1	0.0
			60	0.0

3.1.4 V5- Average Annual Salinity

Reach	ICM		Target Year	Salinity (ppt)
Barrier1	642	FWOP	0	0.0
			1	0.0
			60	0.5
		FWP	0	0
			1	0.0
			60	0.5
Barrier2	648	FWOP	0	0.0
			1	0.0
			60	0.4
		FWP	0	0
			1	0.0
			60	0.4
Barrier3	640	FWOP	0	0.0
			1	0.0
			60	0.5
		FWP	0	0
			1	0.0
			60	0.5
Barrier_3 Structures		FWOP	0	0.0
			1	0.0
			60	0.5
		FWP	0	0
			1	0.0
			60	0.5

3.1.5 V6- Access Value

Reach	ICM		Target Year	Fish Access
Barrier1	642	FWOP	0	0.880
			1	0.880
			60	0.880
		FWP	0	0.880
			1	0.0
			60	0.880
Barrier2	648	FWOP	0	0.880
			1	0.880
			60	0.880
		FWP	0	0.880
			1	0.0
			60	0.880
Barrier3	640	FWOP	0	0.880
			1	0.880
			60	0.880
		FWP	0	0.880
			1	0.0
			60	0.880
Barrier_3 Structures		FWOP	0	0.4
			1	0.4
			60	0.4
		FWP	0	0.4
			1	0.0
			60	0.4

Reach B

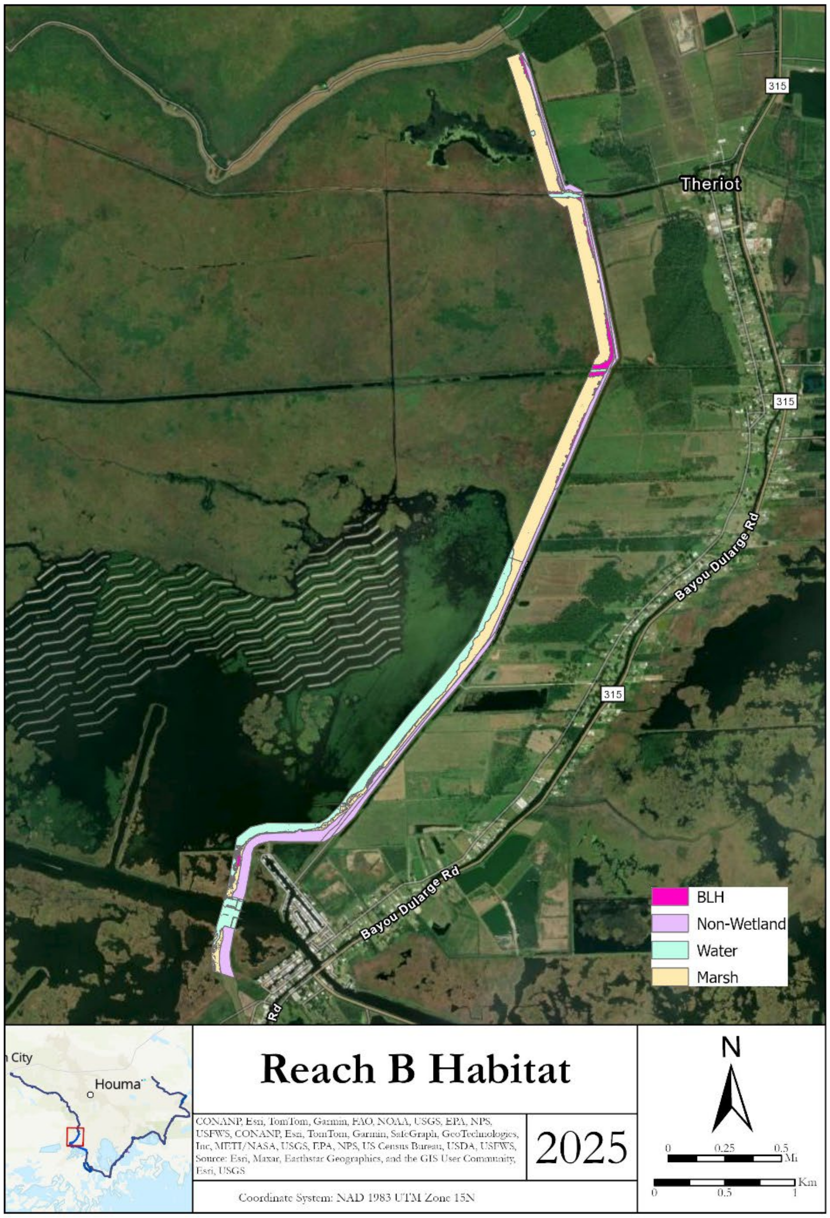

Figure 6: Map of ICM 866 and 666 in Reach B

3.1.6 V1-Percent Marsh

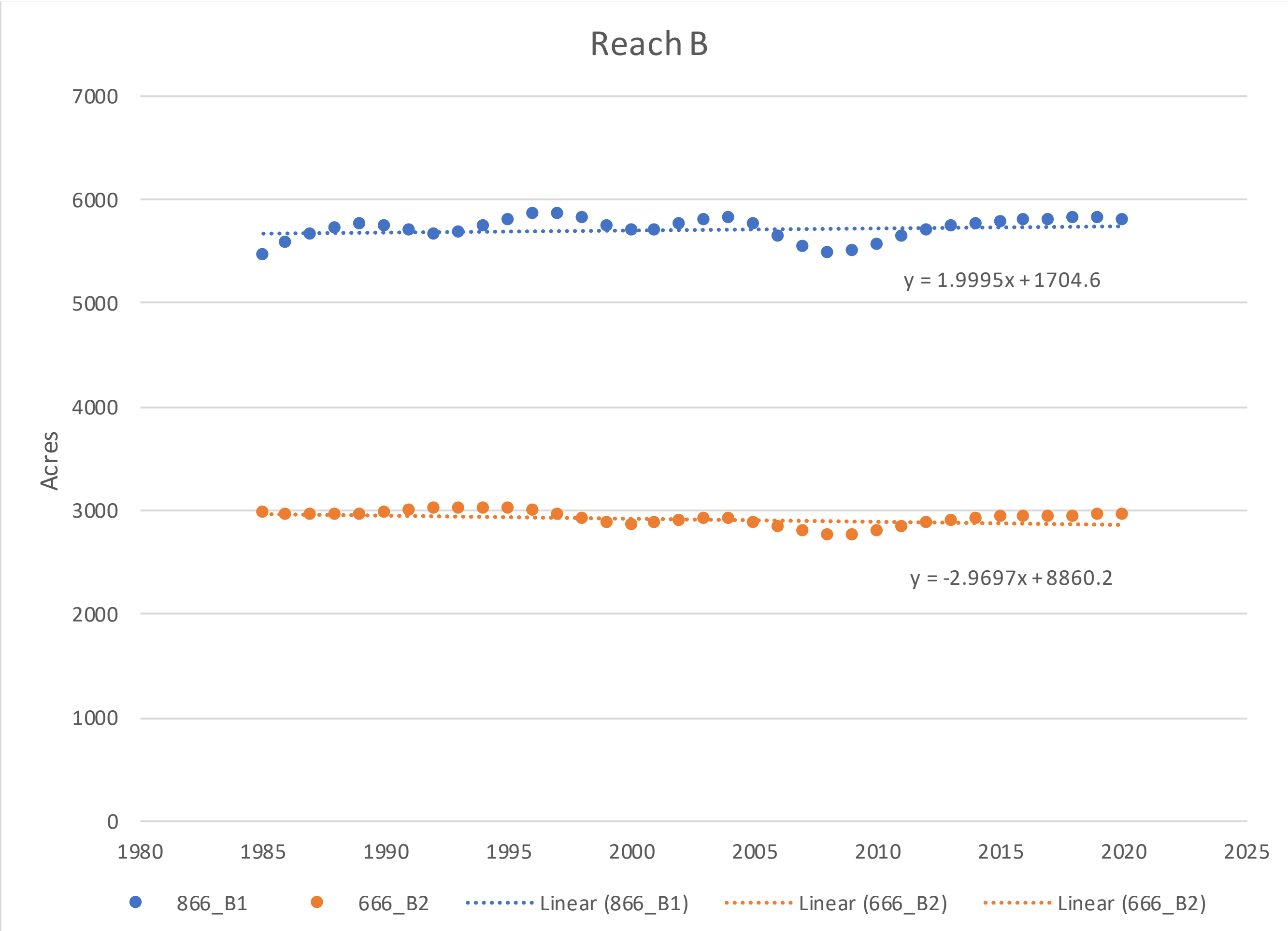

Figure 7: Acres of marsh for ICMs 866 and 666 each year from 1985 to 2020 with regression lines.

Reach	ICM		Target Year	% Marsh
B_1	866	FWOP	0	70.5
			1	70
			60	55.9
		FWP	0	70.5
			1	0
			60	0
B_2	666	FWOP	0	33.5
			1	33.4
			60	23.7
		FWP	0	33.5
			1	0
			60	0
B Structures		FWOP	0	34.0
			1	34.0

			60	24.0
		FWP	0	34.0
			1	0
			60	0

3.1.7 *V2- Percent Submerged Aquatic Vegetation (SAV)*

Reach	ICM		Target Year	% SAV
B_1	866	FWOP	0	4
			1	4
			60	0
		FWP	0	4
			1	0
			60	0
B_2	666	FWOP	0	0
			1	0
			60	0
		FWP	0	0
			1	0
			60	0
B Structures		FWOP	0	0
			1	0
			60	0
		FWP	0	0
			1	0
			60	0

3.1.8 *V3- Interspersion*

Reach	ICM		Target Year	% Interspersion
B_1	866	FWOP	0	C3 50%; C4 50%
			1	C1 50%; C4 50%
			60	C3-45%; C4-55%
		FWP	0	C3 50%; C4 50%
			1	C5-100%
			60	C5-100%
B_2	666	FWOP	0	C3-50% C5-50%
			1	C1-50% C5-50%
			60	C3-50% C5-50%
		FWP	0	C3-50% C5-50%
			1	C5-100%
			60	C5-100%
B Structures		FWOP	0	C3-50% C5-50%
			1	C1-50% C5-50%
			60	C3-50% C5-50%
		FWP	0	C3-50% C5-50%
			1	C5-100%
			60	C5-100%

3.1.9 *V4- Percent Shallow Open Water*

Reach	ICM		Target Year	% <1.5 ft
B_1	866	FWOP	0	7.0
			1	7.0
			60	0.0
		FWP	0	7.0
			1	0.0
			60	0.0
B_2	666	FWOP	0	0.0
			1	0.0
			60	0.0
		FWP	0	0
			1	0.0
			60	0.0
B Structures		FWOP	0	0.0
			1	0.0
			60	0.0
		FWP	0	0
			1	0.0
			60	0.0

3.1.10 *V5- Average Annual Salinity*

Reach	ICM		Target Year	Salinity (ppt)
B_1	866	FWOP	0	1.2
			1	1.2
			60	4.4
		FWP	0	1.2
			1	1.2
			60	4.4
B_2	666	FWOP	0	1.6
			1	1.7
			60	5.0
		FWP	0	1.6
			1	1.7
			60	5.0
		FWOP	0	1.6

B_2 Structures			1	1.7
			60	5.0
		FWP	0	1.6
			1	1.7
			60	5.0

3.1.11 V6- Access Value

Reach	ICM		Target Year	Fish Access
B_1	866	FWOP	0	0.97
			1	0.97
			60	0.97
		FWP	0	0.97
			1	0.00
			60	0.97
B_2	666	FWOP	0	1.00
			1	1.00
			60	1.00
		FWP	0	1.00
			1	0.00
			60	1.00
B_2 Structures		FWOP	0	1.00
			1	1.00
			60	1.00
		FWP	0	1.00
			1	0.00
			60	1.00

3.2 Reach E

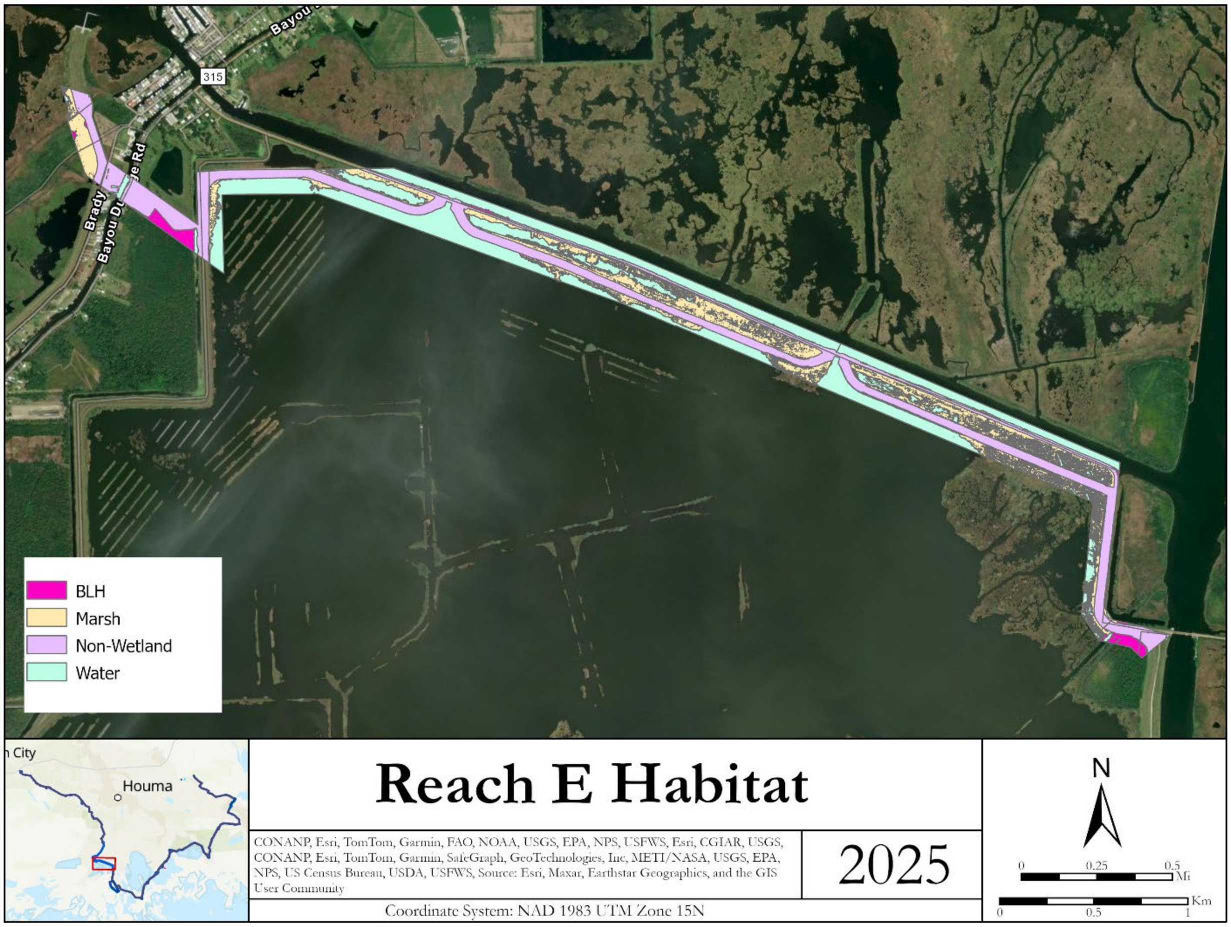

Figure 8: Reach E habitat map

3.2.1 V1-Percent Marsh

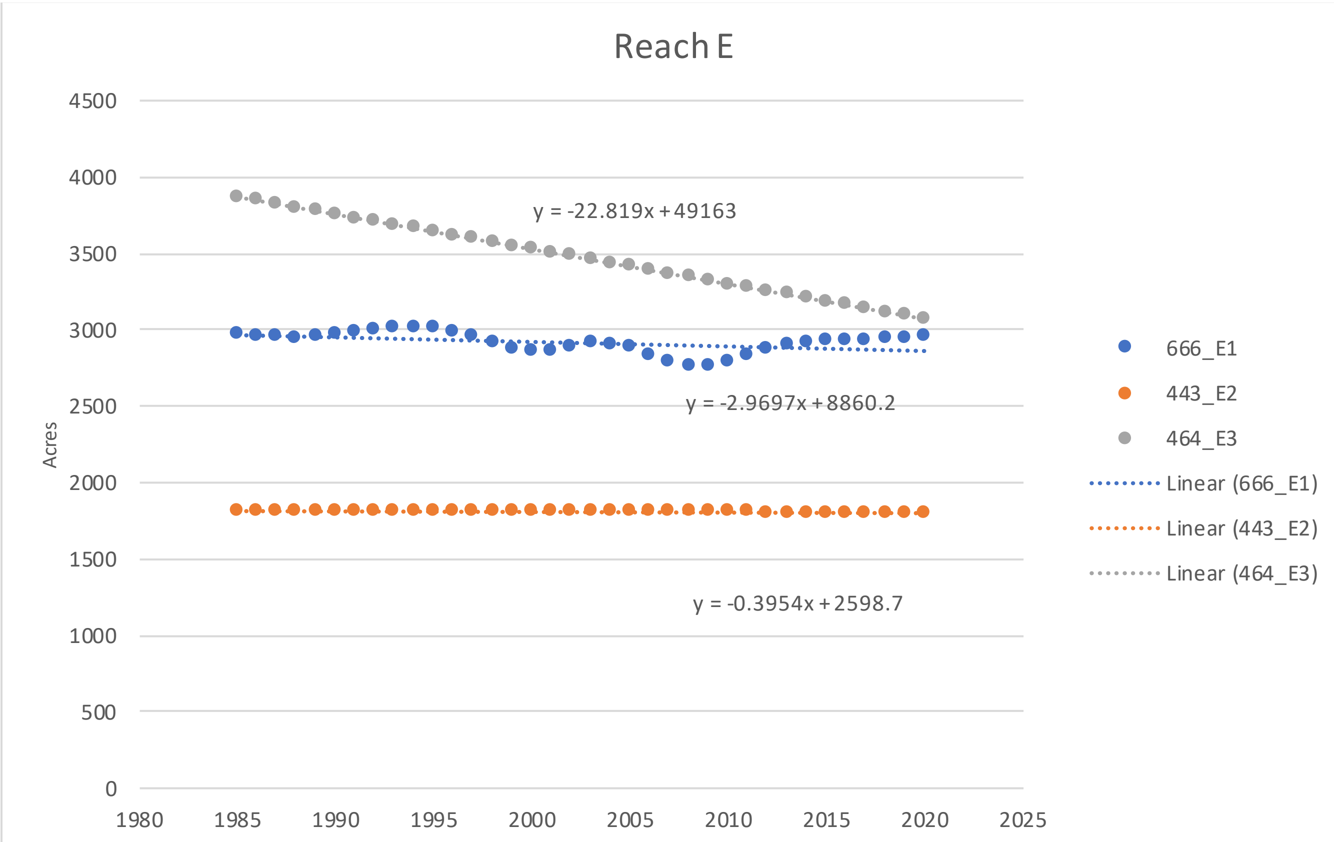

Figure 9: Acres of marsh for ICMs 666, 443, and 464 each year from 1985 to 2020 with regression lines.

Reach	ICM		Target Year	% Marsh
E_1	666	FWOP	0	97.3
			1	97
			60	68.8
		FWP	0	97.3
			1	0
			60	0
E_2	443	FWOP	0	4.6
			1	4.6
			60	3.9
		FWP	0	4.6
			1	0
			60	0
E_3	434	FWOP	0	41.6
			1	41.2
			60	10.5

		FWP	0	41.6
			1	0
			60	0

3.2.2 V2- Percent Submerged Aquatic Vegetation (SAV)

Reach	ICM		Target Year	% SAV
E_1	666	FWOP	0	4
			1	4
			60	0
		FWP	0	4
			1	0
			60	0
E_2	443	FWOP	0	0
			1	0
			60	0
		FWP	0	0
			1	0
			60	0
E_3	434	FWOP	0	3
			1	3
			60	0
		FWP	0	3
			1	0
			60	0

3.2.3 V3- Interspersion

Reach	ICM		Target Year	% Interspersion
E_1	666	FWOP	0	C3-100%
			1	C1-100%
			60	C3-100%
		FWP	0	C3-100%
			1	C5-100%

			60	C5-100%
E_2	443	FWOP	0	C3-100%
			1	C1-100%
			60	C3-100%
		FWP	0	C3-100%
			1	C5-100%
			60	C5-100%
E_3	434	FWOP	0	C3-50% C5-50%
			1	C1-50% C5-50%
			60	C3-50% C5-50%
		FWP	0	C3-50% C5-50%
			1	C5-100%
			60	C5-100%

3.2.4 V4- Percent Shallow Open Water

Reach	ICM		Target Year	% <1.5 ft
E_1	666	FWOP	0	7.0
			1	7.0
			60	0.0
		FWP	0	7
			1	0.0
			60	0.0
E_2	443	FWOP	0	0.0
			1	0.0
			60	0.0
		FWP	0	0
			1	0.0
			60	0.0
E_3	434	FWOP	0	21.0
			1	18.0
			60	0.0

		FWP	0	21
			1	0.0
			60	0.0

3.2.5 V5- Average Annual Salinity

Reach	ICM		Target Year	Salinity (ppt)
E_1	666	FWOP	0	1.7
			1	1.7
			60	5.0
		FWP	0	1.7
			1	1.7
			60	5.0
E_2	443	FWOP	0	3.4
			1	3.5
			60	6.2
		FWP	0	3.4
			1	3.5
			60	6.5
E_3	434	FWOP	0	4.2
			1	4.2
			60	5.6
		FWP	0	4.2
			1	4.2
			60	5.6

3.2.6 V6- Access Value

Reach	ICM		Target Year	Fish Access
E_1	666	FWOP	0	1.00
			1	1.00
			60	1.00
		FWP	0	1.00
			1	0.00
			60	1.00
E_2	443	FWOP	0	1.00
			1	1.00
			60	1.00

		FWP	0	1.00
			1	0.00
			60	1.00
E_3	434	FWOP	0	0.88
			1	0.88
			60	0.88
		FWP	0	0.88
			1	0.00
			60	0.88

3.3 Reach G

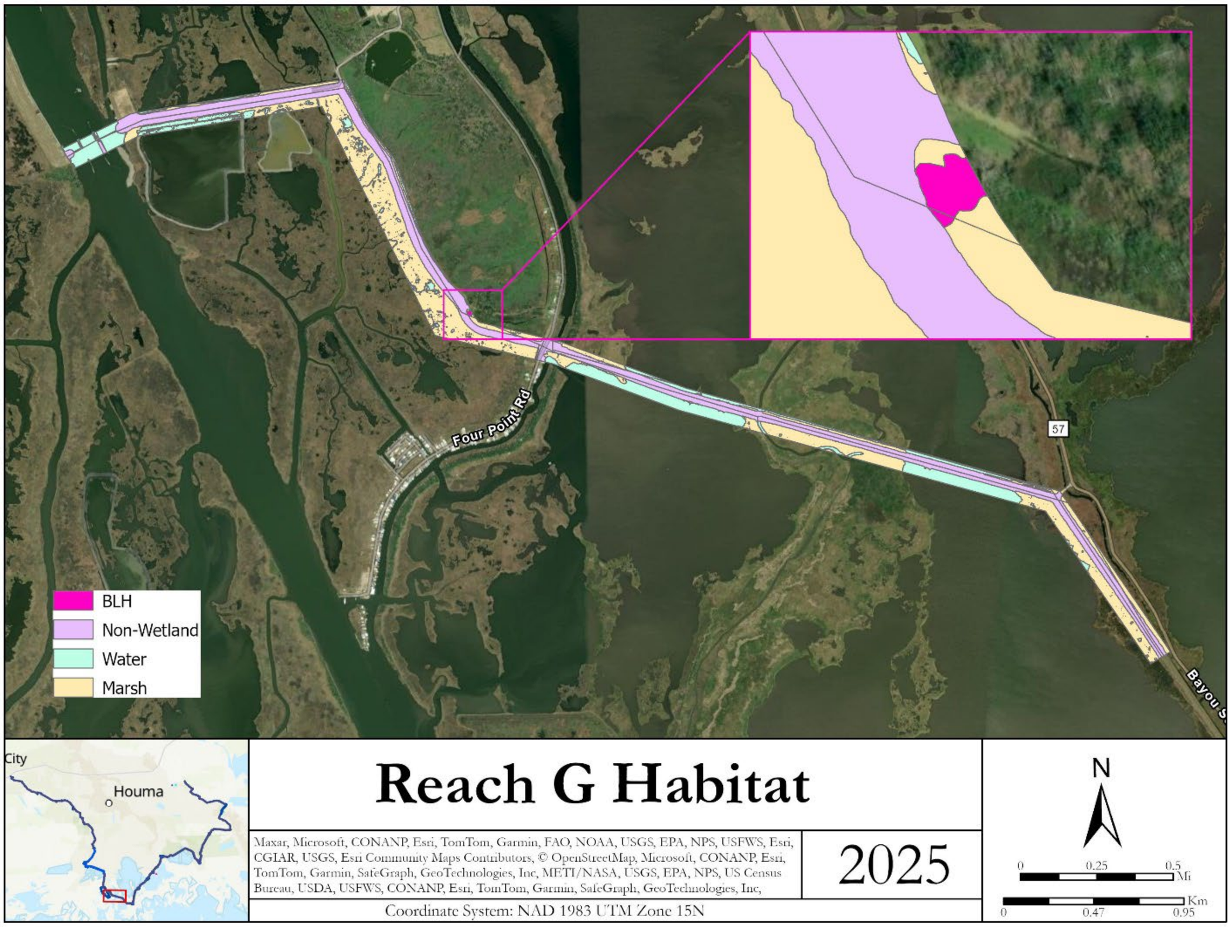

Figure 10: Map of Reach G habitat

3.3.1 V1-Percent Marsh

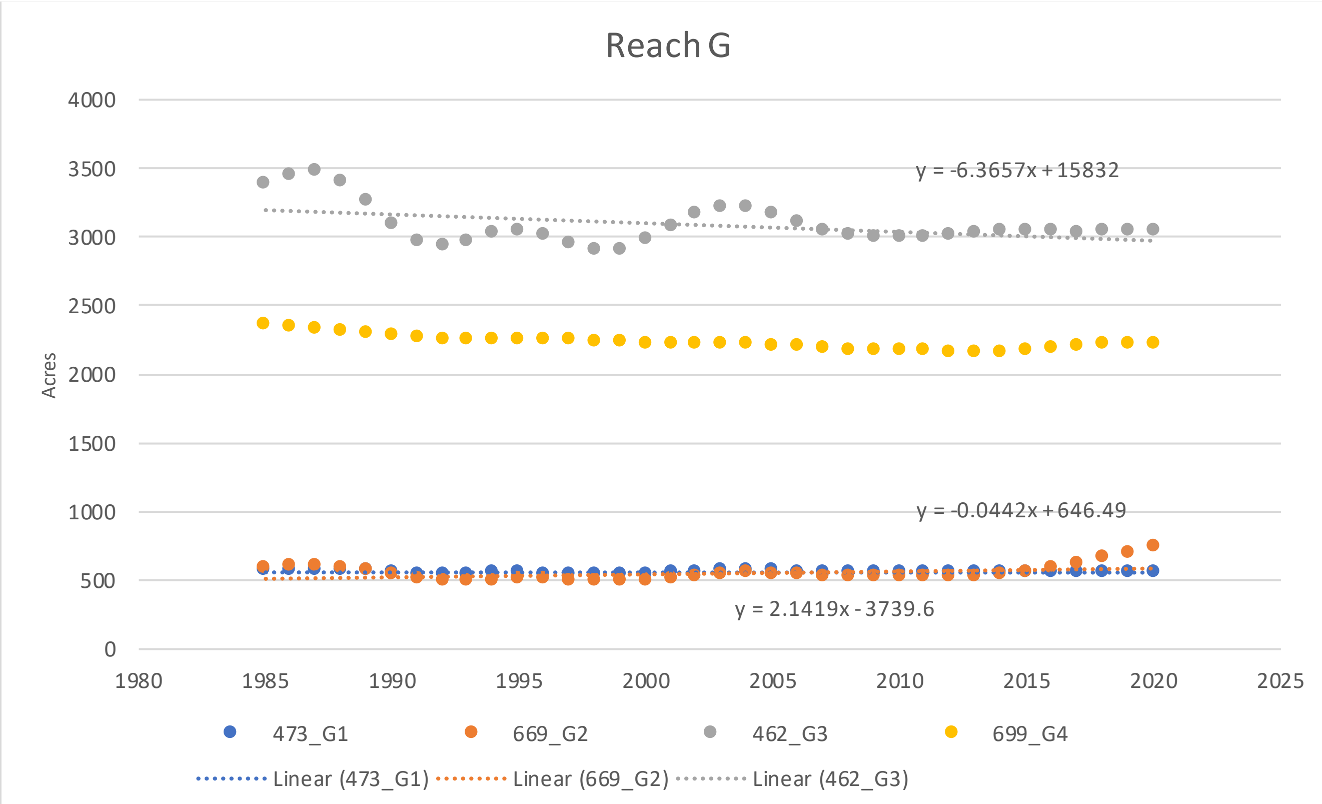

Figure 11: Acres of marsh for ICMs 473, 669, and 462 each year from 1985 to 2020 with regression lines.

Reach	ICM		Target Year	% Marsh
G_1	473	FWOP	0	70.8
			1	70.7
			60	54.8
		FWP	0	70.8
			1	0
			60	0
G Structures	473	FWOP	0	51.5
			1	51.4
			60	39.8
		FWP	0	51.5
			1	0
			60	0
G_2	669	FWOP	0	20.8
			1	20.8

			60	16.6
		FWP	0	20.8
			1	0
			60	0
G_3	462	FWOP	0	72.4
			1	72.1
			60	45.7
		FWP	0	72.4
			1	0
			60	0
G_4	699	FWOP	0	53.8
			1	53.7
			60	34.9
		FWP	0	53.8
			1	0
			60	0

3.3.2 V2- Percent Submerged Aquatic Vegetation (SAV)

Reach	ICM		Target Year	% SAV
G_1	473	FWOP	0	8
			1	8
			60	0
		FWP	0	8
			1	0
			60	0
G Structures		FWOP	0	8
			1	8
			60	0
		FWP	0	8
			1	0
			60	0
G_2	669	FWOP	0	0
			1	0
			60	0
		FWP	0	0
			1	0
			60	0

G_3	462	FWOP	0	0
			1	0
			60	0
		FWP	0	0
			1	0
			60	0
G_4	699	FWOP	0	0
			1	0
			60	0
		FWP	0	0
			1	0
			60	0

3.3.3 V3- Interspersion

Reach	ICM		Target Year	% Interspersion
G_1	473	FWOP	0	C1-80% C3-10% C5-10%
			1	C1-80% C1-10% C5-10%
			60	C3-80% C3-10% C5-10%
		FWP	0	C1-80% C3-10% C5-10%
			1	C5-100%
			60	C5-100%
G_1 Structures		FWOP	0	C1-80% C3-10% C5-10%
			1	C1-80% C1-10% C5-10%
			60	C3-80% C3-10% C5-10%
		FWP	0	C1-80% C3-10% C5-10%
			1	C5-100%
			60	C5-100%
G_2	669	FWOP	0	C1-5% C5-95%
			1	C2-5% C5-95%

			60	C3-5% C5-95%
		FWP	0	C1-5% C5-95%
			1	C5-100%
			60	C5-100%
G_3	462	FWOP	0	C1-60% C3-20% C5-20%
			1	C1-60% C1-20% C5-20%
			60	C3-60% C3-20% C5-20%
		FWP	0	C1-60% C3-20% C5-20%
			1	C5-100%
			60	C5-100%
G_4	699	FWOP	0	C3-50% C5-50%
			1	C1-50% C5-50%
			60	C3-50% C5-50%
		FWP	0	C3-50% C5-50%
			1	C5-100%
			60	C5-100%

3.3.4 V4 Percent Shallow Open Water

Reach	ICM		Target Year	% <1.5 ft
G_1	473	FWOP	0	62.0
			1	57.0
			60	0.0
		FWP	0	62
			1	0.0
			60	0.0
G_1 Structures		FWOP	0	62.0
			1	57.0
			60	0.0
		FWP	0	62
			1	0.0
			60	0.0

G_2	669	FWOP	0	6.0
			1	6.0
			60	0.0
		FWP	0	6
			1	0.0
			60	0.0
G_3	462	FWOP	0	5.0
			1	5.0
			60	0.0
		FWP	0	5
			1	0.0
			60	0.0
G_4	699	FWOP	0	18.0
			1	18.0
			60	0.0
		FWP	0	18
			1	0.0
			60	0.0

3.3.5 V5- Average Annual Salinity

Reach	ICM		Target Year	Salinity (ppt)
G_1	473	FWOP	0	15.3
			1	15.5
			60	16.7
		FWP	0	15.3
			1	15.5
			60	16.7
G_1 Structures		FWOP	0	15.3
			1	15.5
			60	16.7
		FWP	0	15.3
			1	15.5
			60	16.7
G_2	669	FWOP	0	9.9
			1	10.0
			60	11.4
		FWP	0	9.9
			1	10.0

			60	11.4
G_3	462	FWOP	0	16.5
			1	16.5
			60	19.9
		FWP	0	16.5
			1	16.5
			60	19.9
G_4	699	FWOP	0	9.7
			1	9.7
			60	12.4
		FWP	0	9.7
			1	9.7
			60	12.4

3.3.6 V6- Access Value

Reach	ICM		Target Year	Fish Access
G_1	473	FWOP	0	1.00
			1	1.00
			60	1.00
		FWP	0	1.00
			1	0.00
			60	1.00
G_1 Structures		FWOP	0	1.00
			1	1.00
			60	1.00
		FWP	0	1.00
			1	0.00
			60	1.00
G_2	669	FWOP	0	1.00
			1	1.00
			60	1.00
		FWP	0	1.00
			1	0.00
			60	1.00
G_3	462	FWOP	0	0.94
			1	0.94
			60	0.94
		FWP	0	0.94
			1	0.00

			60	0.94
G_4	699	FWOP	0	0.40
			1	0.40
			60	0.40
		FWP	0	0.40
			1	0.00
			60	0.40

3.4 Reach H

Lake Quitman
Highway 56
56
57
BLH
Non-Wetland
Water
Marsh
City
Houma
Reach H Habitat
CONANP, Esri, TomTom, Garmin, FAO, NOAA, USGS, EPA, NPS, USFWS, Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community, CONANP, Esri, TomTom, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, USDA, USFWS, Esri, USGS
Coordinate System: NAD 1983 UTM Zone 15N
N
0 0.35 0.7 Mi
0 0.5 1 Km

Figure 12: Reach H habitat map.

3.4.1 V1- Percent Marsh

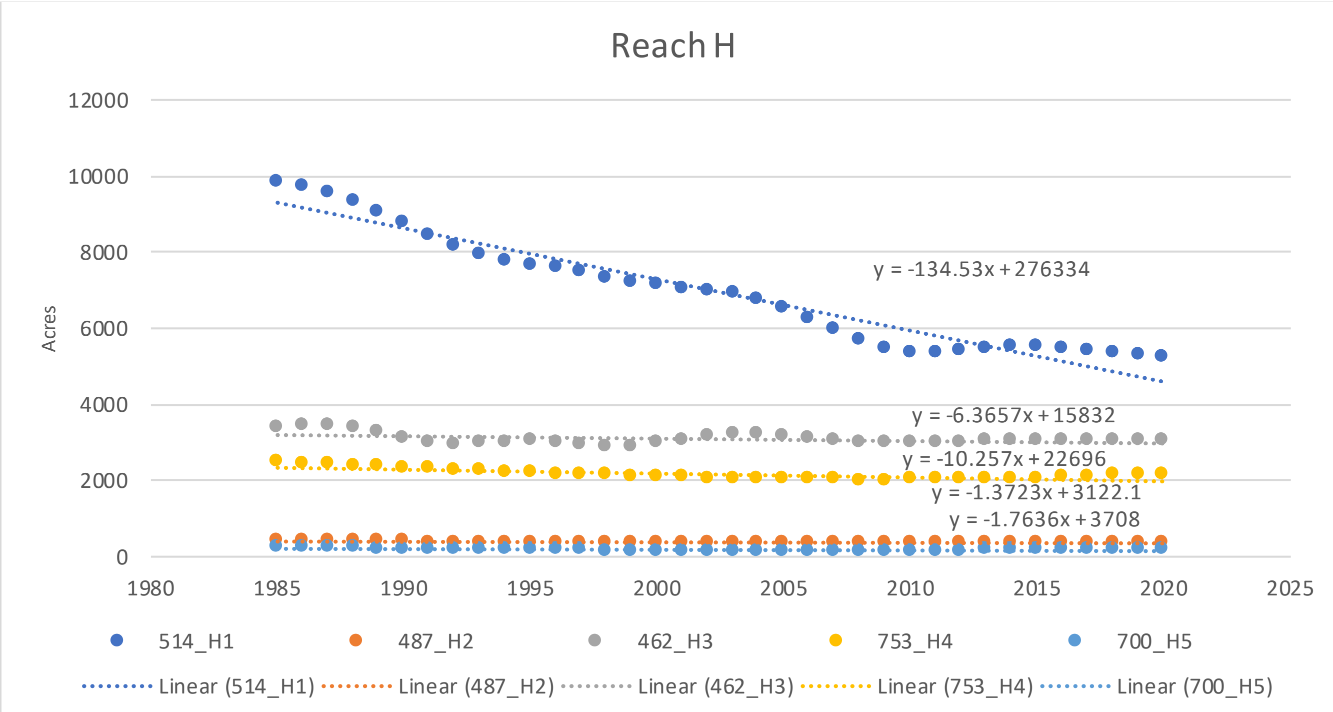

Figure 13: Acres of marsh for ICMs 514, 487, 462, 753, and 700 each year from 1985 to 2020 with regression lines.

Reach	ICM		Target Year	% Marsh
H_1	514	FWOP	0	97.2
			1	93.5
			60	0
		FWP	0	97.2
			1	0
			60	0
H_2	487	FWOP	0	84.2
			1	83.7
			60	42.5
		FWP	0	84.2
			1	0
			60	0
H_3	462	FWOP	0	78.6
			1	78.3
			60	49.6

		FWP	0	78.6
			1	0
			60	0
H_4	753	FWOP	0	59.1
			1	58.6
			60	24.5
		FWP	0	59.1
			1	0
			60	0
H Structures		FWOP	0	46
			1	45.6
			60	19.1
		FWP	0	46
			1	0
			60	0
H_5	700	FWOP	0	57.4
			1	56.5
			60	0
		FWP	0	57.4
			1	0
			60	0

3.4.2 V2- Percent Submerged Aquatic Vegetation (SAV)

Reach	ICM		Target Year	% SAV
H_1	514	FWOP	0	0
			1	0
			60	0
		FWP	0	0
			1	0
			60	0
H_2	487	FWOP	0	0
			1	0
			60	0
		FWP	0	0
			1	0
			60	0
H_3	462	FWOP	0	0
			1	0
			60	0

		FWP	0	0
			1	0
			60	0
H_4	753	FWOP	0	0
			1	0
			60	0
		FWP	0	0
			1	0
			60	0
H_4 Structures		FWOP	0	0
			1	0
			60	0
		FWP	0	0
			1	0
			60	0
H_5	700	FWOP	0	2
			1	2
			60	0
		FWP	0	2
			1	0
			60	0

3.4.3 V3- Interspersion

Reach	ICM		Target Year	% Interspersion
H_1	514	FWOP	0	C3-90% C5-10%
			1	C1-90% C5-10%
			60	C5-100%
		FWP	0	C3-90% C5-10%
			1	C5-100%
			60	C5-100%
H_2	487	FWOP	0	C3-90% C5-10%
			1	C1-90% C5-10%
			60	C3-90% C5-10%

		FWP	0	C3-90% C5-10%
			1	C5-100%
			60	C5-100%
H_3	462	FWOP	0	C1-45% C3-45% C5-10%
			1	C2-45% C1-45% C5-10%
			60	C3-90% C5-10%
		FWP	0	C1-45% C3-45% C5-10%
			1	C5-100%
			60	C5-100%
H_4	753	FWOP	0	C3-50% C5-50%
			1	C1-50% C5-50%
			60	C3-50% C5-50%
		FWP	0	C3-50% C5-50%
			1	C5-100%
			60	C5-100%
H_4 Structures		FWOP	0	C3-50% C5-50%
			1	C1-50% C5-50%
			60	C3-50% C5-50%
		FWP	0	C3-50% C5-50%
			1	C5-100%
			60	C5-100%
H_5	700	FWOP	0	C3-100%
			1	C1-20% C3-80%
			60	C3-20% C4-80%
		FWP	0	C3-100%
			1	C5-100%
			60	C5-100%

3.4.4 V4- Percent Shallow Open Water

Reach	ICM		Target Year	% <1.5 ft
H_1	514	FWOP	0	3.0
			1	3.0
			60	0.0
		FWP	0	3
			1	0.0
			60	0.0
H_2	487	FWOP	0	28.0
			1	23.0
			60	0.0
		FWP	0	28.0
			1	0.0
			60	0.0
H_3	462	FWOP	0	3.0
			1	3.0
			60	0.0
		FWP	0	3
			1	0.0
			60	0.0
H_4	753	FWOP	0	17.0
			1	16.0
			60	0.0
		FWP	0	17.0
			1	0.0
			60	0.0
H_4 Structures		FWOP	0	17.0
			1	16.0
			60	0.0
		FWP	0	17
			1	0.0
			60	0.0
H_5	700	FWOP	0	40.0
			1	40.0
			60	0.0
		FWP	0	40
			1	0.0
			60	0.0

3.4.5 V5- Average Annual Salinity

Reach	ICM		Target Year	Salinity (ppt)
H_1	514	FWOP	0	1.2
			1	1.2
			60	4.4
		FWP	0	1.2
			1	1.2
			60	4.4
H_2	487	FWOP	0	1.2
			1	1.2
			60	4.4
		FWP	0	1.2
			1	1.2
			60	4.4
H_3	462	FWOP	0	16.5
			1	16.5
			60	19.9
		FWP	0	16.5
			1	16.5
			60	19.9
H_4	753	FWOP	0	13.8
			1	13.8
			60	17.1
		FWP	0	13.8
			1	13.8
			60	17.1
H_4 Structures		FWOP	0	13.8
			1	13.8
			60	17.1
		FWP	0	13.8
			1	13.8
			60	17.1
H_5	700	FWOP	0	7.7
			1	7.8
			60	9.6
		FWP	0	7.7
			1	7.8
			60	9.6

3.4.6 V6- Access Value

Reach	ICM		Target Year	Fish Access
H_1	514	FWOP	0	0.400
			1	0.400
			60	0.400
		FWP	0	0.400
			1	0.00
			60	0.40
H_2	487	FWOP	0	0.40
			1	0.40
			60	0.44
		FWP	0	0.40
			1	0.00
			60	0.40
H_3	462	FWOP	0	0.94
			1	0.94
			60	0.94
		FWP	0	0.94
			1	0.00
			60	0.94
H_4	753	FWOP	0	0.98
			1	0.98
			60	0.98
		FWP	0	0.98
			1	0.00
			60	0.98
H_4 Structures		FWOP	0	0.98
			1	0.98
			60	0.98
		FWP	0	0.98
			1	0.00
			60	0.98
H_5	700	FWOP	0	0.70
			1	0.70
			60	0.70
		FWP	0	0.70
			1	0.00
			60	0.70

3.5 Reach I


Chauvin
55
S Madison Rd
Highway 55
55
Lapeyrouse
Lake Terrebonne
BLH
Non-Wetland
Water
Marsh
City
Houma
Reach I Habitat
CONANP, Esri, TomTom, Garmin, FAO, NOAA, USGS, EPA, NPS, USFWS, Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community, Esri Community Maps Contributors, CONANP, Esri, TomTom, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, US Census Bureau, USDA, USFWS, CONANP, Esri,
2025
Coordinate System: NAD 1983 UTM Zone 15N
N
0 0.3 0.6 Mi
0 0.5 1 Km

Figure 14: Reach I habitat map.

3.5.1 V1- Percent Marsh

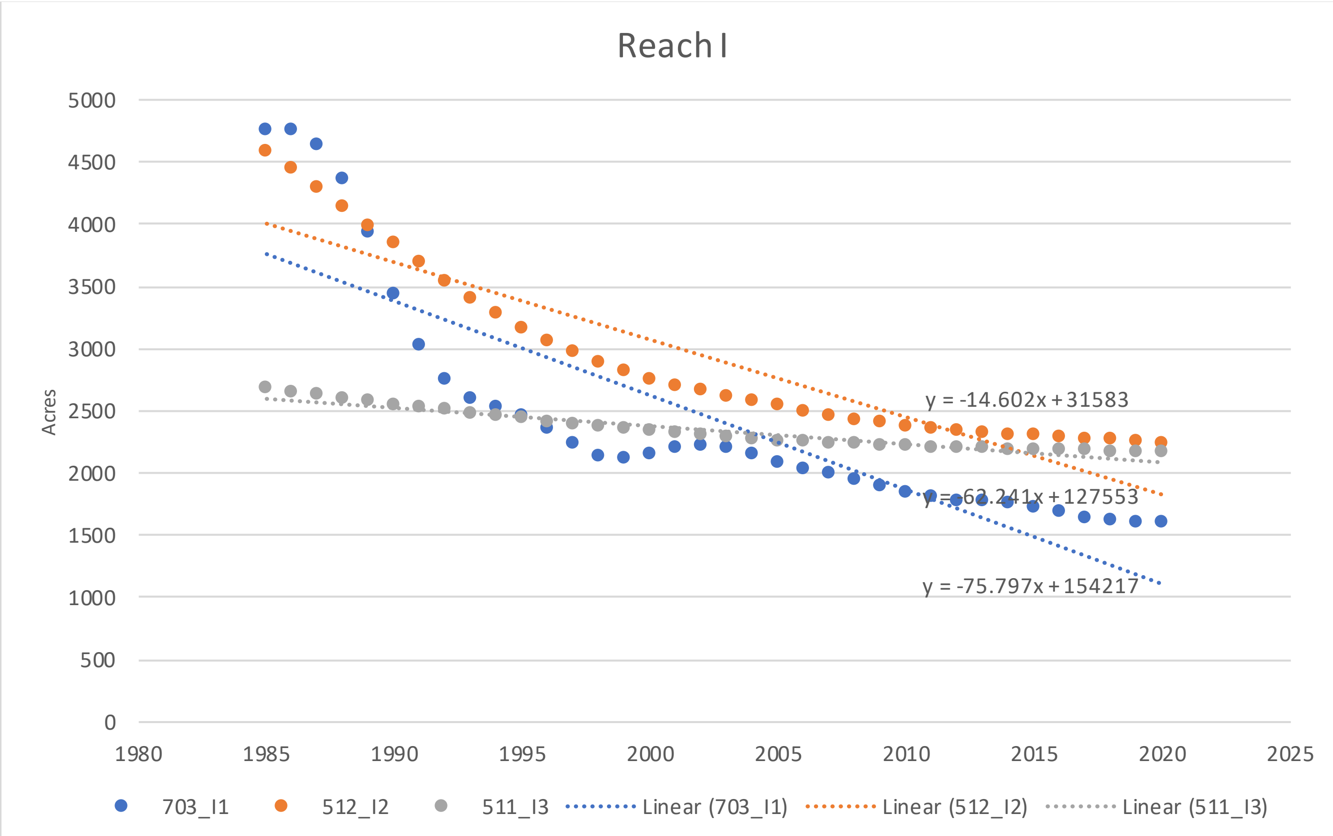

Figure 15: Acres of marsh for ICMs 703, 512, and 511 each year from 1985 to 2020 with regression lines.

Reach	ICM		Target Year	% Marsh
I_1	703	FWOP	0	70.3
			1	63
			60	0
		FWP	0	70.3
			1	0
			60	0
I_1 Structures		FWOP	0	1.7
			1	1.5
			60	0
		FWP	0	1.7
			1	0
			60	0

I_2	512	FWOP	0	81.8
			1	78.2
			60	0
		FWP	0	81.8
			1	0
			60	0
I_2 Structures		FWOP	0	56.3
			1	53.8
			60	0
		FWP	0	56.3
			1	0
			60	0
I_3	511	FWOP	0	53
			1	52.5
			60	15.1
		FWP	0	53
			1	0
			60	0
I_3 Structures		FWOP	0	29.4
			1	29.1
			60	8.4
		FWP	0	29.4
			1	0
			60	0

3.5.2 V2- Percent Submerged Aquatic Vegetation (SAV)

Reach	ICM		Target Year	% SAV
I_1	703	FWOP	0	0
			1	0
			60	0
		FWP	0	0
			1	0
			60	0
I_1 Structures		FWOP	0	0
			1	0
			60	0
		FWP	0	0
			1	0
			60	0

I_2	512	FWOP	0	1
			1	1
			60	0
		FWP	0	1
			1	0
			60	0
I_2 Structures		FWOP	0	1
			1	1
			60	0
		FWP	0	1
			1	0
			60	0
I_3	511	FWOP	0	25
			1	25
			60	0
		FWP	0	25
			1	0
			60	0
I_3 Structures		FWOP	0	25
			1	25
			60	0
		FWP	0	25
			1	0
			60	0

3.5.3 V3- Interspersion

Reach	ICM		Target Year	% Interspersion
I_1	703	FWOP	0	C2-100%
			1	C2-100%
			60	C3-100%
		FWP	0	C2-100%
			1	C5-100%
			60	C5-100%
I_1 Structures		FWOP	0	C2-100%
			1	C2-100%

			60	C3-100%
		FWP	0	C2-100%
			1	C5-100%
			60	C5-100%
I_2	512	FWOP	0	C1-50% C3-50%
			1	C1-50% C2-50%
			60	C3-100%
		FWP	0	C1-50% C3-50%
			1	C5-100%
			60	C5-100%
I_2 Structures		FWOP	0	C1-50% C3-50%
			1	C1-50% C2-50%
			60	C3-100%
		FWP	0	C1-50% C3-50%
			1	C5-100%
			60	C5-100%
I_3	511	FWOP	0	C3-70% C5-30%
			1	C1-70% C5-30%
			60	C3-70% C5-30%
		FWP	0	C3-70% C5-30%
			1	C5-100%
			60	C5-100%
I_3 Structures		FWOP	0	C3-70% C5-30%
			1	C1-70% C5-30%
			60	C3-70% C5-30%
		FWP	0	C3-70% C5-30%
			1	C5-100%
			60	C5-100%

3.5.4 V4- Percent Shallow Open Water

Reach	ICM		Target Year	% <1.5 ft
I_1	703	FWOP	0	65.0
			1	63.0
			60	0.0
		FWP	0	65.0
			1	0.0
			60	0.0
I_1 Structures		FWOP	0	65.0
			1	63.0
			60	0.0
		FWP	0	65.0
			1	0.0
			60	0.0
I_2	512	FWOP	0	23.0
			1	20.0
			60	0.0
		FWP	0	23
			1	0.0
			60	0.0
I_2 Structures		FWOP	0	23.0
			1	20.0
			60	0.0
		FWP	0	23.0
			1	0.0
			60	0.0
I_3	511	FWOP	0	44.0
			1	41.0
			60	0.0
		FWP	0	44
			1	0.0
			60	0.0
I_3 Structures		FWOP	0	44.0
			1	41.0
			60	0.0
		FWP	0	44
			1	0.0
			60	0.0

3.5.5 V5- Average Annual Salinity

Reach	ICM		Target Year	Salinity (ppt)
I_1	703	FWOP	0	9.8
			1	10.1
			60	23.2
		FWP	0	9.8
			1	10.1
			60	23.2
I_1 Structures		FWOP	0	9.8
			1	10.1
			60	23.2
		FWP	0	9.8
			1	10.1
			60	23.2
I_2	512	FWOP	0	15.2
			1	15.4
			60	22.6
		FWP	0	15.2
			1	15.4
			60	22.6
I_2 Structures		FWOP	0	15.2
			1	15.4
			60	22.6
		FWP	0	15.2
			1	15.4
			60	22.6
I_3	511	FWOP	0	9.1
			1	9.1
			60	9.8
		FWP	0	9.1
			1	9.1
			60	9.8
I_3 Structures		FWOP	0	9.1
			1	9.1
			60	9.8
		FWP	0	9.1
			1	9.1
			60	9.8

3.5.6 V6- Access Value

Reach	ICM		Target Year	Fish Access
I_1	703	FWOP	0	1.00
			1	1.00
			60	1.00
		FWP	0	1.00
			1	0.00
			60	1.00
I_1 Structures		FWOP	0	1.00
			1	1.00
			60	1.00
		FWP	0	1.00
			1	0.00
			60	1.00
I_2	512	FWOP	0	0.520
			1	0.520
			60	0.520
		FWP	0	0.520
			1	0.00
			60	0.520
I_2 Structures		FWOP	0	0.520
			1	0.520
			60	0.520
		FWP	0	0.520
			1	0.00
			60	0.520
I_3	511	FWOP	0	0.40
			1	0.40
			60	0.40
		FWP	0	0.40
			1	0.00
			60	0.40
I_3 Structures		FWOP	0	0.40
			1	0.40
			60	0.40
		FWP	0	0.40
			1	0.00
			60	0.40

3.6 Reach J

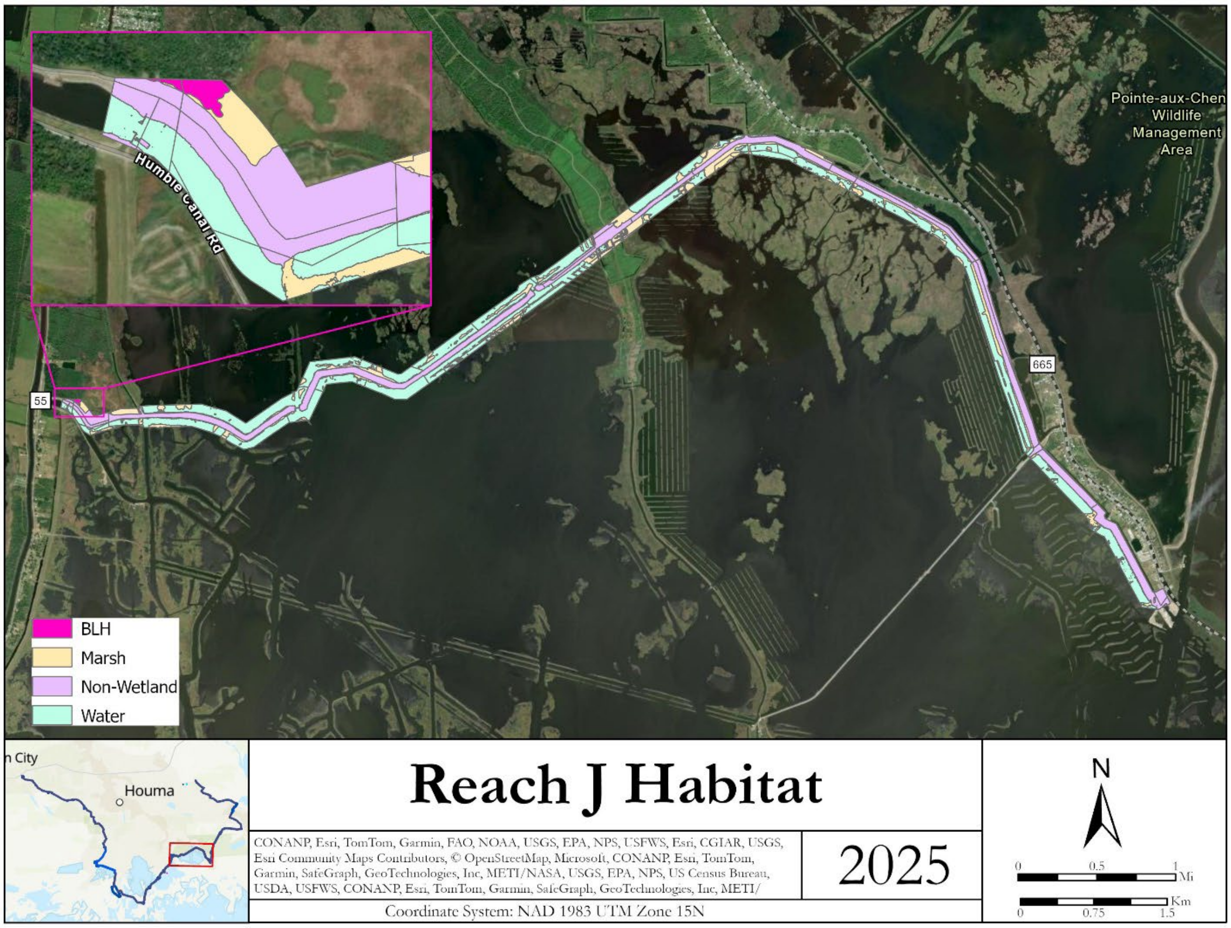

Figure 16: Reach J habitat map

3.6.1 V1-Percent Marsh

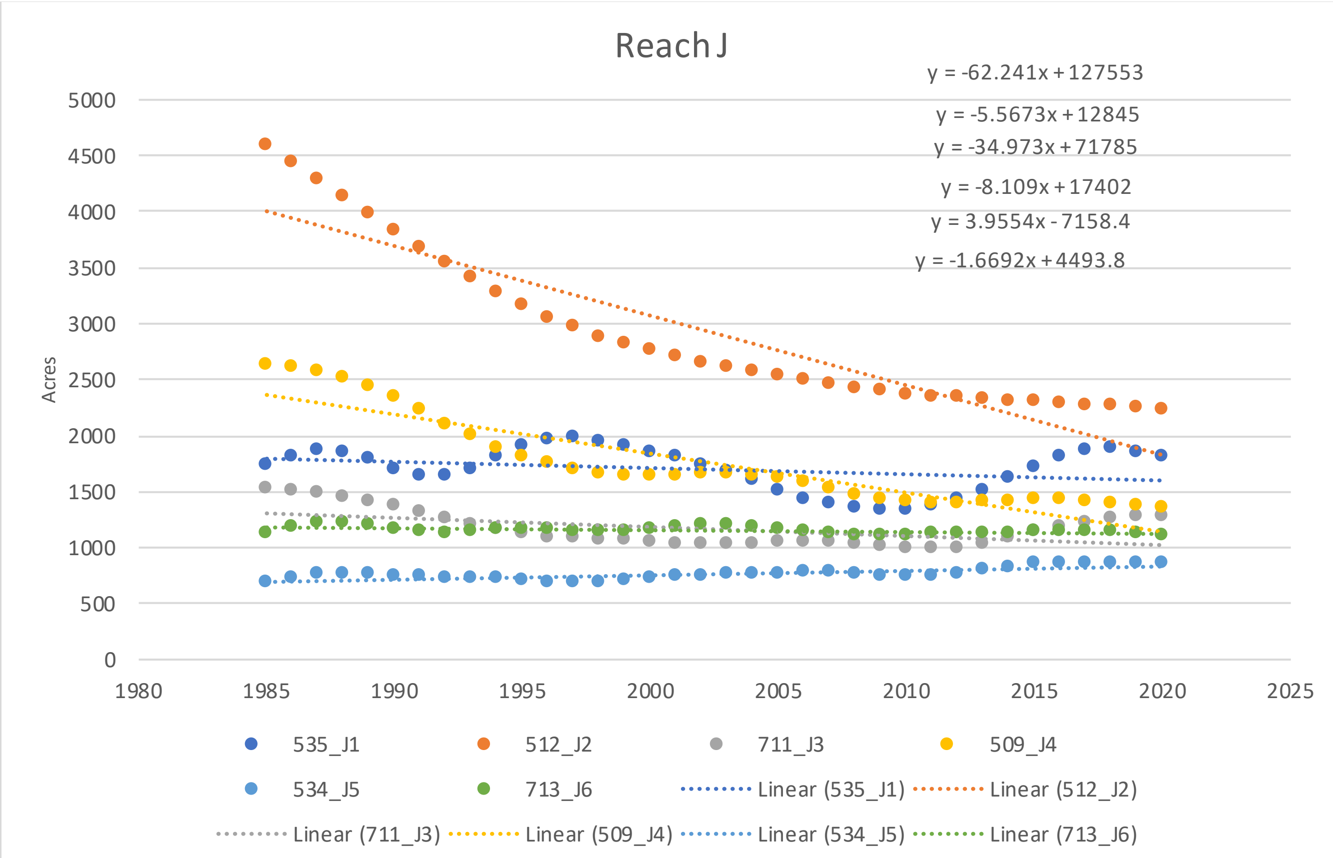

Figure 17: Acres of marsh for ICMs 535, 512, 711, 509, 534, and 713 each year from 1985 to 2020 with regression lines.

Reach	ICM		Target Year	% Marsh
J_1	535	FWOP	0	23.2
			1	23.1
			60	12.4
		FWP	0	23.2
			1	0
			60	0
J_2	512	FWOP	0	18.7
			1	17.9
			60	0
		FWP	0	18.7
			1	0
			60	0

J_3	711	FWOP	0	34.4
			1	34.0
			60	7.4
		FWP	0	34.4
			1	0
			60	0
J_4	509	FWOP	0	14.7
			1	14.1
			60	0
		FWP	0	14.7
			1	0
			60	0
J_4 Structures		FWOP	0	13
			1	12.5
			60	0
		FWP	0	13
			1	0
			60	0
J_5	534	FWOP	0	41.9
			1	42.0
			60	46.0
		FWP	0	41.9
			1	0
			60	0
J_6	713	FWOP	0	0
			1	0
			60	0
		FWP	0	0
			1	0
			60	0

3.6.2 V2- Percent Submerged Aquatic Vegetation (SAV)

Reach	ICM		Target Year	% SAV
J_1	535	FWOP	0	15
			1	15
			60	0
		FWP	0	15
			1	0
			60	0

J_2	512	FWOP	0	13
			1	13
			60	0
		FWP	0	13
			1	0
			60	0
J_3	711	FWOP	0	8
			1	8
			60	0
		FWP	0	8
			1	0
			60	0
J_4	509	FWOP	0	0
			1	0
			60	0
		FWP	0	0
			1	0
			60	0
J_4 Structures		FWOP	0	0
			1	0
			60	0
		FWP	0	0
			1	0
			60	0
J_5	534	FWOP	0	0
			1	0
			60	0
		FWP	0	0
			1	0
			60	0
J_6	713	FWOP	0	64
			1	64
			60	0
		FWP	0	64
			1	0
			60	0

3.6.3 V3- Interspersion

Reach	ICM	Target Year	% Interspersion

J_1	535	FWOP	0	C3-20% C5-80%
			1	C3-20% C5-80%
			60	C4-20% C5-80%
		FWP	0	C3-20% C5-80%
			1	C5-100%
			60	C5-100%
J_2	512	FWOP	0	C5 100%
			1	C5 100%
			60	C5 100%
		FWP	0	C5 100%
			1	C5-100%
			60	C5-100%
J_3	711	FWOP	0	C3-15% C5-85%
			1	C3-15% C5-85%
			60	C4-15% C5-85%
		FWP	0	C3-15% C5-85%
			1	C5-100%
			60	C5-100%
J_4	509	FWOP	0	C3-10% C5-90%
			1	C3-10% C5-90%
			60	C4-10% C5-90%
		FWP	0	C3-10% C5-90%
			1	C5-100%
			60	C5-100%
J_4 Structures		FWOP	0	C3-10% C5-90%
			1	C3-10% C5-90%
			60	C4-10% C5-90%

		FWP	0	C3-10% C5-90%
			1	C5-100%
			60	C5-100%
J_5	534	FWOP	0	C1-50% C5-50%
			1	C1-20% C5-80%
			60	C2-20% C5-80%
		FWP	0	C1-50% C5-50%
			1	C5-100%
			60	C5-100%
J_6	713	FWOP	0	C5 100%
			1	C5 100%
			60	C5 100%
		FWP	0	C5 100%
			1	C5-100%
			60	C5-100%

3.6.4 V4- Percent Shallow Open Water

Reach	ICM		Target Year	% <1.5 ft
J_1	535	FWOP	0	28.0
			1	27.0
			60	0.0
		FWP	0	28
			1	0.0
			60	0.0
J_2	512	FWOP	0	38.0
			1	36.0
			60	0.0
		FWP	0	38.0
			1	0.0
			60	0.0
J_3	711	FWOP	0	50.0
			1	49.0
			60	0.0
		FWP	0	50
			1	0.0
			60	0.0
J_4	509	FWOP	0	39.0

			1	36.0
			60	0.0
		FWP	0	39.0
			1	0.0
			60	0.0
J_4 Structures		FWOP	0	39.0
			1	36.0
			60	0.0
		FWP	0	39.0
			1	0.0
			60	0.0
J_5	534	FWOP	0	62.0
			1	62.0
			60	0.0
		FWP	0	62
			1	0.0
			60	0.0
J_6	713	FWOP	0	17.0
			1	14.0
			60	0.0
		FWP	0	17
			1	0.0
			60	0.0

3.6.5 V5- Average Annual Salinity

Reach	ICM		Target Year	Salinity (ppt)
J_1	535	FWOP	0	2.7
			1	2.8
			60	7.5
		FWP	0	2.7
			1	2.8
			60	7.5
J_2	512	FWOP	0	15.2
			1	15.4
			60	22.6
		FWP	0	15.2
			1	15.4
			60	22.6
J_3	711	FWOP	0	15.3

			1	15.4
			60	22.8
		FWP	0	15.3
			1	15.4
			60	22.8
J_4	509	FWOP	0	16.1
			1	16.2
			60	23.4
		FWP	0	16.1
			1	16.2
			60	23.4
J_4 Structures		FWOP	0	16.1
			1	16.2
			60	23.4
		FWP	0	16.1
			1	16.2
			60	23.4
J_5	534	FWOP	0	5.8
			1	5.9
			60	12.5
		FWP	0	5.8
			1	5.9
			60	12.5
J_6	713	FWOP	0	5.8
			1	5.9
			60	12.5
		FWP	0	5.8
			1	5.9
			60	12.5

3.6.6 V6- Access Value

Reach	ICM		Target Year	Fish Access
J_1	535	FWOP	0	0.40
			1	0.40
			60	0.40
		FWP	0	0.40
			1	0.00
			60	0.40
J_2	512	FWOP	0	0.94

			1	0.94
			60	0.94
		FWP	0	0.94
			1	0.00
			60	0.94
J_3	711	FWOP	0	0.30
			1	0.30
			60	0.30
		FWP	0	0.30
			1	0.00
			60	0.30
J_4	509	FWOP	0	1.00
			1	1.00
			60	1.00
		FWP	0	1.00
			1	0.00
			60	1.00
J_4 Structures		FWOP	0	1.00
			1	1.00
			60	1.00
		FWP	0	1.00
			1	0.00
			60	1.00
J_5	534	FWOP	0	0.40
			1	0.40
			60	0.40
		FWP	0	0.40
			1	0.00
			60	0.40
J_6	713	FWOP	0	0.40
			1	0.40
			60	0.40
		FWP	0	0.40
			1	0.00
			60	0.40

3.7 Reach K

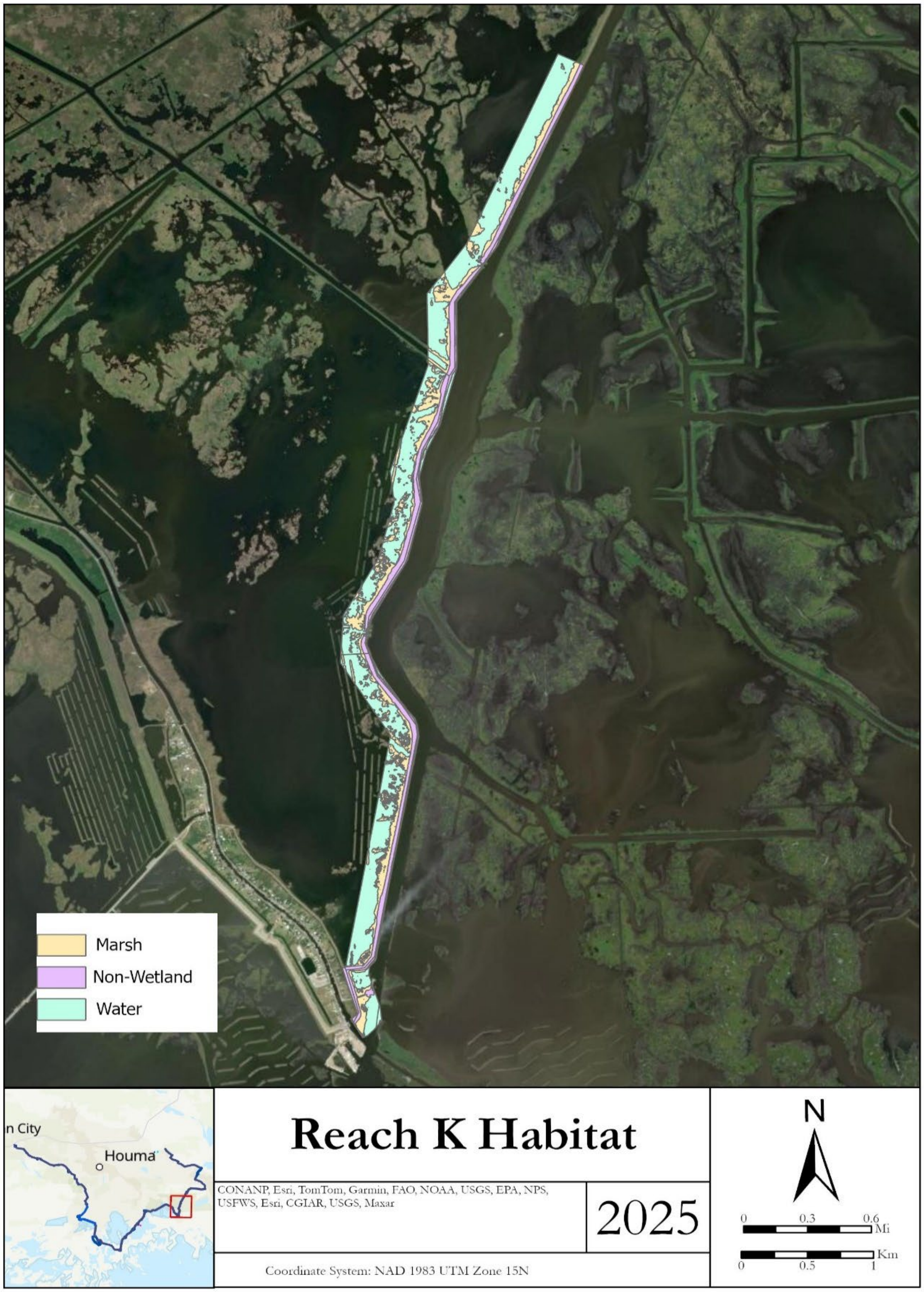

Figure 18: Reach K habitat map.

3.7.1 V1- Percent Marsh

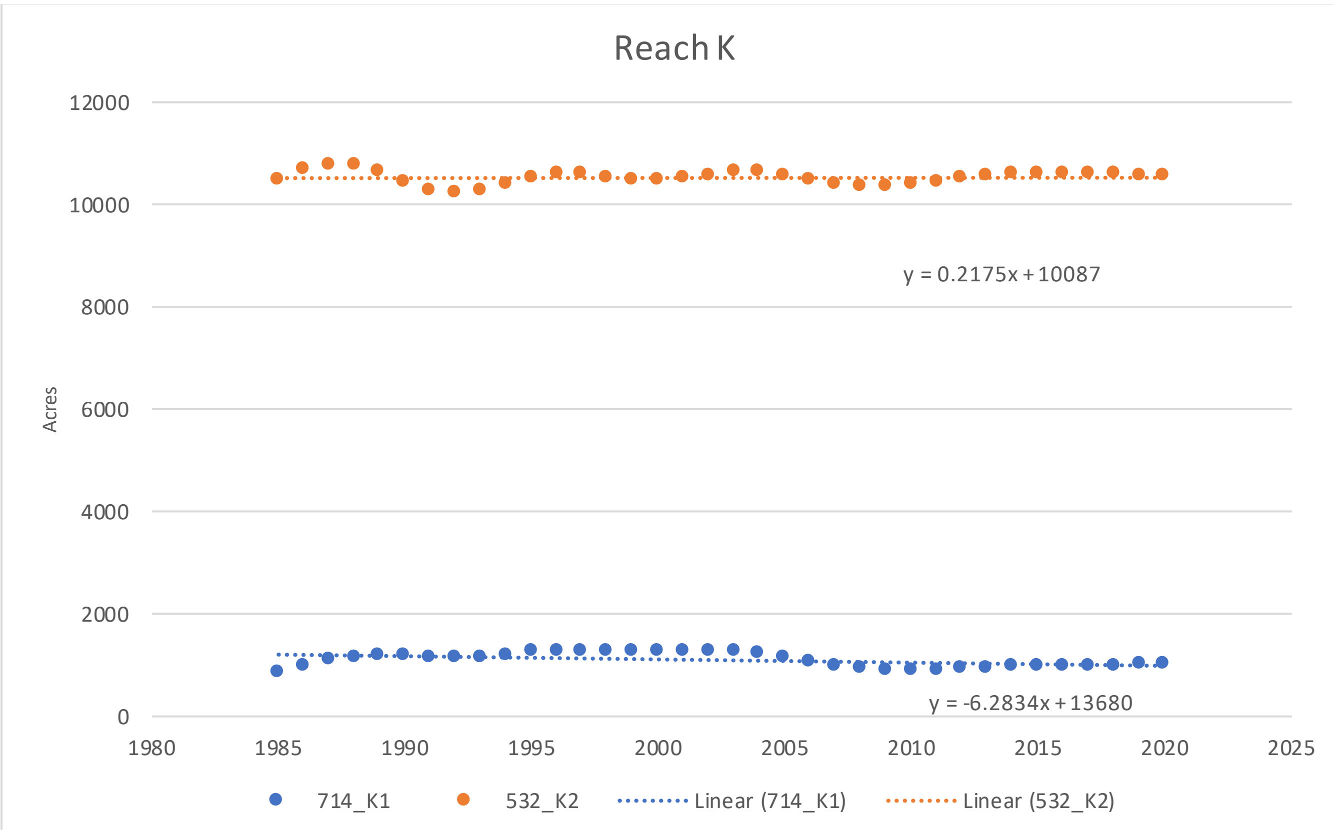

Figure 19: Acres of marsh for ICMs 714 and 532 each year from 1985 to 2020 with regression lines.

Reach	ICM		Target Year	% Marsh
K_1	714	FWOP	0	32.8
			1	32.5
			60	10.8
		FWP	0	32.8
			1	0
			60	0
K_2	532	FWOP	0	24.6
			1	24.6
			60	19.2
		FWP	0	24.6
			1	0
			60	0

3.7.2 V2- Percent Submerged Aquatic Vegetation (SAV)

Reach	ICM		Target Year	% SAV
K_1	714	FWOP	0	33
			1	33
			60	0
		FWP	0	33
			1	0
			60	0
K_2	532	FWOP	0	0
			1	0
			60	0
		FWP	0	0
			1	0
			60	0

3.7.3 V3- Interspersion

Reach	ICM		Target Year	% Interspersion
K_1	714	FWOP	0	C4-100%
			1	C4-100%
			60	C5-100%
		FWP	0	C4-100%
			1	C5-100%
			60	C5-100%
K_2	532	FWOP	0	C5-100%
			1	C5-100%
			60	C5-100%
		FWP	0	C5-100%
			1	C5-100%
			60	C5-100%

3.7.4 V4- Percent Shallow Open Water

Reach	ICM		Target Year	% <1.5 ft
K_1	714	FWOP	0	45.0
			1	42.0
			60	0.0
		FWP	0	45
			1	0.0
			60	0.0
K_2	532	FWOP	0	5.0
			1	5.0
			60	0.0
		FWP	0	5
			1	0.0
			60	0.0

3.7.5 V5- Average Annual Salinity

Reach	ICM		Target Year	% <1.5 ft
K_1	714	FWOP	0	5.8
			1	5.9
			60	12.5
		FWP	0	5.8
			1	5.9
			60	12.5
K_2	532	FWOP	0	4.4
			1	4.5
			60	11.5
		FWP	0	1.5
			1	4.5
			60	11.5

3.7.6 V6- Access Value

Reach	ICM		Target Year	Fish Access
K_1	714	FWOP	0	0.40
			1	0.40
			60	0.40
		FWP	0	0.40

			1	0.00
			60	0.40
K_2	532	FWOP	0	0.88
			1	0.88
			60	0.88
		FWP	0	0.88
			1	0.00
			60	0.88

3.8 Reach L

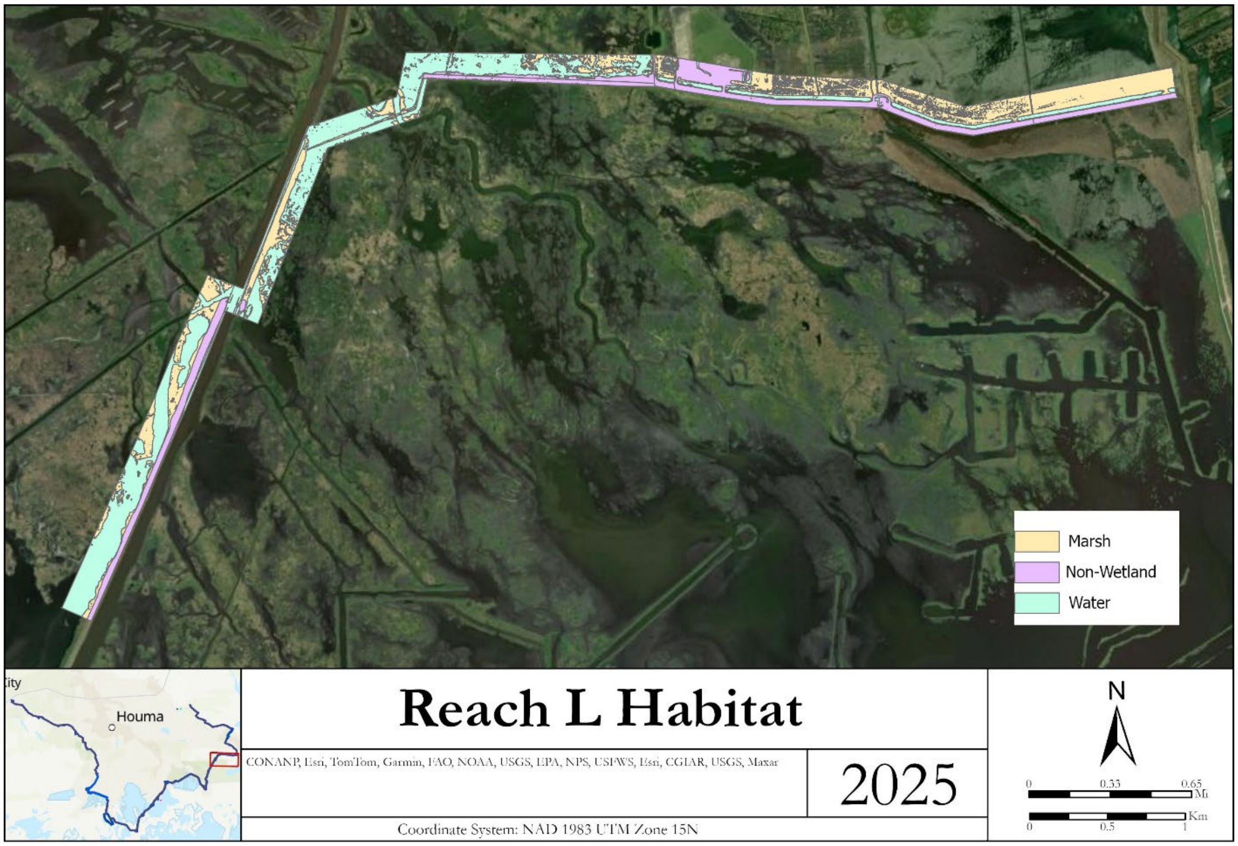

Figure 20: Reach L habitat map

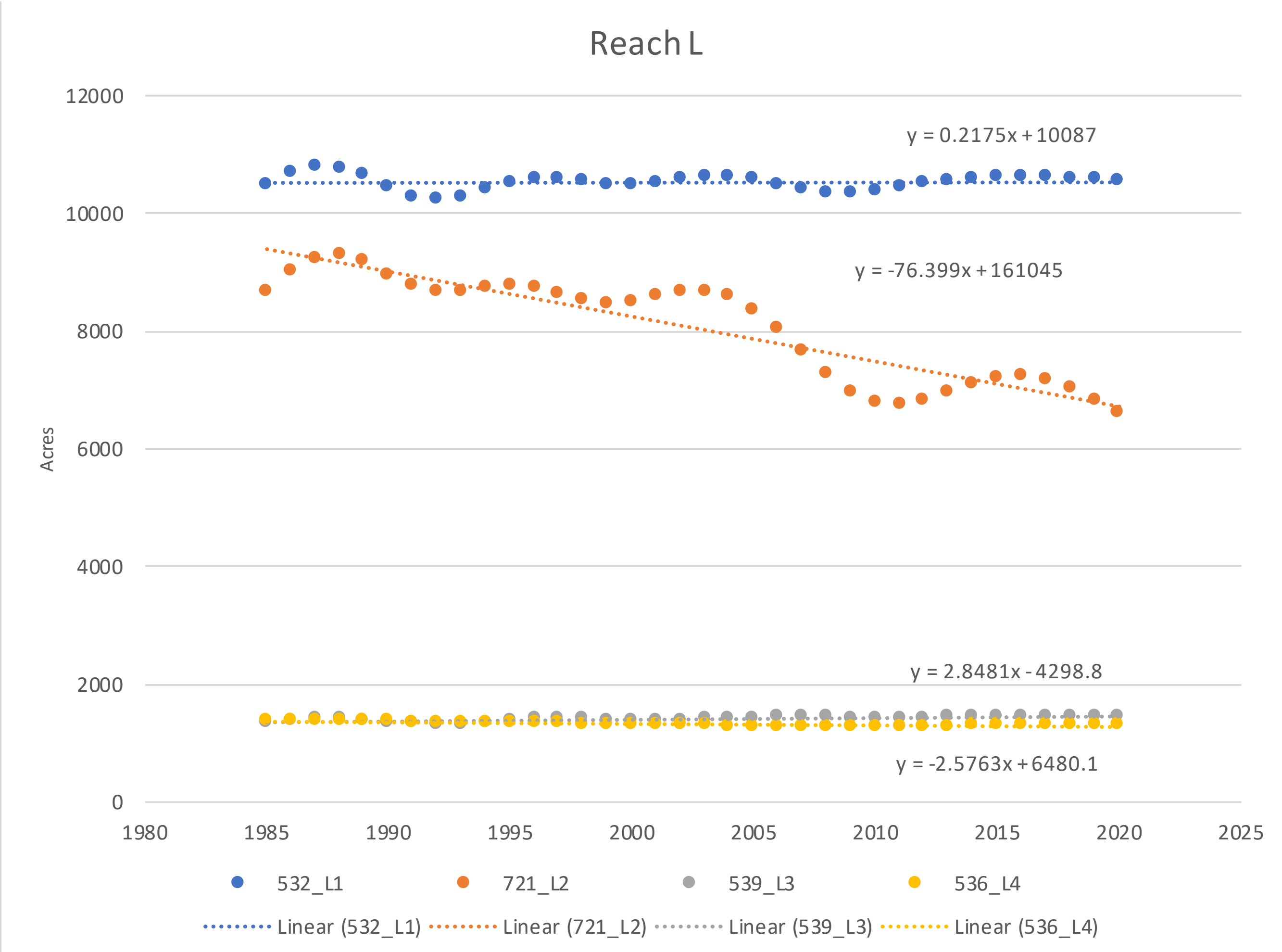

Figure 21: Acres of marsh for ICMs 532, 721, 539, and 536 each year from 1985 to 2020 with regression lines.

3.8.1 V1-Percent Marsh

Reach	ICM		Target Year	% Marsh
L_1	532	FWOP	0	28.3
			1	28.3
			60	22.1
		FWP	0	28.3
			1	0
			60	0
L_2	721	FWOP	0	30.2
			1	29.8
			60	0
		FWP	0	30.2

			1	0
			60	0
L_2 Structures		FWOP	0	40.4
			1	39.8
			60	0
		FWP	0	40.4
			1	0
			60	0
L_3	539	FWOP	0	21.9
			1	21.9
			60	17.5
		FWP	0	21.9
			1	0
			60	0
L_4	536	FWOP	0	75
			1	74.7
			60	47.9
		FWP	0	75
			1	0
			60	0

3.8.2 V2- Percent Submerged Aquatic Vegetation (SAV)

Reach	ICM		Target Year	% SAV
L_1	532	FWOP	0	0
			1	0
			60	0
		FWP	0	0
			1	0
			60	0
L_2	721	FWOP	0	0
			1	0
			60	0
		FWP	0	0
			1	0
			60	0
L_2 Structures		FWOP	0	0
			1	0
			60	0

		FWP	0	0
			1	0
			60	0
L_3	539	FWOP	0	5
			1	5
			60	0
		FWP	0	5
			1	0
			60	0
L_4	536	FWOP	0	0
			1	0
			60	0
		FWP	0	0
			1	0
			60	0

3.8.3 V3- Interspersion

Reach	ICM		Target Year	% Interspersion
L_1	532	FWOP	0	C3-40% C5-60%
			1	C1-40% C5-60%
			60	C2-40% C5-60%
		FWP	0	C3-40% C5-60%
			1	C5-100%
			60	C5-100%
L_2	721	FWOP	0	C3-100%
			1	C3-100%
			60	C4-100%
		FWP	0	C3-100%
			1	C5-100%
			60	C5-100%
L_2 Structures		FWOP	0	C3-100%

			1	C3-100%
			60	C4-100%
		FWP	0	C3-100%
			1	C5-100%
			60	C5-100%
L_3	539	FWOP	0	C3-45% C5-55%
			1	C3-45% C5-55%
			60	C4-45% C5-55%
		FWP	0	C3-45% C5-55%
			1	C5-100%
			60	C5-100%
L_4	536	FWOP	0	C3-75% C5-25%
			1	C1-90% C5-10%
			60	C3-90% C5-10%
		FWP	0	C3-75% C5-25%
			1	C5-100%
			60	C5-100%

3.8.4 V4- Percent Shallow Open Water

Reach	ICM		Target Year	% <1.5 ft
L_1	532	FWOP	0	13.0
			1	13.0
			60	0.0
		FWP	0	13
			1	0.0
			60	0.0
L_2	721	FWOP	0	20.0
			1	20.0
			60	0.0
		FWP	0	20.0
			1	0.0
			60	0.0

L_2 Structures		FWOP	0	20.0
			1	20.0
			60	0.0
		FWP	0	20.0
			1	0.0
			60	0.0
L_3	539	FWOP	0	69.0
			1	69.0
			60	0.0
		FWP	0	69.0
			1	0.0
			60	0.0
L_4	536	FWOP	0	99.0
			1	99.0
			60	0.0
		FWP	0	99
			1	0.0
			60	0.0

3.8.5 V5- Average Annual Salinity

Reach	ICM		Target Year	Salinity (ppt)
L_1	532	FWOP	0	0.3
			1	0.4
			60	2.1
		FWP	0	0.3
			1	0.4
			60	2.1
L_2	721	FWOP	0	3.8
			1	3.9
			60	7.5
		FWP	0	3.8
			1	3.9
			60	7.5
L_2 Structures		FWOP	0	3.8
			1	3.9
			60	7.5
		FWP	0	3.8
			1	3.9
			60	7.5

L_3	539	FWOP	0	3.8
			1	3.9
			60	7.5
		FWP	0	3.8
			1	3.9
			60	7.5
L_4	536	FWOP	0	0.0
			1	0.0
			60	0.4
		FWP	0	0
			1	0.0
			60	0.4

3.8.6 V6- Access Value

Reach	ICM		Target Year	Fish Access
L_1	532	FWOP	0	0.50
			1	0.50
			60	0.50
		FWP	0	0.50
			1	0.00
			60	0.50
L_2	721	FWOP	0	1.00
			1	1.00
			60	1.00
		FWP	0	1.00
			1	0.00
			60	0.76
L_2 Structures		FWOP	0	1.00
			1	1.00
			60	1.00
		FWP	0	1.00
			1	0.00
			60	0.76
L_3	539	FWOP	0	1.00
			1	1.00
			60	1.00
		FWP	0	1.00
			1	0.00
			60	0.76

L_4	536	FWOP	0	0.20
			1	0.20
			60	0.20
		FWP	0	0.20
			1	0.00
			60	0.20

3.9 <u>Reach Lockport to Larose</u>

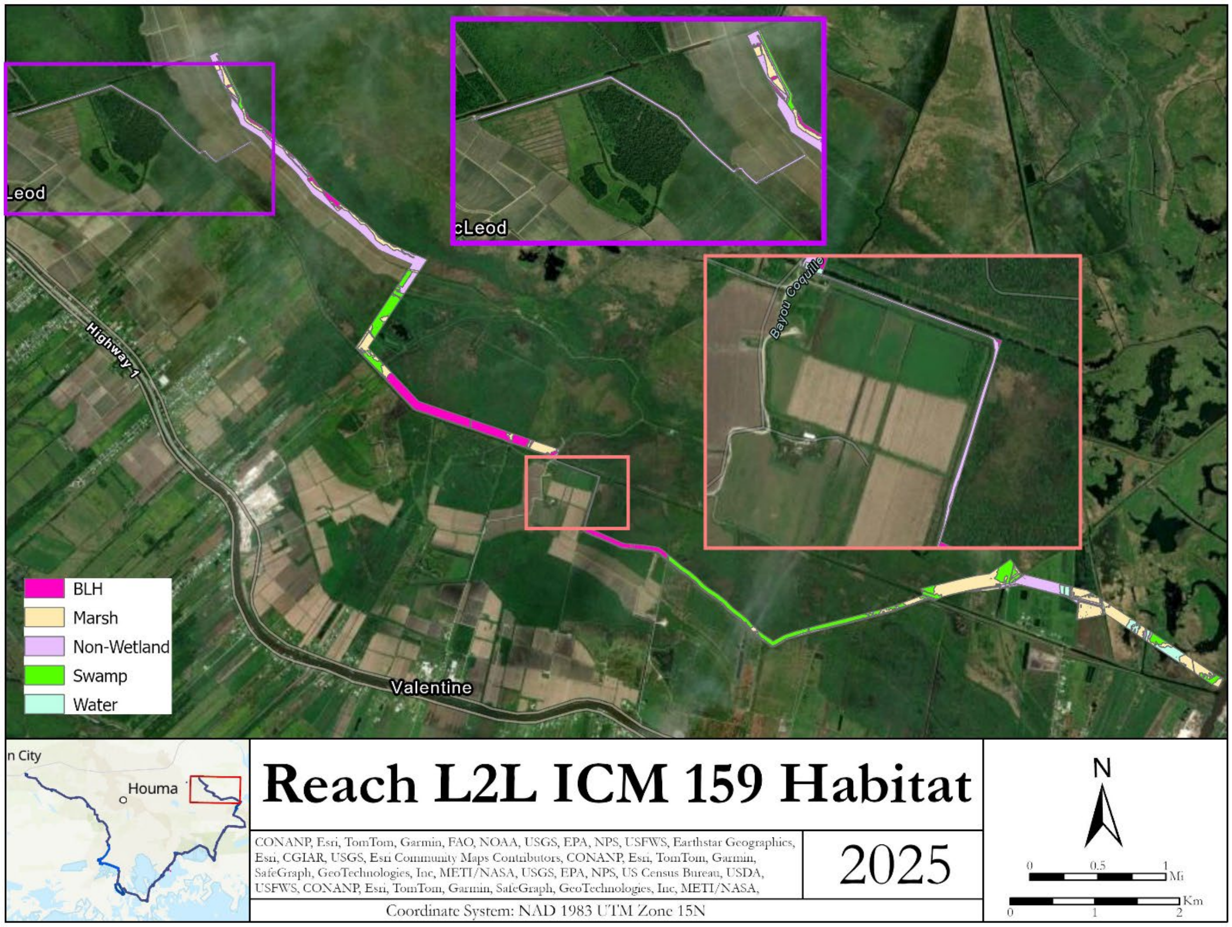

Figure 22: Reach Lockport to Larose 159 habitat map

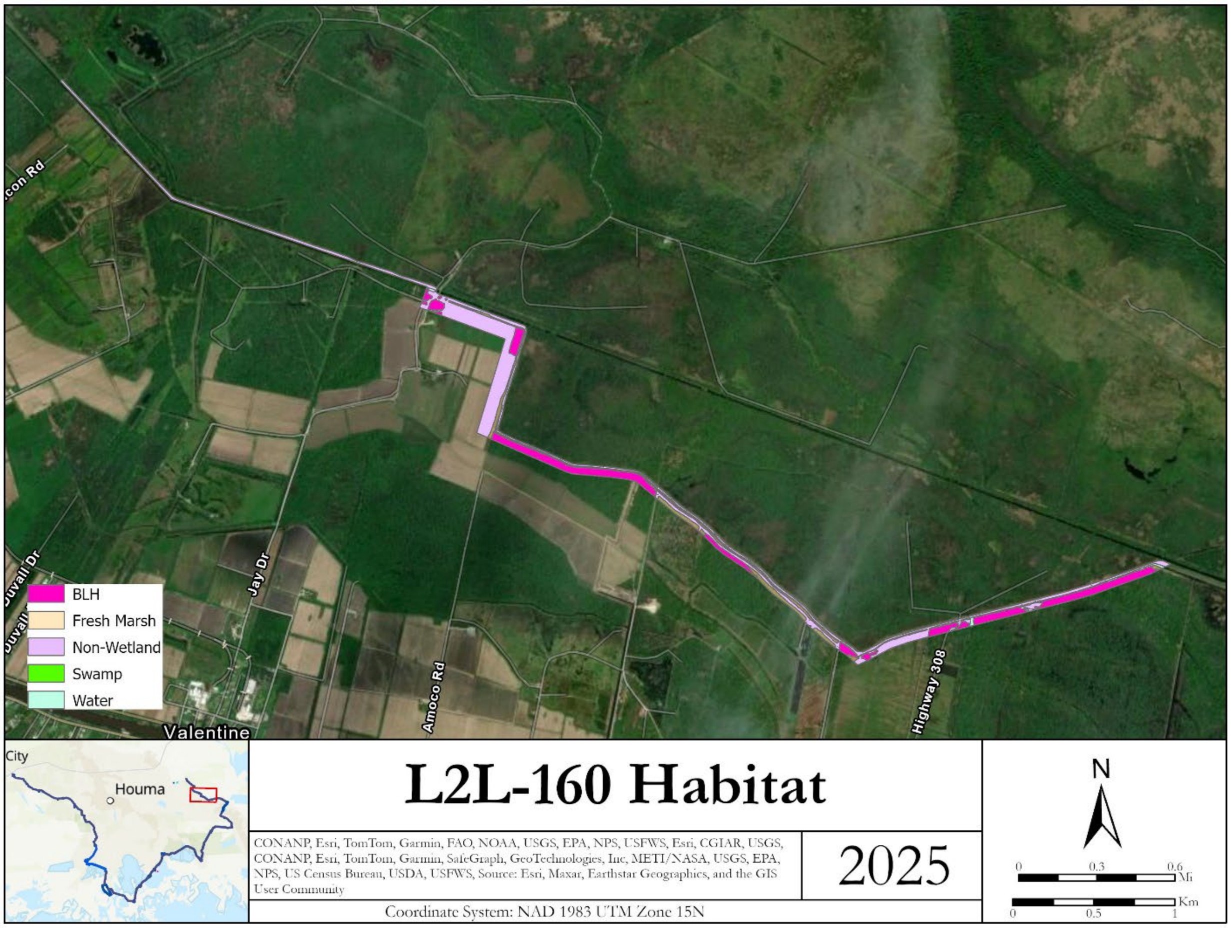

Figure 23: Reach Lockport to Larose 160 habitat map

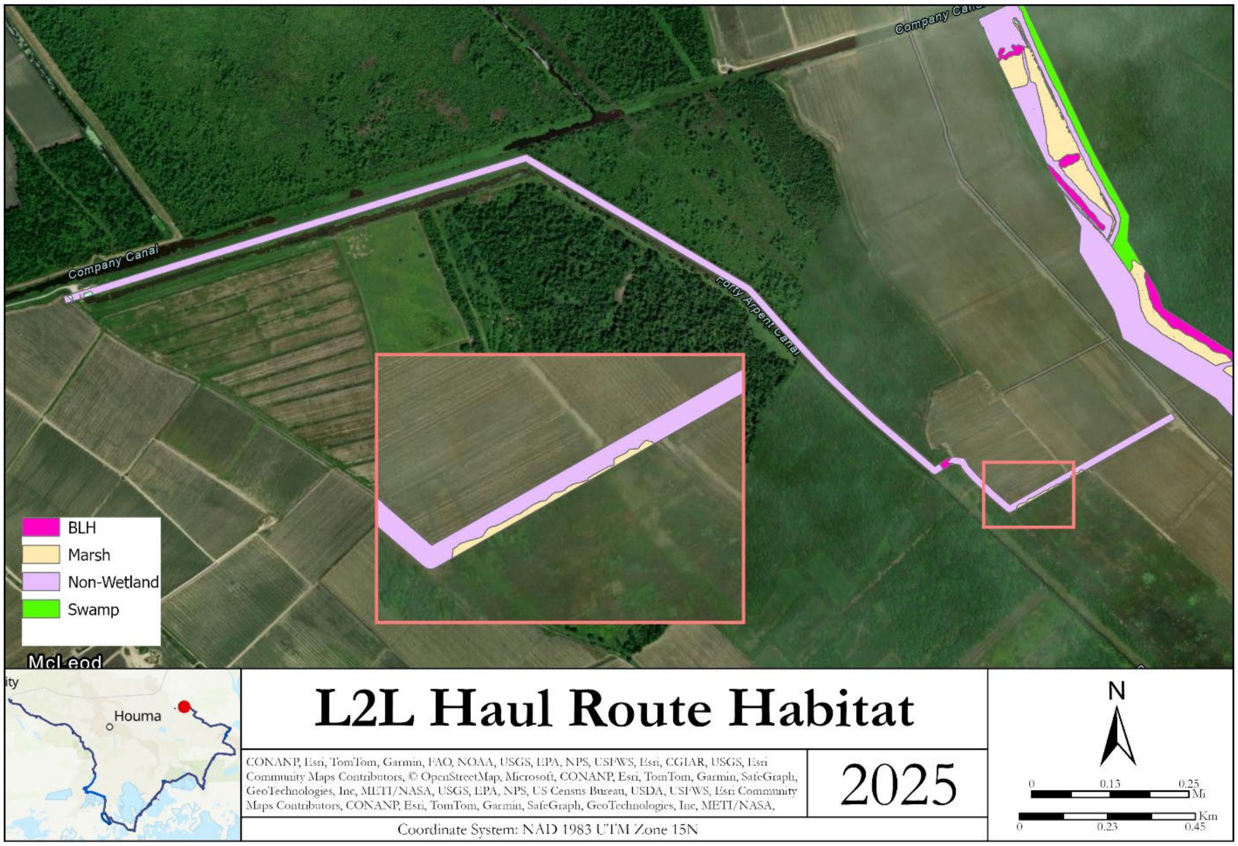

Figure 24: Reach Lockport to Larose haul route habitat map

3.9.1 V1-Percent Marsh

Reach	ICM		Target Year	% Marsh
L2L_1	159	FWOP	0	86.7
			1	86.6
			60	70.2
		FWP	0	86.7
			1	0.0
			60	0.0
L2L_1 Structures		FWOP	0	50.5
			1	50.5
			60	40.9
		FWP	0	50.5
			1	0.0
			60	0.0
L2L_2	160	FWOP	0	68.4

			1	68.2
			60	53.5
		FWP	0	68.4
			1	0.0
			60	0.0

3.9.2 V2- Percent Submerged Aquatic Vegetation (SAV)

Reach	ICM		Target Year	% SAV
L2L_1	159	FWOP	0	10
			1	10
			60	0
		FWP	0	10
			1	0
			60	0
L2L_1 Structures		FWOP	0	10
			1	10
			60	0
		FWP	0	10
			1	0
			60	0
L2L_2	160	FWOP	0	10
			1	10
			60	0
		FWP	0	10
			1	0
			60	0

3.9.3 V3- Interspersion

Reach	ICM		Target Year	% Interspersion
L2L_1	159	FWOP	0	C3 – 100%
			1	C3 – 100%
			60	C1 – 100%
		FWP	0	C3 – 100%
			1	C5 – 100%
			60	C5 – 100%
L2L_1 Structures		FWOP	0	C3 – 100%
			1	C3 – 100%

			60	C1 – 100%
		FWP	0	C3 – 100%
			1	C5 – 100%
			60	C5 – 100%
L2L_2	160	FWOP	0	C3 – 100%
			1	C3 – 100%
			60	C1 – 100%
		FWP	0	C3 – 100%
			1	C5 – 100%
			60	C5 – 100%

3.9.4 V4- Percent Shallow Open Water

Reach	ICM		Target Year	% <1.5 ft
L2L_1	159	FWOP	0	41
			1	41
			60	0
		FWP	0	41
			1	0
			60	0
L2L_1 Structures		FWOP	0	41
			1	41
			60	0
		FWP	0	41
			1	0
			60	0
L2L_2	160	FWOP	0	41
			1	41
			60	0
		FWP	0	41
			1	0
			60	0

3.9.5 V5- Average Annual Salinity

Reach	ICM		Target Year	Salinity (ppt)
L2L_1	159	FWOP	0	0.4
			1	0.4
			60	1.1

		FWP	0	0.4
			1	0.4
			60	1.1
L2L_1 Structures		FWOP	0	0.4
			1	0.4
			60	1.1
		FWP	0	0.4
			1	0.4
			60	1.1
L2L_2	160	FWOP	0	0
			1	0
			60	0
		FWP	0	0
			1	0
			60	0

3.9.6 V6- Access Value

Reach	ICM		Target Year	Fish Access
L2L_1	159	FWOP	0	0.7000
			1	0.7000
			60	0.7000
		FWP	0	0.7000
			1	0.0000
			60	0.7000
L2L_1 Structures		FWOP	0	0.4000
			1	0.4000
			60	0.4000
		FWP	0	0.4000
			1	0.0000
			60	0.4000
L2L_2	160	FWOP	0	0.7000
			1	0.7000
			60	0.7000
		FWP	0	0.7000
			1	0.0000
			60	0.7000

3.10 Reach LCN

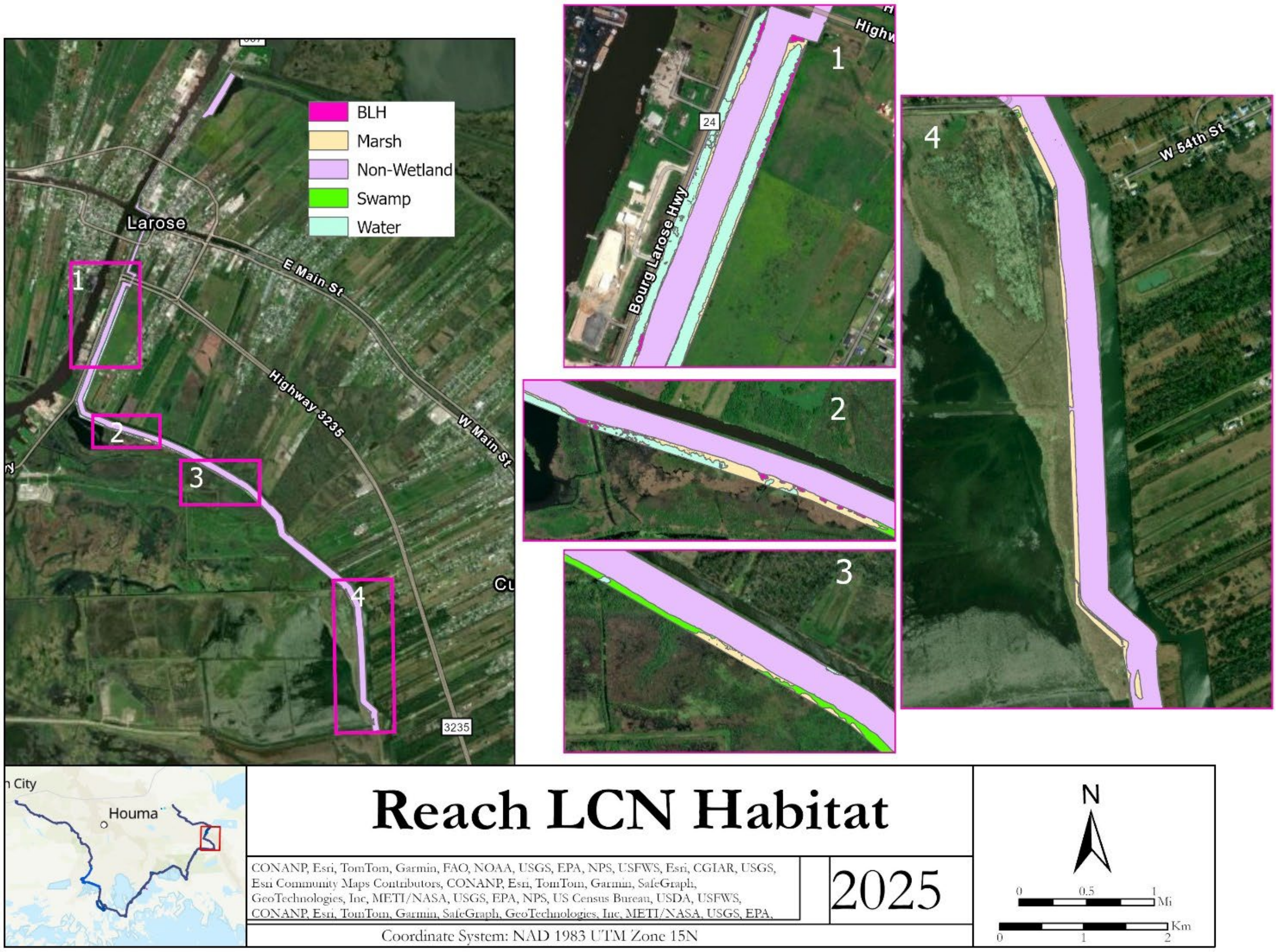

Figure 26: Reach LCN habitat map

3.10.1 V1-Percent Marsh

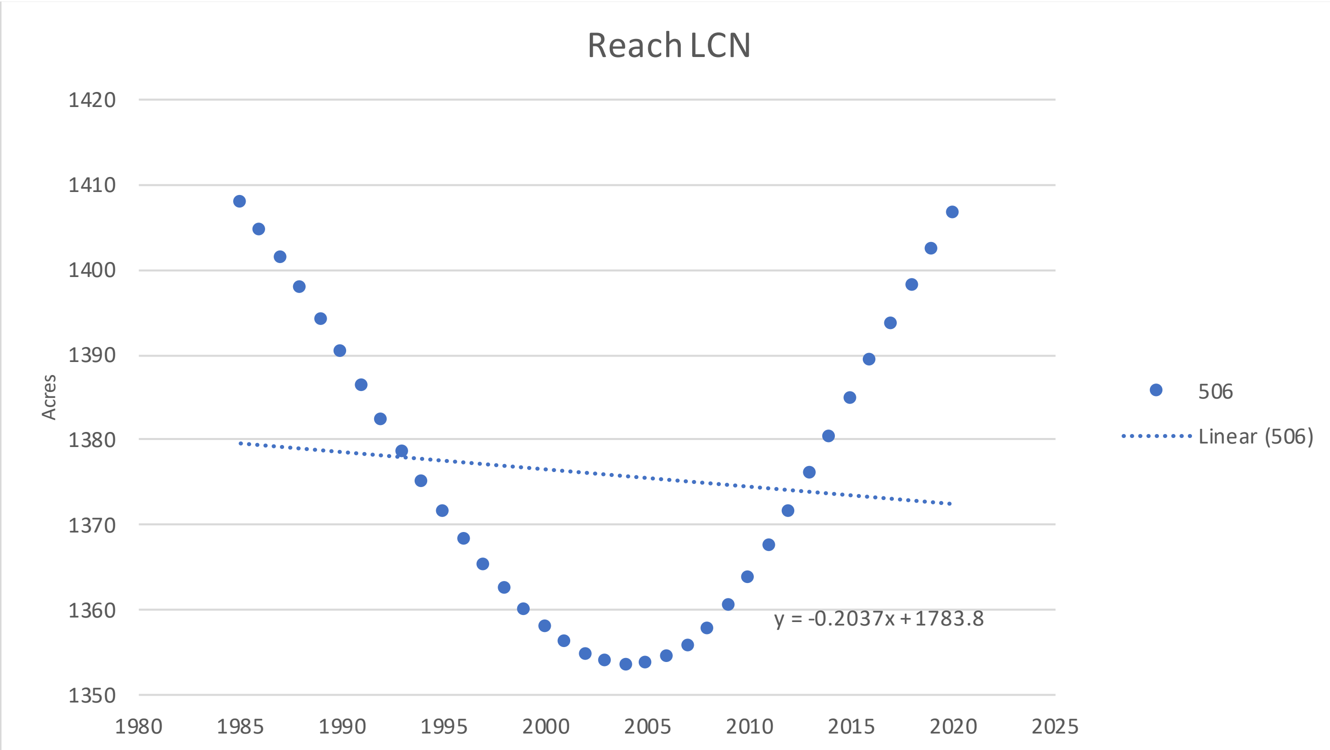

Figure 27: Acres of marsh for ICMs 506 each year from 1985 to 2020 with regression lines.

Reach	ICM		Target Year	% Marsh
LCN	506	FWOP	0	37.8
			1	37.7
			60	29.1
		FWP	0	37.8
			1	0
			60	0
LCN Structures		FWOP	0	7.2
			1	7.1
			60	5.5
		FWP	0	7.2
			1	0
			60	0

3.10.2 V2- Percent Submerged Aquatic Vegetation (SAV)

Reach	ICM	Target Year	% SAV

LCN	506	FWOP	0	0
			1	0
			60	0
		FWP	0	0
			1	0
			60	0
LCN Structures		FWOP	0	0
			1	0
			60	0
		FWP	0	0
			1	0
			60	0

3.10.3 V3- Interspersion

Reach	ICM		Target Year	% Interspersion
LCN	506	FWOP	0	C3-100%
			1	C3-100%
			60	C1-100%
		FWP	0	C3-100%
			1	C5-100%
			60	C5-100%
LCN Structures		FWOP	0	C3-100%
			1	C3-100%
			60	C1-100%
		FWP	0	C3-100%
			1	C5-100%
			60	C5-100%

3.10.4 V4- Percent Shallow Open Water

Reach	ICM		Target Year	% <1.5 ft
LCN	506	FWOP	0	10.0

			1	10.0
			60	0.0
		FWP	0	10
			1	0.0
			60	0.0
LCN Structures		FWOP	0	10.0
			1	10.0
			60	0.0
		FWP	0	10.0
			1	0.0
			60	0.0

3.10.5 V5- Average Annual Salinity

Reach	ICM		Target Year	% <1.5 ft
LCN	506	FWOP	0	3.8
			1	3.9
			60	7.0
		FWP	0	3.8
			1	3.9
			60	7.0
LCN Structures		FWOP	0	3.8
			1	3.9
			60	7.0
		FWP	0	3.8
			1	3.9
			60	7.0

3.10.6 V6- Access Value

Reach	ICM		Target Year	Fish Access
LCN	506	FWOP	0	1.0
			1	1.0
			60	1.0
		FWP	0	1
			1	0.0
			60	1.0
LCN Structures		FWOP	0	1.0
			1	1.0

			60	1.0
		FWP	0	1.0
			1	0.0
			60	1.0

Part 3: WVA Swamp Community Model for Civil Works Version 2.0

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

Wetland Value Assessment Swamp Community Model for Civil Works (Version 2.0)

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

November 2018

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US Army Corps of Engineers
New Orleans District

WETLAND VALUE ASSESSMENT METHODOLOGY
Swamp Community Model

Introduction

This document describes revisions to the Wetland Value Assessment (WVA) Swamp Community Model for recertification 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 (CW) projects.

The Wetland Value Assessment (WVA) methodology is a quantitative habitat-based assessment methodology developed for use in determining wetland benefits of project proposals submitted for funding under the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA). The WVA was developed by the CWPPRA Environmental Work Group (EnvWG) after the passage of CWPPRA in 1990. The EnvWG includes members from U.S. Fish and Wildlife Service, Louisiana Coastal Protection and Restoration Authority, Natural Resources Conservation Service, National Oceanic and Atmospheric Administration, Environmental Protection Agency, and USACE. Various other subject matter experts, such as professors and scientists, also helped develop the original WVAs. The WVA quantifies changes in fish and wildlife habitat quality and quantity that are expected to result from a proposed wetland restoration project. The WVA operates under the assumption that optimal conditions for fish and wildlife habitat within a given coastal wetland habitat 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 or expressed through the use of community models developed specifically for each habitat type. The results of the WVA, measured in Average Annual Habitat Units (AAHUs), can be combined with cost data to provide a measure of the effectiveness of a restoration project in terms of annualized cost per AAHU gained. In addition, the WVA methodology could provide an estimate of the number of acres AAHUs negatively impacted by a CW project.

The WVA community models have been designed to function at a community level and therefore attempt to define an optimum combination of habitat conditions for all fish and wildlife species utilizing a given habitat type. Each model consists of 1) a list of variables that are considered important in characterizing fish and wildlife habitat, 2) a Suitability Index (SI) graph for each variable, which defines the assumed relationship between habitat quality (Suitability Index) and different variable values, and 3) a mathematical formula that combines the Suitability Index for each variable into a single value for habitat quality; that single value is referred to as the Habitat Suitability Index, or HSI. The output of each model (the HSI) is assumed to have a linear relationship with the suitability of a coastal wetland system in providing fish and wildlife habitat.

USACE approved the CWPPRA WVA Swamp Community Model in 2011 that was initially developed by the Louisiana Department of Natural Resources (LDNR) and later revised by CWPPRA. The LDNR model was developed to quantify the impacts of permitted activities and compensatory mitigation proposals in the Louisiana coastal zone and contained a more complete list of variables to characterize habitat quality of swamp in the coastal zone. Because that model was developed for regulatory purposes, it contained some variables which were not being impacted by candidate CWPPRA restoration projects. Therefore, in 2001, the CWPPRA Environmental Work Group (EnvWG) decided to modify that model by removing landscape variables (i.e. size of contiguous forested areas, surrounding land uses, and disturbance) and updated other variables to better reflect the impacts of proposed restoration projects. The 2001 CWPPRA model was approved for use for CW projects as the WVA Swamp Community Model for Civil Works (Version 1.0) in November 2011. The WVA Swamp Community Model for Civil Works (Version 2.0) is a revised version that adds the three landscape variables included in the original LDNR model to the model approved for use in November 2011.

The WVA Swamp Community Model was developed to determine the suitability of swamp habitat in providing resting, foraging, and nesting habitat for a diverse assemblage of wildlife species. The model is generally applied to areas supporting or capable of supporting a canopy of woody vegetation which covers at least 33% of the area's surface, and with at least 60% of that canopy consisting of any combination of baldcypress (*Taxodium distichum*), tupelo gum (*Nyssa sylvatica*), red maple (*Acer rubrum*), buttonbush (*Cephalanthus occidentalis*), and/or water elm (*Planera aquatic*). The Interagency Review Team (IRT) has agreed that 33% canopy cover criterion should be treated as a general “rule of thumb” for model application, with some exceptions (to be documented in the Project Information Sheet). Areas with canopy cover less than 33% are then considered using the fresh marsh model. If greater than 40% of the woody vegetation canopy consists of species such as oaks (*Quercus* spp.), hickories (*Carya* spp.), American elm (*Ulmus americana*), green ash (*Fraxinus pennsylvanica*), American sweetgum (*Liquidambar styraciflua*), sugarberry (*Celtis laevigata*), boxelder (*Acer negundo*), persimmon (*Diospyros virginiana*), honey locust (*Gleditsia tracanthos*), red mulberry (*Morus rubra*), eastern cottonwood (*Populus deltoids*), American sycamore (*Platanus occidentalis*), etc., then a bottomland hardwood model should be applied.

USACE Planning Models Improvement Program (PMIP)

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 CW 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 June 13, 2018, USACE, Mississippi Valley Division, New Orleans District (CEMVN) initiated coordination requesting feedback from WVA experts from the US Fish and Wildlife Service (David Walther, Cathy Breaux, and Kevin Roy), the National Marine

Fisheries Service (Patrick Williams and later Dawn Davis on August 7, 2018), US Geological Survey (Michelle Fischer), the US Environmental Protection Agency (Raul Gutierrez), and Louisiana Department of Wildlife and Fisheries (Dave Butler and Kyle Balkum). The Natural Resource Conservation Service (Ron Boustany) was later included in the WVA reapproval coordination on August 20, 2018. On September 25, CEMVN also reached out to Daniel Allen from Fort Worth District (CESWF). In addition, Sharon McCarthy from Louisiana Department of Natural Resources, Office of Coastal Management provided LDNR WVA models for addressing mitigation potentials on September 28, 2018.

Geographic Scope

The maximum area that the swamp model should be applied to is the coastal forested wetlands of the southeastern United States. These wetlands have similar community structure and function (Gosselink et al. 1990, Mitsch and Gosselink 2007, Mitsch et al. 2009). Coastal swamps from South Carolina to east Texas share a similar climate and respond both positively and negatively to the same environmental conditions.

The WVA models examined herein were designed to capture habitat suitability of the flora and associated fauna that inhabit swamps of coastal Louisiana. While these community assemblages are similar across the above mentioned geographical area, they vary widely in special case species such as Rafinesque’s big-eared bat (*Corynorhinus rafinesquii rafinesquii*), bald eagle (*Haliaeetus leucocephalus*), Louisiana black bear (*Ursus americanus lutelous*), and a variety of Neotropical migratory songbirds.

Geographic Range of Applicability

Figure 1 indicates the geographical range of applicability for the Wetland Value Assessment Swamp Community Model. This model was developed for swamp habitats of coastal Louisiana, which share common functions, values, and habitats with the rest of the southern United States (Wharton et al. 1982). Four coastal level III ecoregions, 34, 73, 75, and 76, were initially used to focus on potential coastal habitats in the Southern U.S (Daigle et al., 2006; Griffith et al., 2007). Level IV ecoregions within these were screened for applicability based on their likelihood to contain swamp habitats. After screening, 26 level IV ecoregions remain as the geographic range of applicability (Table 1). Potential users outside of the geographical range of applicability presented here are encouraged to coordinate with ECO-PCX prior to applying this WVA community model for their project.

Table 1. Level IV ecoregions being considered for geographical range of applicability for the Wetland Value Assessment Swamp Community Model for Civil Works (Version 2.0).

Northern Humid Gulf Coastal Prairies	Gulf Coast Flatwoods
Southern Subhumid Gulf Coastal Prairies	Southwestern Florida Flatwoods
Floodplains and Low Terraces	Eastern Florida Flatwoods
Coastal Sand Plain	Okefenokee Plains
Lower Rio Grande Valley	Sea Island Flatwoods
Lower Rio Grande Alluvial Floodplain	Okefenokee Swamp
Texas-Louisiana Coastal Marshes	Bacon Terraces
Lafayette Loess Plains	Floodplains and Low Terraces
Southern Holocene Meander Belts	Sea Islands/Coastal Marsh
Southern Pleistocene Valley Trains	Big Bend Coastal Marsh
Southern Backswamps	Everglades
Inland Swamps	Big Cypress
Deltaic Coastal Marshes and Barrier Islands	Miami Ride/Atlantic Coastal Strip

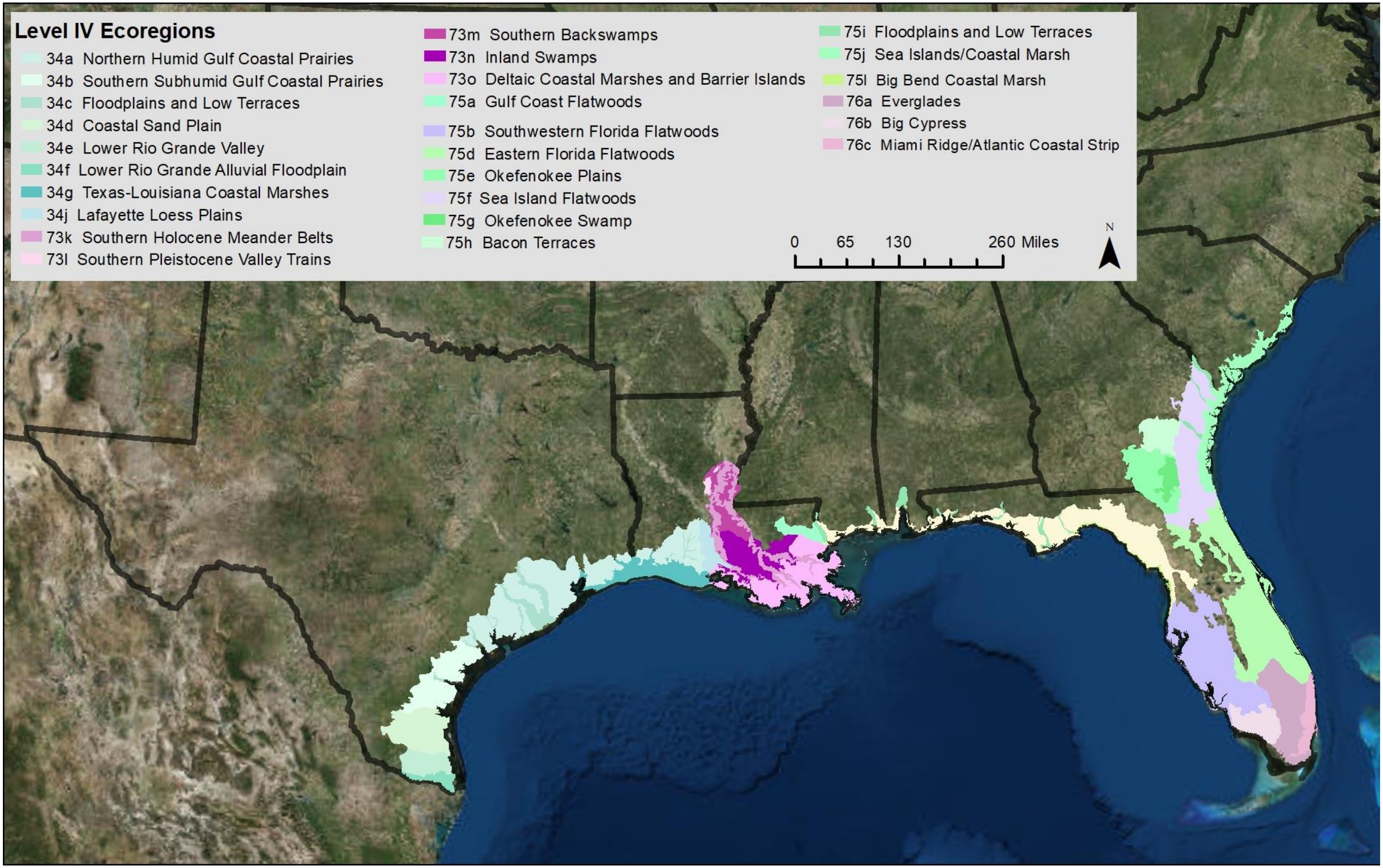


Figure 1. Geographic Range of Applicability for the WVA Swamp Community Model.

Minimum Area of Application

The minimum area of application of the swamp model is defined by the sample size required to collect three true replicates within each habitat type (see the instructions in the Sampling Technique section). The reason for this is that small patches of each habitat type may be critical for survival during extreme climatic events. For example, a small patch of Bottomland Hardwood Forest (BLH) within a swamp may enable survival of many species during high-water events caused by tropical storms. In contrast, small patches of swamp within a BLH could prove critical during periods of drought when water is at a premium. Practical constraints also mandate that the WVA models be applied to relatively small areas. For example, a large swamp restoration project may call for the gapping of spoil banks that impound it. Those gaps will destroy small areas of bottomland hardwood forest and the WVA bottomland hardwood model must be applied to these.

The size required to obtain at least three true replicates of each habitat type is considerably smaller, approximately 13.5 acres, or 5.4 hectares (ha), than the viable population size of one or more critical species. For example, certain species of Neotropical migratory birds require a minimum of 6,920 acres (2,800 ha) of forest interior to sustain viable populations (Robbins et al. 1989). Gosselink and Lee (1989) estimate that 494,200 acres (200,000 ha) of forested habitat is required to sustain a viable population of the Louisiana black bear (*Ursus americanus luteolus*). In cases where the model is applied to areas less than 13.5 acres, users must determine scale using best professional judgment.

Field Investigations

The first step in evaluating candidate projects is to conduct a field investigation of the project area. This field investigation has several purposes: 1) familiarize the IRT with the project area, 2) visit the locations of project features, 3) determine habitat conditions in the project area, 4) compile a list of vegetative species and discuss habitat classification, and 5) collect data for the WVA (e.g., cover of submerged aquatics, water depths, salinities, etc.).

The primary purpose of the field investigation is to allow members of the IRT to familiarize themselves with the project area and project features in order to make informed decisions in the evaluation of the WVA. The interagency field investigation should not be treated as the only opportunity to conduct surveys or take measurements to develop designs and/or cost estimates for the project. That information could be obtained during previous field trips or should plan a follow-up field trip. In cases where the project area is very large, it may be necessary to divide the group into small work parties to collect WVA information across the project area or to allow some areas to be investigated by at least a subset of the entire group. However, an effort should be made to keep the group together to facilitate discussion about wetland conditions in the project area, the causes of habitat loss, the project features, and the effectiveness of the project features.

Project Boundary Determination

The project boundary is the area where a measurable biological impact, in regard to the WVA variables, is expected to occur with project implementation. The area must be divided into subareas based on habitat type so that the correct model can be applied. The most recent Vegetative Type Maps (Sasser et al. 2014) are typically used to delineate marsh areas from adjacent areas of swamp. United States Geological Survey (USGS) Gap Analysis Project (GAP) data (USGS, 2011) is also utilized, particularly when forested wetlands are included. However, recent field investigations or other data (e.g., National Wetlands Inventory, www.fws.gov/wetlands) may be utilized to delineate habitat types within the project area. Reclassifying habitat should not be viewed as a means of reducing the number of subareas to simplify the project evaluation. Incorrect habitat classification can result in an inaccurate measure of project benefits, depending on project impacts. Reasons for habitat classification and/or reclassification should be documented.

In some instances, small areas of a particular habitat type may be combined with the more prevalent type within the project area. For example, a 100-acre area of bottomland hardwoods may be combined with an adjacent 5,000-acre tract of swamp. Determining the benefits for each individual small area could unnecessarily complicate the evaluation, be time-consuming, and may not significantly affect the overall project benefits. Any decision to combine a small area of one habitat type with a larger area of a different habitat type must be approved by the IRT.

Note: Remote sensing could also be determined through the use of aerial/satellite photographs, light imaging detection and ranging (LIDAR) information, USGS habitat and quadrangle maps and site visits. The boundary and revisions to the boundary are made by interagency group consensus. For non-restoration projects, boundaries are usually provided as areas designated for construction or clearing (typically to provide temporary or permanent rights-of-way) or areas that will experience changes in hydrology.

Selection of Target Years

In general, USACE Civil Works (CW) project WVAs are conducted for a period of 50 years which corresponds to the typical period of analysis of a CW study (Table 2). Each project evaluation must include target years (TY) 0, 1, and 50 (or last year of the period of analysis). Target year 0 (TY0) represents baseline or existing conditions in the project area and TY50 (or last year of the period of analysis) represents the projected conditions at the end of the project life. A linear fit (over the project life) is used to make the projection unless there are expected changes that may occur in the intervening years. Examples of these changes include (but are not limited to):

1. Storm events: Storm frequencies for the Louisiana coast vary depending on the period of record analyzed but generally have occurred every 8 to 10 years. For sites located along the gulf shoreline, it may be necessary to select a target year which corresponds to a storm event which is likely to occur within the project life in order to capture the effects of the storm. In forested wetlands, damaging winds from storms could cause tree mortality and reduce canopy cover by knocking trees down. Selection of a storm impact target year should be based on the storm return frequency that would result in substantial impact for the project vicinity. Climate change impacts to storm frequency and intensity varies spatially (Bender et al., 2010). It is not clear precisely how climate change will impact storm frequency and intensity, but many modelling results agree that we could expect decreased frequency and increased intensity (Walsh et al., 2016). However, an increase in frequency of tropical cyclonic storms was observed in the northern Atlantic in the recent past (1970-2005), which could, in part, be due to a warming climate (Webster et al, 2005). Storm impact and return frequency by barrier system, should be used as justification when selecting target years (Stone et al. 1997). If the Future Without Project condition (FWOP) loss rates are based on data which include the effects of storm events then care must be taken to ensure that effects of storm events are not double counted.

2. Changes in frequency and duration of flooding: As relative sea level (RSL) rise continues, flooding frequency and duration may increase which could result in habitat loss and/or conversion. Project features could also decrease flooding frequency and duration or increase flooding duration if drainage is retarded by structures.

3. Salinity changes: Salinity may increase resulting in reduced tree growth or eventual mortality and subsequent conversion of habitat.

4. Project implementation: Additional CW (or non-CW) projects may be built which could influence the conditions in the current project area.

5. Maintenance events: These would include items such as phased vegetative plantings, replacement of hydrologic restoration structures, etc.

6. Increase or decrease in vegetative cover: These could be associated with project features (initial or phased) or environmental changes (see numbers 2, 3, and 5).

Table 2. Summary of Target Years used for USACE Civil Works projects.

Project/Habitat Type	Target Year						
	0	**1**	**3**	**5**	**10, 20, 30, 40**	**50**	**>50**
Swamp Civil Works	Measured baseline		100% credit for marsh/dune plantings	100% credit for woody plantings	Storm Events (?)		Storm Event (?)

Use of the Community Habitat Model

Each community model contains a set of variables which is important in characterizing the habitat quality of several coastal wetland habitat types relative to the fish and wildlife communities dependent on those environments. Baseline (TY0) values are determined for each of those variables to describe existing conditions in the project area. Future values for those variables are projected to describe conditions in the area without the project and with the project. Projecting future values is the most complicated, and sometimes controversial part of this process. It requires the substantiation of with monitoring data, research findings, scientific literature, or examples of project success in other areas. Not all future projections can be substantiated by the results of monitoring or research, and, as with all wetland assessment methodologies, some projections are based on best professional judgment and can be subjective. It should be noted that future projections are the responsibility of the IRT (i.e., agency representatives, academics, and others) to use the best information available in developing those projections. Many times, the collective knowledge of the IRT is the only tool available to predict project impacts (positive or negative). Teams should be comprised of many individuals with diverse backgrounds and all project scenarios are discussed by the group and a final outcome is usually reached by consensus. Key assumptions made during the evaluation process, e.g., regarding the effects of climate change or storms, should be recorded on the Project Information Sheet (See Appendix III). There are occasionally off-site conditions and human disturbances adjacent to a project area. These have an effect on the animals in the project area, however these disturbances are considered to be the same under FWOP and Future With Project (FWP) conditions.

Model Application

The swamp community model should be applied to areas supporting or capable of supporting a canopy of woody vegetation which covers at least 33% of the area and with at least 60% of that canopy consisting of any combination of baldcypress, tupelo gum, red maple, buttonbush, and/or water elm. The model also states that if woody canopy cover is less than 33%, the fresh marsh model should be applied. Some areas with less than 33% canopy cover may provide functions and values more closely associated with a swamp than a fresh marsh. Therefore, the 33% canopy cover criterion should be treated as a general rule of thumb for model application and that some exceptions may exist. If greater than 40% of the canopy consists of species such as oaks, hickories, American elm, green ash, sweetgum, sugarberry, box elder, persimmon, honey locust, red mulberry, eastern cottonwood, American sycamore, etc., a bottomland hardwood community model should be applied.

Baseline Habitat Classification and Land/Water Data

Typically, the most recent habitat data for the project boundary are provided by USGS. However, other datasets, e.g., Digital Orthophoto Quadrangles (DOQs; https://lta.cr.usgs.gov/DOQs), may be more appropriate for some applications. Upland and/or non-wetland habitats (e.g., spoil banks, developed areas, cropland) are usually removed from the project area. Acreages for those habitat types should not be included within the project area acreage.

Wetland loss is the conversion of emergent habitat to open water. However, in many areas along the coast, the historic loss of swamp habitat has not resulted in a conversion to open water but conversion to marsh. Because much of the historic loss of swamp has not resulted in a conversion to open water, USGS habitat and land/water data generally do not allow the calculation of a “loss” rate for swamp habitat. However, habitat classification data could be utilized to determine a “conversion” rate of swamp to marsh and that rate could be utilized in the WVA. In those instances, areas of swamp converting to fresh marsh should be evaluated as open water habitat using the fresh marsh model. Allowing those areas to be evaluated as marsh habitat would underestimate project benefits as conversion to marsh, under FWOP, would not result in a net loss of wetland habitat. If an area of swamp was determined to completely convert to marsh over the project life, then the converted habitat is treated as open water and evaluated using the fresh marsh model. However, other conventions may be proposed and considered.

In other instances, where swamp has converted to open water, a loss rate could be calculated for the WVA. In addition, the Coast 2050 reports provide estimated loss rates for swamp by mapping units (Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation and Restoration Authority 1998). That information should also be investigated and provided to the IRT for discussion during the WVA. However, it is important to note that due to the tree canopy, aerial imagery often poorly quantifies degradation of forested wetland habitat. Whichever scenario exists for the project area, whether it is loss of habitat to open water or conversion to marsh, the team should investigate the situation carefully and provide as much supporting documentation as possible.

As previously discussed for the marsh models, baseline habitat acreages must be adjusted to the current year.

Sampling Technique

The location and configuration of the area to be assessed direct the manner in which data are gathered. The plot size used by wetland forest ecologists of the southeastern United States is generally about 25 m x 25 m, or 625 m^2 (Conner et al. cites herein, Shaffer et al. 2003, 2009, Keim and King 2006). This plot size can be approximated by a circle constructed with a 41-foot (12.5 m) string which serves as the circle's radius. Perimeter trees can be flagged with survey tape to mark the plot while sampling. It is important to note that ecosystem function of forest interiors often is not reflected by forest edges (Gosselink et al. 1990, Llewellyn et al. 1996, Shaffer et al. 2009). Therefore, for larger forests data must be gathered at a distance (as much as 328 feet, 100 meters) from the edge that will minimize the edge's influence on the variables. Once the habitat of interest is reached, it may be necessary to sample several representative areas within it. Representative areas are generally reached by consensus and the process is operationally random. The center of each plot should be marked and the edge can be marked with string or flagging. Use of biodegradable string in hip chains to measure plot widths can be left in place during sampling; it provides a visible cue for the plot size and allows circular plots to be divided into quarters that aid in data gathering.

For mature even-aged forests with relatively few midstory trees, a factor 10 wedge prism may be utilized to gather data; however, data gathered for a project should utilize only one method. Because using a wedge prism can decrease the amount of time at a sample site, more sample sites can be measured. Proper techniques for using a wedge prism can be found in both the following US Forest Service and Corps publications: https://erdc-library.erdc.dren.mil/xmlui/bitstream/handle/11681/7195/TR%20EL-95-24.pdf?sequence=1&isAllowed=y and http://fia.fs.fed.us/library/field-guides-methods-proc/docs/core_ver_4-0_10_2007_p2.pdf.

There may be some situations (e.g., scientific research projects) when a more robust sampling scheme is necessary. In those situations, replicates of each forested habitat type (e.g., degraded, relict, throughput; Shaffer et al. 2009) should be located at least 1,640 feet (500 m) apart, yielding a theoretical equilateral triangle measuring 13.4 acres (5.4 ha) as the minimum area appropriate for data collection. The plot size used by wetland forest ecologists of the southeastern United States is generally about 25 m x 25 m, or 625 m^2 (Conner et al. cites herein, Shaffer et al. 2003, 2009, Keim and King 2006). This plot size can be approximated by a circle constructed with a 41-foot (12.5 m) string which serves as the circle's radius. Perimeter trees can be flagged with survey tape to mark the plot while sampling.

Variable Selection

Variable selection for the original swamp model was based on a review of; 1) Habitat Suitability Index (HSI) models published by the U.S. Fish and Wildlife Service (USFWS) for wood duck, barred owl, swamp rabbit, mink, downy woodpecker, and gray squirrel, 2) a community model for forest birds, published by USFWS, 3) "A Habitat Evaluation System for Water Resources Planning", published by USACE, and 4) a draft version of "A Community Habitat Evaluation Model for Bottomland Hardwood Forests in the Southeastern United States", coauthored by USACE and USFWS.

Several habitat variables appeared repeatedly in the various models. In general, it was concluded that those variables which occurred most frequently in the various models were the most important for assessing habitat quality. The species-specific (i.e., HSI) models concentrated on assessment of site-specific habitat quality features such as tree species composition, forest stand structure (understory, midstory, overstory conditions), stand maturity, and hydrology. Other models reviewed concentrated on how a site fits into the overall "landscape." The final variables selected were reviewed by representatives of the LDNR, the USFWS, USACE, the U.S. Environmental Protection Agency, and the Louisiana Department of Wildlife and Fisheries. The final list of variables includes 1) stand structure, 2) stand maturity, 3) hydrology, and 4) mean high salinity during the growing season, 5) size of contiguous forested area, 6) suitability and traversability of surrounding land use, and 7) disturbance.

After using the LDNR model for several years, CWPPRA recognized that for restoration projects several of the model variables were not being impacted, thus model sensitivity and project benefits were being compromised. Values for the non-impacted variables (i.e., size of the contiguous forested area, suitability and traversability of surrounding land uses, and disturbance) were the same under future without-project and future with-project conditions for CWPPRA swamp restoration projects. In an effort to improve model sensitivity, those variables were omitted. In addition, the stand structure, stand maturity, and hydrology variables were revised and a salinity variable was included in the model. A salinity variable was included in the original swamp model developed by the CWPPRA EnvWG and was recognized as an important variable in characterizing the habitat quality of swamp ecosystems. This CWPPRA revised model is equivalent to the CW Swamp WVA Community Model 1.1.

The CW Swamp WVA Community Model 2.0 includes the three landscape variables that were a part of the original LDNR swamp model. Therefore, the final list of variables includes; 1) stand structure, 2) stand maturity, 3) water regime, 4) mean high salinity during the growing season, 5) size of contiguous forested area, 6) suitability and traversability of surrounding land use, and 7) disturbance.

Subsidence and Sea Level Change

At the time of publication, current guidance for incorporating the direct and indirect physical effects of projected future sea level change across the period of analysis cycle in managing, planning, engineering, designing, constructing, operating, and maintaining USACE projects and systems of projects can be found in Engineering Regulation 1100-2-8162 (Incorporating Sea level change in civil works programs). This Regulation discusses sea level change and subsidence. Please use current regulation concerning subsidence sea level change located in the Planning Community Toolbox (https://planning.erdc.dren.mil/toolbox/guidance.cfm?Option).

Suitability Index Graph Development

Each of the WVA community models approved for USACE CW projects includes SI graphs for each variable. Suitability Index graphs are unique to each variable and define the relationship between that variable and habitat quality. Suitability Index (SI) graph development for this model was very similar to the process used for other community models such as the coastal marsh community models. 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, published and unpublished data and studies, and personal knowledge of those involved in model development. A review of contemporary, peer-reviewed scientific literature was also conducted for each of the variables, providing ecological support for the form of the SI graph for each of the variables (Appendix I).

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

Variable V1 - Stand structure

Most swamp tree species do not produce hard mast; consequently, wildlife foods predominantly consist of soft mast, other edible seeds, invertebrates, and vegetation. Because most swamp tree species produce some soft mast or other edible seeds, the actual tree species composition is not usually a limiting factor. More limiting is the presence of stand structure to provide resting, foraging, breeding, nesting, and nursery habitat and the medium for invertebrate production. This medium can exist as herbaceous vegetation, scrub-shrub/midstory cover, or overstory canopy and preferably as a combination of all three. This variable assigns the lowest suitability to sites with a limited amount of all three stand structure components, the highest suitability to sites with a significant amount of all three stand structure components, and mid-range suitability to various combinations when one or two stand structure components are present. A mature stand dominated by overstory trees also receives the highest suitability rating (SI = 1.0).

Variable V2 - Stand maturity

Because of man's historical conversion of swamp, the loss of swamp to saltwater intrusion, historical and ongoing timber harvesting, and a reduced tree growth rate in the subsiding coastal zone, swamps with mature sizeable trees are a unique but ecologically important feature. Older trees provide important wildlife requisites such as snags and nesting cavities and the medium for invertebrate production. Additionally, as the stronger trees establish themselves in the canopy, weaker trees are outcompeted and eventually die, forming additional snags and downed treetops that would not be present in younger stands.

The SI for this variable is based upon the average diameter-at-breast height (dbh) for canopy-dominant and canopy co-dominant trees within the plot/sample. The suitability graph assumes that snags, cavities, downed treetops, and invertebrate production are present in suitable amounts when the average dbh of canopy-dominant and canopy-codominant trees is above 16 inches for baldcypress and above 12 inches for tupelo gum and other species. Therefore, stands with those characteristics are considered optimal for this variable (SI = 1.0). This variable utilizes two SI graphs, one for baldcypress and one for tupelo gum and other species, and a weighted SI value is calculated. The weighted SI is calculated using the basal area for baldcypress and the basal area for tupelo gum and other species.

Another important consideration for this variable is stand density, measured in terms of basal area (ft^2). A scenario sometimes encountered in mature swamp ecosystems is an overstory consisting of a very few, widely-scattered, mature baldcypress. If stand density was not considered, and average dbh only, then those stands would receive a high SI for this variable without providing many of the important habitat components of a mature swamp ecosystem, specifically a suitable number of trees for nesting, foraging, and other habitat functions. Therefore, the SI for this variable is dependent on average dbh and total basal area which is used as a measure of stand density. The weighted SI is multiplied by a basal area factor which takes into account stand density (i.e., total basal area).

Variable V3 - Water regime

This variable considers the duration and amount of water flow/exchange. Four flow/exchange and four flooding duration categories are described to characterize the water regime. The optimal water regime is assumed to be seasonal flooding with abundant and consistent riverine/tidal input and water flow-through (SI=1.0). Seasonal flooding with periodic drying cycles is assumed to contribute to increased nutrient cycling (primarily through oxidation and decomposition of accumulated detritus), increased vertical structure complexity (due to growth of other plants on the swamp floor), and increased recruitment of dominant overstory trees. In addition, abundant and consistent input and water flow-through is optimal, because under that regime the full functions and values of a swamp in providing fish and wildlife habitat are assumed to be maximized. Temporary flooding is also assumed to be desirable. Habitat suitability is assumed to decrease as water exchange between the swamp and adjacent systems is reduced. The combination of permanently flooded conditions and no water exchange (e.g., an impounded swamp where the only water input is through rainfall and the only water loss is through evapotranspiration and ground seepage) is assumed to be the least desirable (SI=0.1). Those conditions can produce poor water quality during warm weather, reducing fish use and invertebrate production.

Variable V4 - Mean high salinity during the growing season

Mean high salinity during the growing season (i.e. March 1 to October 31) is defined as the average of the upper 33% of salinity measurements taken during the specified period of record. Similar to V_2 (Stand Maturity), this variable also utilizes two SI graphs, one for baldcypress and one for tupelo gum and other species, and a weighted SI value is calculated. The weighted SI is calculated using the basal area for baldcypress and the basal area for tupelo gum and other species utilized for V_2.

Baldcypress is able to tolerate higher salinities than other swamp species. Thus, optimal conditions for baldcypress are assumed to occur at mean high salinities of less than 1.5 parts per thousand (ppt). Optimal salinities for other species such as tupelo gum and many herbaceous species are assumed to occur at mean high salinities less than 0.5 ppt. Habitat suitability is assumed to decrease rapidly at mean high salinities in excess of 1.5 ppt for baldcypress and in excess of 0.5 ppt for other swamp species.

Variable V5 – Size of Contiguous Forested Area

Although edge and diversity, which are dominant features of small forested tracts, are important for certain wildlife species, it is important to understand four concepts: 1) species which thrive in edge habitat are highly mobile and presently occur in substantial numbers, 2) because of forest fragmentation and timber harvesting, edge and diversity are quite available, 3) most species found in "edge" habitats are "generalists" in habitat use and are quite capable of existing in larger tracts, and 4) those species in greatest need of conservation are "specialists" in habitat use and require large forested tracts. Therefore, the basic assumption for this variable is that larger forested tracts are less common and offer higher quality habitat than smaller tracts. For this model, tracts greater than 500 acres in size are considered large enough to warrant being considered optimal.

Use of geographic information system (GIS) and satellite photographs is the primary method of determining the contiguous forested area. DOQs provide the best resolution for this variable; more than one year can be utilized to verify any breaks in contiguity.

Variable V6 – Suitability and Traversability of Surrounding Land Uses

Many wildlife species commonly associated with swamp will often use adjacent areas as temporary escape or resting cover and seasonal or diurnal food sources. Surrounding land uses which meet specific needs can render a given area of swamp more valuable to a cadre of wildlife species. Additionally, the type of surrounding land use may encourage, allow, or discourage wildlife movement between two or more desirable habitats. Land uses which allow such movement essentially increase the amount of habitat available to wildlife populations. The weighting factor assigned to various land uses reflects their estimated potential to meet specific needs and allow movement between more desirable habitats.

The most recent aerial/satellite photographs and habitat/land classification databases should be used for this variable. A 0.5 mile buffer should be delineated around the project area (use of a buffer tool in GIS simplifies this step) and within that buffer, the land cover types designated in V5 should be identified and acreage determined. Land loss rates and/or habitat conversion rates should be applied to these areas provided that the land cover type percentages will change enough to change this variable’s value.

Variable V7 – Disturbance

Human-induced disturbance can displace individuals, modify home ranges, interfere with reproduction, cause stress, and force animals to use important energy reserves. The effect of disturbance is a factor of the distance to disturbance and the type of disturbance. A separate suitability graph was developed for each of those factors and the results are combined to yield a single Suitability Index for Disturbance. If the source of disturbance is located beyond 500 feet from the perimeter of the site or if the type of disturbance is "insignificant", the effects of disturbance are assumed to be negligible and SI = 1.0. If the source of disturbance is located within 50 feet of the perimeter of the site and the disturbance is "Constant or Major", the effects of disturbance are assumed to be maximum and SI = 0.1. Other combinations of distance to, and type of, disturbance yield moderate SI's of 0.26, 0.41, 0.5, and 0.65.

Use of GIS and satellite photographs is the primary method of determining the type of possible disturbance such as highways, industrial areas, waterways, agriculture, homes, etc. Because this variable does not need as fine a resolution as V5, the use of aerial/satellite photographs other than DOQs may be sufficient.

Habitat Suitability Formulas

During development, Variables V_1 and V_3, stand structure and water regime, were considered the most important variables in characterizing the habitat quality of a swamp and were given greater influence. Variable V_2, stand maturity, was given slightly less weight than stand structure and water regime. Variable V_4, salinity, was deemed less important than V_1, V_2, and V_3. The landscape variables (V_5, V_6, and V_7) were deemed to be the least important and were all given equal and lowest influence. All variables are grouped to produce a geometric mean and variable influence is only controlled by the weight (i.e., exponent) assigned to each variable.

HSI Calculation: $HSI = (SIv_1^{3} \times SIv_2^{2.5} \times SIv_3^{3} \times SIv_4^{1.5} \times SI_{V5} \times SI_{V6} \times SI_{V7})^{1/13}$

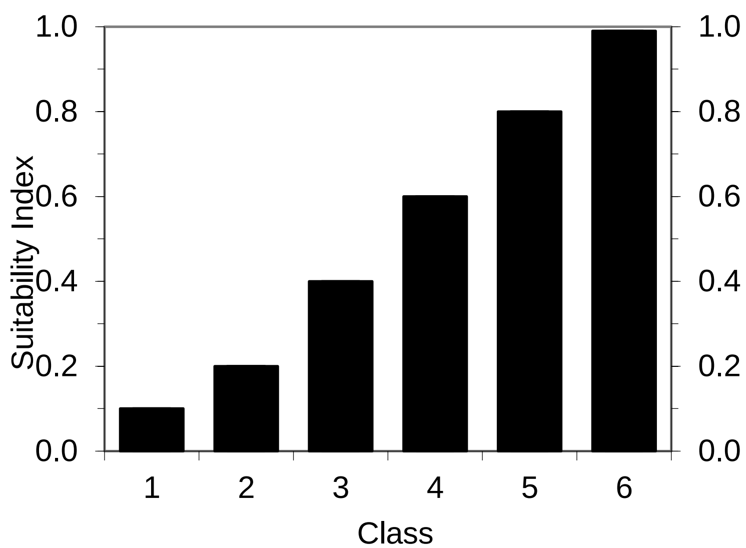
SWAMP

Variable V_1 Stand structure

Each component of stand structure should be viewed independently to determine the percent closure or coverage.

	Overstory		**Scrub-shrub/ Midstory Cover**		**Herbaceous Cover**
Class 1.	<33%				
Class 2.	≥33%<50%	and	<33%	and	<33%
Class 3.	≥33%<50%	and	≥33%	or	≥33%
			OR		
	≥50%<75%	and	<33%	and	<33%
Class 4.	≥50%<75%	and	≥33%	or	≥33%
			OR		
	≥75%	and	<33%	and	<33%
Class 5.	≥33%<50%	and	≥33%	and	≥33%
Class 6.	≥50%	and	≥33%	and	≥33%
			OR		
	≥75%	and	≥33%	or	≥33%

Suitability Graph



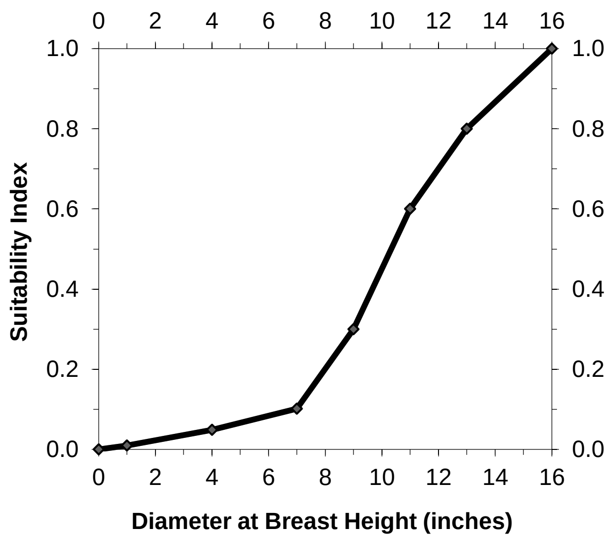
SWAMP

Variable V_2 Stand maturity

Average dbh of canopy-dominant and canopy-codominant trees.

Notes:
1. Canopy-dominant and codominant trees are those whose crown rises above or is an integral part of the overstory.
2. For trees with buttress swell, dbh is the diameter measured at 12" above the swell.
3. The basal area for baldcypress and the basal area for tupelo gum and other species must be calculated to determine a weighted SI.
4. The SI for this variable is multiplied by the factors in the table below depending on stand density.

Suitability Graph



Suitability Index Line Formulas for baldcypress:

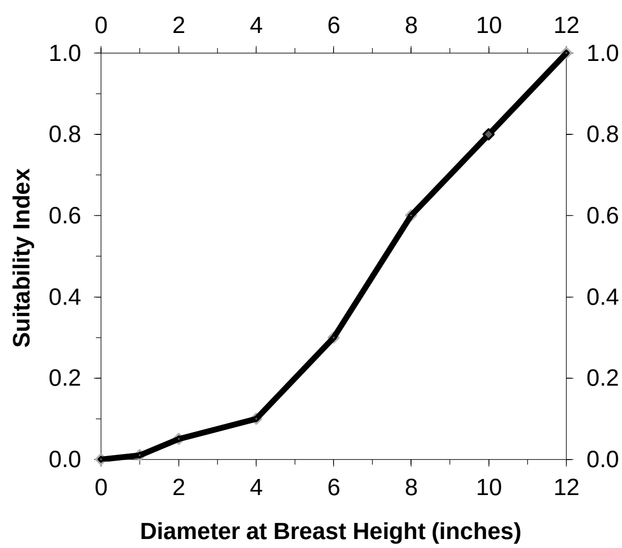
If dbh = 0 then SI = 0
If 0 < dbh $\le$ 1 then SI = .01 * dbh
If 1 < dbh $\le$ 4 then SI = (.013 * dbh) - .002
If 4 < dbh $\le$ 7 then SI = (.017 * dbh) - .019
If 7 < dbh $\le$ 9 then SI = (.1 * dbh) - .6
If 9 < dbh $\le$ 11 then SI = (.15 * dbh) - 1.05
If 11 < dbh $\le$ 13 then SI = (.1 * dbh) - .5
If 13 < dbh $\le$ 16 then SI= (.067 * dbh) - .072
If dbh > 16 then SI = 1.0

Suitability Index Line Formulas for tupelogum et al.:

If dbh = 0 then SI = 0
If 0 < dbh $\le$ 1 then SI = .01 * dbh
If 1 < dbh $\le$ 2 then SI = (.04 * dbh) - .03
If 2 < dbh $\le$ 4 then SI = .025 * dbh
If 4 < dbh $\le$ 6 then SI = (.1 * dbh) - .3
If 6 < dbh $\le$ 8 then SI = (.15 * dbh) - .6
If 8 < dbh $\le$ 12 then SI = (.1 * dbh) - .2
If dbh > 12 then SI = 1.0

Density	Basal Area	Factor
Open	$<40ft^2$	0.2
Moderately Open	$40ft^2 \le BA \le 80ft^2$	0.4
Moderate	$81ft^2 \le BA \le 120ft^2$	0.6
Moderately Dense	$121ft^2 \le BA \le 160ft^2$	0.8
Dense	$>161ft^2$	1.0

Suitability Graph



SWAMP

Variable V_3 Water regime

		Flow/Exchange			
		High	Moderate	Low	None
Flooding Duration	Permanent	0.65	0.45	0.30	0.10
	Semi-Permanent	0.75	0.65	0.45	0.25
	Seasonal	1.00	0.85	0.70	0.50
	Temporary	0.9	0.75	0.65	0.40

Flooding Duration

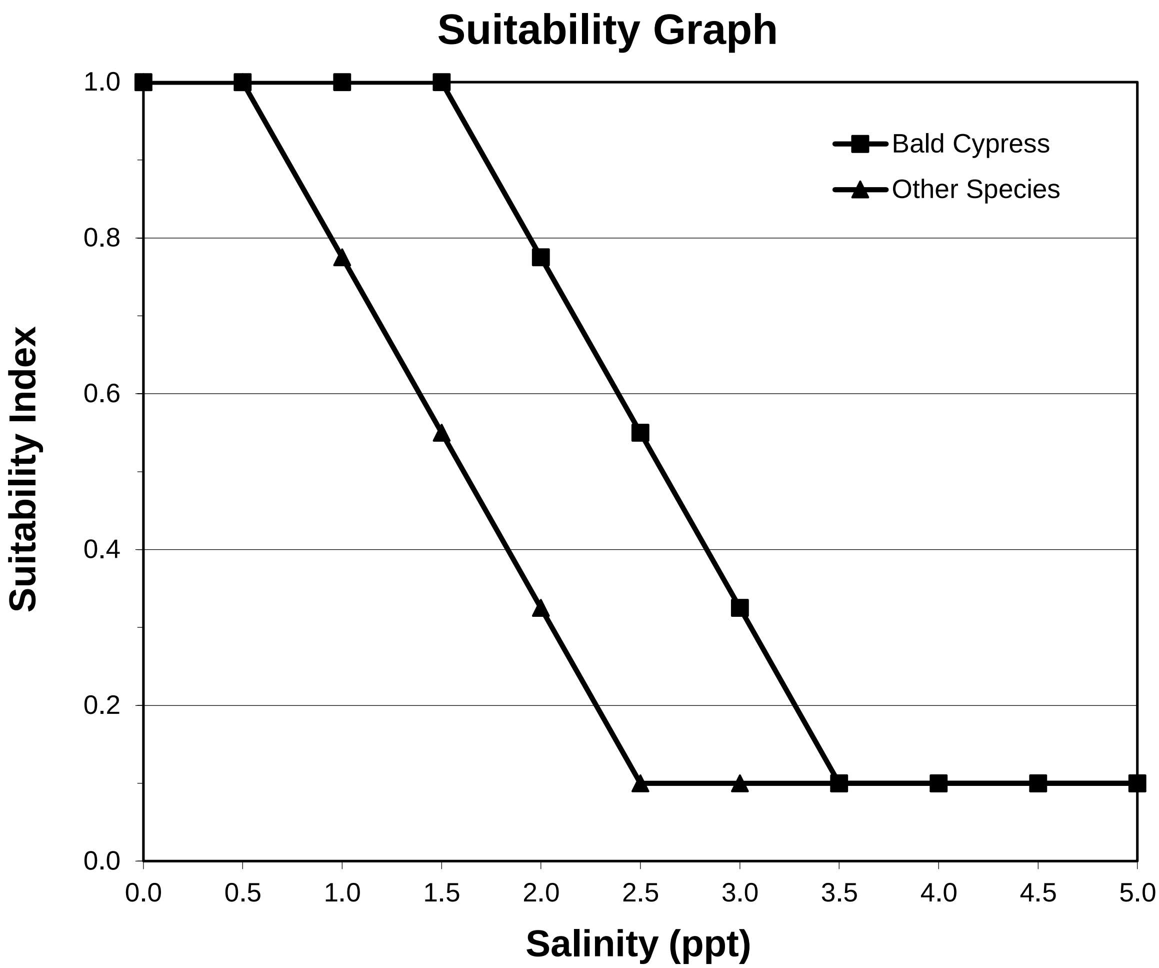
1. Permanently Flooded/Dewatered: Water covers the substrate throughout the year in all years except in extreme drought; or water no longer covers the substrate throughout the year in all years except in major flood events.
2. Semipermanently Flooded: Surface water is present throughout the growing season and may extend beyond the growing season in most years.
3. Seasonally Flooded: Surface water is present for extended periods, especially in the growing season, but is absent by the end of the growing season in most years.
4. Temporarily Flooded: Surface water is present for brief periods during the growing season, but the water table usually lies below the surface for most of the year.

Flow/Exchange

1. High: Receives abundant and consistent riverine input and through-flow.
2. Moderate: Moderate water exchange through riverine and/or tidal input.
3. Low: Limited water exchange through riverine and/or tidal input or just rainfall on an area that is not efficiently drained. Area may be under pump or forced drainage, but is managed for forest and/or ecological health.
4. None: No water exchange (stagnant, impounded) or under an efficient drainage system. Area may be under pump or forced drainage, but is not managed for forest and/or ecological health.

SWAMP

Variable V_4 Mean high salinity during the growing season (March to November)



Baldcypress Salinity Regression

If 0 < ppt <= 1.5, then SI = 1.0
If 1.5 > ppt < 3.5, then SI = (-0.45 * ppt) + 1.675
If ppt >= 3.5 then SI = 0.1

All Other Tree Species Salinity Regression

If 0 < ppt <= 0.5, then SI = 1.0
If 0.5 > ppt < 2.5, then SI = (-0.45 * ppt) + 1.225
If ppt >= 2.5 then SI = 0.1

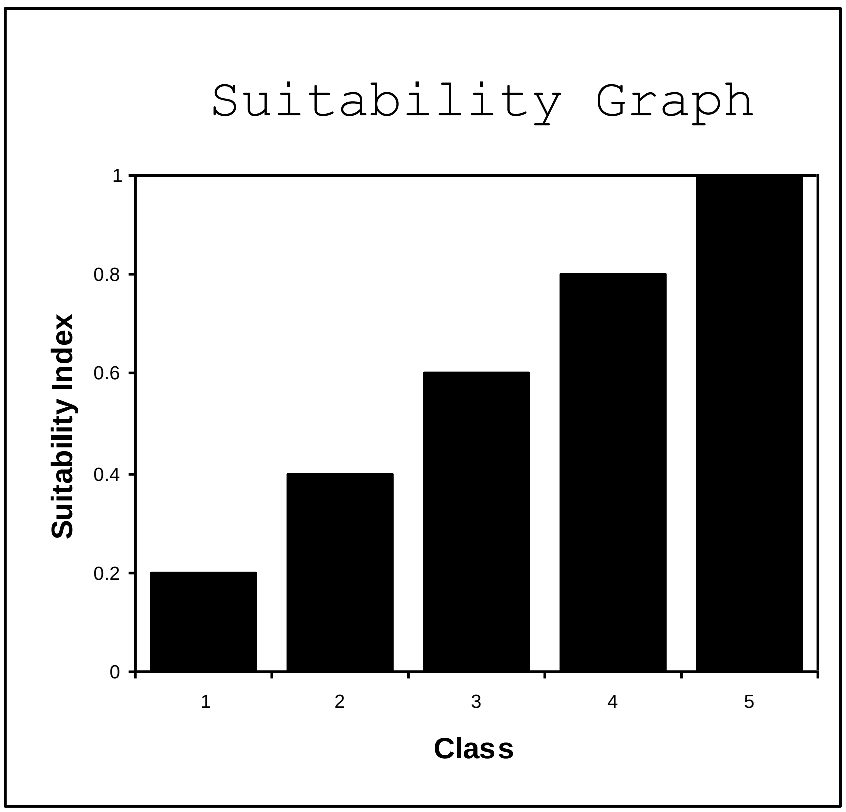
Mean high salinity during the growing season is defined as the average of the highest 33 percent of consecutive salinity readings taken during the period of record (March 1 through October 31).

SWAMP

Variable V_5 Size of Contiguous Forested Area

Note: Corridors less than 75 feet wide do not constitute a break in the forested area contiguity.
Note: If dbh is < 5 then this variable is not used.

Class 1.	0 to 5 acres
Class 2.	5.1 to 20 acres
Class 3.	20.1 to 100 acres
Class 4.	100.1 to 500 acres
Class 5.	> 500 acres



Variable V_6 Suitability and Traversability of Surrounding Land Uses

Within a 0.5 mile of the perimeter of the site, determine the percent of the area that is occupied by each of the following land uses (must account for 100% of the area). Multiply the percentage of each land use by the suitability weighting factor shown below, add the adjusted percentages and divide by 100 for a Suitability Index for this variable.

Land Use	**Weighting Factor**		**% of 0.5 mile circle**		**Weighted Percent**
Bottomland hardwood, other forested areas, marsh habitat, etc.	1.0	X		=	
Abandoned agriculture, overgrown fields, dense cover, etc.	0.6	X		=	
Pasture, hayfields, etc.	0.4	X		=	
Active agriculture, open water	0.2	X		=	
Nonhabitat: linear, residential, commercial, industrial development, etc.	0.01	X		=	
					___ /100 = SI

SWAMP

Variable V_7 Disturbance

The effect of disturbance is a factor of the distance to, and the type of, disturbance, hence both are incorporated in the SI formula.

Note: Linear and/or large project sites may be exposed to various types of disturbances at various distances. The SI for this variable should be weighted to account for those variances.

Distance Classes	**Type Classes**
Class 1. 0 to 50 ft.	**Class 1.** Constant/Major. (Major highways, industrial, commercial, major navigation.)
Class 2. 50.1 to 500 ft.	**Class 2.** Frequent/Moderate. (Residential development, moderately used roads, waterways commonly used by small to mid-sized boats).
Class 3. > 500 ft.	**Class 3.** Seasonal/Intermittent. (Agriculture, aquaculture.)
	Class 4. Insignificant. (Lightly Used roads and waterways, individual homes, levees, rights of way).

Suitability Indices for Distance/Type Class

	Type Class				
		1	2	3	4
Distance Class	1	.01	.26	.41	1
	2	.26	.50	.65	1
	3	1	1	1	1

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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 V1 – Stand Structure

From a community perspective, a swamp containing overstory and midstory trees, as well as herbaceous ground cover, in roughly even amounts, offers the highest degree of food and shelter for a diverse assemblage of wildlife (Brokaw and Lent 1999, Haila 1999, Bodie and Semlitsch 2000, Chambers et al. 2005). However, at present, a swamp in coastal Louisiana with less than 50% overstory cover is either on a trajectory of degradation (Keim and King 2006, Shaffer et al. 2009a) or is a young or recently cut over ecosystem on a trajectory towards maturity. Healthy mature swamp will likely have low cover of herbaceous vegetation, due to light limitation and prevalent flooding (Chambers et al. 2005). Conversely, as swamps degrade, generally due to altered hydrologic conditions, saltwater intrusion, or both, the canopy begins to open allowing midstory, shrub-scrub and groundcover vegetation to increase (Allen 1958; Allen 1962, Conner et al. 1981, White 1983, Barras et al. 1994, llen et al. 1996, Aust et al. 1998, Thomson et al. 2002, Conner and Inabinette 2003, Shaffer et al. 2009a). Therefore, swamp with 50% overstory coverage receives an SI of 1.0.

With respect to Neotropical migratory birds, it has been shown that swamps with intact overstory canopies are more species diverse than degraded swamps (Zoller 2004). The reduction in species diversity was believed to be a result of a reduction of the vertical structure of the forest. Virtually all of the eastern land bird species in the United States and numerous species from the western USA migrate through the coastal forests of Louisiana and utilize the forest canopy (Lowery 1974). Some bird species of special interest, such as the bald eagle and swallow-tailed kite, which nest in the wetland forests of coastal Louisiana, require very tall overstory trees for nesting.

A step function is necessary in the V_1 Suitability Index relationship, because most steps require categorical rules concerning ground, midstory, and overstory cover. In general, combinations of ground cover and midstory cover rank higher than either category alone. From a community perspective, the habitat value certainly increases as vertical and horizontal structure of the forest increases (Bormann and Likens 1979, Oliver and Larson 1990, Perry 1994, Kimmins 1996, Barnes et al. 1998, Chambers et al. 2005). Therefore the ‘and’ ‘or’ step increases are grounded in the literature. From a restoration perspective, a healthy, mature swamp must receive a Suitability Index of 1.0; this swamp will most likely be characterized by near complete overstory canopy closure with little light penetrating to the forest floor.

Variable V2 – Stand Maturity

The healthiest swamps in coastal Louisiana are those characterized by high basal area and large trees (Conner and Day 1976, Nessel and Bayley 1984, Nessel et al. 1982, Conner et al. 1981, Muzika et al. 1987, Megonigal et al. 1997, Hoeppner et al. 2008, Shaffer et al. 2009a). An inverse relationship exists between the density of large overstory trees and hurricane damage (Shaffer et al. 2009a, b), so mature stands better protect faunal community assemblages. Certain species of special interest, such as the Louisiana black bear and the Rafinesque big-eared bat frequently use hollows of large trees for nesting (Taylor 1971, Weaver et al. 1990, Cochran 1999, Hoffman 1999, Hightower et al. 2002, Gooding and Langford 2004). Large hollow water tupelo characteristic of older swamp forests appear particularly important to the Rafinesque big-eared bat (Cochran 1999, Lance et al. 2001, Gooding and Langford 2004).

In general, stand maturity is the most sensitive predictor of FWP vs. FWOP conditions, because it is a surrogate for net primary production, the single best integrator for ecosystem function (Conner and Day 1976, Costanza et al. 1989, Gosselink et al. 1990, Odum 1996, Costanza et al. 1997, Mitsch and Gosselink 2007). Addition of basal area to the 2001 version of the model was imperative (Carter et al. 1973, Brown 1981, Conner et al. 1981, Taylor 1985, Dicke and Toliver 1990, Wilhite and Toliver 1990, Mitsch et al. 1991, Conner and Day 1992), as without it a single large overstory and midstory tree could yield a Suitability Index of 1.0.

Variable V3 – Water Regime

The optimal hydrology for baldcypress – water tupelo swamps consists of several periods of flooding and drawdown, or a “pulsing” hydrology (Montz and Cherubini 1973, Conner and Day 1976, Mitsch et al. 1991, Day et al. 1995, Odum et al. 1995, Visser and Sasser, 1995, Day et al. 2009). A pulsing hydrology also will promote regeneration events as baldcypress and water tupelo seeds must have a bare, moist seedbed to germinate and will not germinate under water (Mattoon 1915, DuBarry 1963).

Wetland and aquatic invertebrates are a major link in food web dynamics of the coastal forests of Louisiana and elsewhere. Differences in invertebrate distribution, composition, and density among wetland habitats are driven by hydrologic regimes and vegetation structure (Murkin et al. 1992, Mitsch and Gosselink 2007). Wetland and aquatic invertebrate productivity is critical for the maintenance of fish and wildlife populations (Chambers et al. 2005). Impounded, stagnant water can reduce invertebrate production as well as diversity (Batzer et al. 1999) and therefore negatively affect the fish and wildlife that depend on them as a food source. Furthermore, impoundments have detrimental effects on mature trees through reduced net production, crown dieback, increased susceptibility to insects and pathogens, and increased mortality (Conner et al. 1981, King 1995, Keeland et al. 1997).

Variable V4 – Salinity

In terms of FWP vs. FWOP conditions, salinity is an important variable to include in the WVA swamp model (Penfound and Hathaway 1938, Pezeshki et al. 1989, Conner 1994, Allen et al. 1994, USACE 1999, Thomson et al. 2002, Conner and Inabinette 2003, van Heerden et al., 2007, FitzGerlad et al., 2008, Shaffer et al. 2009a,b). However, unlike Stand Maturity, two relationships are necessary to accurately differentiate between the saltwater tolerances of baldcypress vs. water tupelo, ash, and swamp red maple (Dickson and Broyer 1972, Pezeshki et al. 1989, Keeland and Sharitz 1995, Pezeshki et al. 1995, Conner et al. 1997, Souther-Effler 2004, Chambers et al. 2005, Shaffer et al. 2009a,b). We know, for example, that the average high salinity in the Manchac/Maurepas area was about 1.5 ppt for a period of approximately 50 years (Wiseman et al. 1990, Thomson et al. 2002). This salinity was sufficiently high to cause massive degradation and lethality to water tupelo, ash, and swamp red maple trees, but not baldcypress (Shaffer et al. 2009a). The drought of 1998 – 2000, however, caused salinity extremes (Thomson et al. 2002) sufficient to kill century-old baldcypress (Shaffer et al. 2009a). The slope for water tupelo, ash, and maple should range between 0.5 ppt and 2.5 ppt (Pezeshki et al. 1989, Conner and Askew 1993, Conner et al. 1997, McCarron et al. 1998, Chambers et al. 2005), whereas that for baldcypress should range between 1.5 and 3.5 ppt (USACE 1963, Conner and Askew 1993, Krauss et al. 1998, Krauss et al., 2000, Souther-Effler 2004, Chambers et al. 2005, Shaffer et al. 2009a, b).

With increased rate of relative sea-level rise (FitzGerald et al. 2008), saltwater intrusion into coastal swamps is expected to increase, which will reduce net primary production and increase mortality (Allen 1992, Krauss et al. 2000, Pezeshki et al. 1990, Souther-Effler 2004). Baldcypress may tolerate salinities as high as 7 ppt, but productivity and survivorship decline with salinities > 3 ppt (Pezeshki et al. 1990, Conner and Askew 1993, Conner 1994, Pezeshki et al. 1995, Allen et al. 1996, Shaffer et al. 2009b).

<u>Variable V5 - Size of Contiguous Forest</u>

Whereas single blocks of forested wetlands used to cover hundreds of thousands of hectares in the Mississippi Alluvial Plain, there now remain only isolated fragments, most less than 250 acres (100 ha) in size and most of these are surrounded by agricultural fields (Gosselink et al. 1990b). Certain species of Neotropical migratory birds require a minimum of 6,900 acres (2,800 ha) of forest interior to sustain viable populations (Robbins et al. 1989, Twedt and Loesch 1999). In their plan to restore large tracks of forested wetlands, The Nature Conservancy focuses on three migratory-bird guilds, namely Bachman's warbler which requires 9,880 acres (4,000 ha) of forest interior for successful breeding habitat, the Cerulean warbler requiring 19,770 acres (8,000 ha) of forest interior, and the swallow-tailed kite requiring 98,840 acres (40,000 ha) of interior forest (Shaffer et al. 2005, Weitzell et al. 2003). Gosselink and Lee (1989) estimate that 494,200 acres (200,000 ha) of forested habitat is required to sustain a viable population of the Louisiana black bear. Fragmented forested wetlands were found to reduced species richness and abundance of plants, macroinvertebrates, amphibians, and birds with greater numbers of exotic species (Faulkner, 2004). In general, ecosystem function of forest interiors often is not reflected by forest edges (Gosselink et al. 1990a,b, Llewellyn et al. 1996, Saunders et al. 1991, Shaffer et al. 1992, 2009). Habitat loss and fragmentation has been shown to significantly decrease bird populations (e.g., Sauer et al. 2017). To date, the forested wetlands of coastal Louisiana have been reduced by over 80% (Llewellyn et al. 1996, Shaffer et al. 2005, Weitzell et al. 2003, Shaffer et al., 2016), rendering large contiguous patches extremely valuable for floral and faunal species diversity (Gosselink et al. 1990). Large expanses of forested wetland dominated parts of coastal Louisiana (e.g., the Pontchartrain Basin was over 90% swamp; Saucier 1963, Shaffer et al., 2016). Much of this has transitioned from Cypress-Tupelo swamp to marsh (Shaffer et al., 2009).

Variable V6 - Suitability and Traversability of Surrounding Habitat

The quality of a bottomland hardwood forest patch is clearly associated with the type of habitat that surrounds it (Gosselink and Lee 1989, Rudis 1995). Certain species of birds and mammals will not traverse other types of habitats, especially those developed by humans, to move from one patch of forested wetland to another (Gosselink and Lee 1989, Gosselink et al. 1990b). Fragmented forested wetlands were found to reduced species richness and abundance of plants, macroinvertebrates, amphibians, and birds with greater numbers of exotic species (Faulkner, 2004). Clearly habitat types such as abandoned agricultural fields or pastures are of higher habitat value than cultivated fields, residential areas, or busy streets.

Variable V7 – Disturbance

Human-induced disturbance can displace individuals, modify home ranges, interfere with reproduction, cause stress, and force animals to use important energy reserves. The effect of a disturbance is a function of the type of disturbance and the distance of the disturbance to the habitat in question (Rudis 1995). Many species of birds and mammals are highly sensitive to disturbance (Twedt et al. 1999, Wigley and Roberts 1997). As described above, animals have different habitat requirements from 6,900 acres (2,800 ha) for certain Neotropical migrants to 494,200 acres (200,000) ha for the Louisiana black bear. In general, ecosystem function of forest interiors often is not reflected by forest edges prone to disturbance (Gosselink et al. 1990a, b, Llewellyn et al. 1996, Shaffer et al. 1992, Shaffer et al., 2009, Shaffer et al., 2016). Furthermore, as patch size increases, the effects of outside disturbances have been shown to decrease (Rudis 1993, 1995). Fifty percent less Neotropical migratory birds were reported in disturbed forested wetlands than undisturbed forested wetlands (Croonquist and Brooks 1993). Similarly, lower frog and toad abundances were lower in urbanized habitats than forested wetlands (Knutson et al., 1999).

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Appendix II
Document Revisions

Version 1.0 – April 2010 document developed via the Corps' WVA certification process.

Version 1.1 – April 10, 2012
1) Pertinent sections from the Procedural Manual incorporated

Version 1.2 – April 26, 2012
1) Variable V4 SI graph and line formulas corrected. The previous version contained incorrect SI curves and incorrect line formulas which were not consistent with the discussion in Appendix A. The line formulas have also been corrected in the Excel spreadsheet.

Version 2.0 – November 2018 document revised via the USACE PMIP process; including the re-inclusion of three landscape variables V5, V6, V7 and update of V1 to include all possibilities.

Appendix III

Project Information Sheet Format

Project Name:

Sponsoring Agency: List Environmental and Engineering Work Group Contacts

Project Location and Description: Describe project location (Coast 2050 region, basin, parish, nearby cities, important bodies of water, total acres, wetland type, etc.). Include a project map.

Problem: Discuss the major causes (historical and current) of habitat loss/degradation in the project area.

Objectives: How will the project address the major causes of habitat loss/degradation in the project area? What are the specific objectives of the project?

Project Features: List all project features including their locations, dimensions, etc. The project map should include the locations of all project features.

Monitoring and Modeling Results for Similar Projects: Relevant monitoring reports and modeling studies should be discussed.

Miscellaneous: As necessary, discuss the following subjects as they relate to the project.

Climate change

Off site disturbances – these are generally the same FWOP and FWP.

Any project risks or uncertainties

V1 – Stand Structure

1) Discuss the historical and current vegetative community and any trends noted for the area.
2) Discuss the methods used to determine percent cover for each component of stand structure.

TY 0 – Existing cover values for overstory, midstory, and herbaceous cover.

FWOP – Provide cover values for each target year (TY) and include all assumptions. Use as many TYs as necessary and justify each.
TY 1 –
TY X –
TY Y –
TY 50 –

FWP – Provide cover values for each target year (TY) and include all assumptions. Use as many TYs as necessary and justify each.
TY 1 –
TY X –
TY Y –
TY 50 –

V2 – Stand Maturity

1) Discuss methods used to collect dbh values for the baseline condition. Provide calculations for basal area.

TY 0 – Average dbh and basal area for baldcypress. Average dbh and basal area for tupelogum and all other species.

FWOP – Provide dbh and basal area values for each target year (TY) and include all assumptions. Use as many TYs as necessary and justify each.
TY 1 –
TY X –
TY Y –
TY 50 –

FWP – Provide dbh values for each target year (TY) and include all assumptions. Use as many TYs as necessary and justify each.
TY 1 –
TY X –
TY Y –
TY 50 –

V3 – Water Regime

1) Discuss methods used to determine the flooding duration and degree of flow/exchange for the baseline condition.

TY 0 – Flooding duration and degree of water flow/exchange.

FWOP – Determine flooding duration and degree of exchange for each target year (TY) and include all assumptions. Use as many TYs as necessary and justify each.
TY 1 –
TY X –
TY Y –
TY 50 –

FWP – Determine flooding duration and degree of exchange for each target year (TY) and include all assumptions. Use as many TYs as necessary and justify each.
TY 1 –
TY X –
TY Y –
TY 50 –

V4 – Mean high salinity during the growing season

1) Discuss methods used to determine the mean high salinity during the growing season for the baseline condition. Provide a location map for gages/stations used in the analysis.

TY 0 – Mean high salinity during the growing season.
FWOP – Determine mean high salinity during the growing season for each target year (TY) and include all assumptions. Use as many TYs as necessary and justify each.
TY 1 –
TY X –
TY Y –
TY 50 –

FWP – Determine mean high salinity during the growing season for each target year (TY) and include all assumptions. Use as many TYs as necessary and justify each.
TY 1 –
TY X –
TY Y –
TY 50 –

Literature Cited

Other Supporting Information

Part 4:WVA Bottomland Hardwoods Community Model for Civil Works Version 1.2

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

Wetland Value Assessment Bottomland Hardwoods Community Model for Civil Works (Version 1.2)

Revised from the Bottomland Hardwoods Community Model developed by the Environmental Working Group of the Coastal Wetlands Planning, Protection and Restoration Act

November 2018

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WETLAND VALUE ASSESSMENT METHODOLOGY
Bottomland Hardwoods Community Model

Introduction

This document describes revisions to the Wetland Value Assessment (WVA) Coastal Bottomland Hardwoods (BLH) Community Model for recertification 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 (CW) projects.

The Wetland Value Assessment (WVA) methodology is a quantitative habitat-based assessment methodology developed for use in determining wetland benefits of project proposals submitted for funding under the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA). The WVA was developed by the CWPPRA Environmental Work Group (EnvWG) after the passage of CWPPRA in 1990. The EnvWG includes members from U.S. Fish and Wildlife Service, Louisiana Coastal Protection and Restoration Authority, Natural Resources Conservation Service, National Oceanic and Atmospheric Administration, Environmental Protection Agency, and USACE. Various other subject matter experts, such as professors and scientists, also helped develop the original WVAs. The WVA quantifies changes in fish and wildlife habitat quality and quantity that are expected to result from a proposed wetland restoration project. The WVA operates under the assumption that optimal conditions for fish and wildlife habitat within a given coastal wetland habitat 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 or expressed through the use of community models developed specifically for each habitat type. The results of the WVA, measured in Average Annual Habitat Units (AAHUs), can be combined with cost data to provide a measure of the effectiveness of a restoration project in terms of annualized cost per AAHU gained. In addition, the WVA methodology could provide an estimate of the number of AAHUs negatively impacted by a CW project.

The WVA community models have been designed to function at a community level and therefore attempt to define an optimum combination of habitat conditions for all fish and wildlife species utilizing a given habitat type. Each model consists of 1) a list of variables that are considered important in characterizing fish and wildlife habitat, 2) a Suitability Index (SI) graph for each variable, which defines the assumed relationship between habitat quality (Suitability Index) and different variable values, and 3) a mathematical formula that combines the Suitability Index for each variable into a single value for habitat quality; that single value is referred to as the Habitat Suitability Index, or HSI. The output of each model (the HSI) is assumed to have a linear relationship with the suitability of a coastal wetland system in providing fish and wildlife habitat.

This model was developed to determine the suitability of bottomland hardwoods habitat in providing resting, foraging, and nesting habitat for a diverse assemblage of wildlife species. The model has been generally applied to areas with at least 40 percent of the woody vegetation canopy consisting of species such as oaks, hickories, American elm, green ash, sweetgum, sugarberry, boxelder, persimmon, honeylocust, red mulberry, eastern cottonwood, and American sycamore. If greater than 40 percent of the canopy consists of any combination of baldcypress, tupelogum, red maple, buttonbush, and/or water elm, then the swamp community model should be applied.

USACE Planning Models Improvement Program

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 June 13, 2018, USACE, Mississippi Valley Division, New Orleans District (CEMVN) initiated coordination requesting feedback from WVA experts from the US Fish and Wildlife Service (David Walther, Cathy Breaux, and Kevin Roy), the National Marine Fisheries Service (Patrick Williams and later Dawn Davis on August 7, 2018), US Geological Survey (Michelle Fischer), the US Environmental Protection Agency (Raul Gutierrez), and Louisiana Department of Wildlife and Fisheries (Dave Butler and Kyle Balkum). The Natural Resource Conservation Service (Ron Boustany) was later included in the WVA reapproval coordination on August 20, 2018. On September 25, CEMVN also reached out to Daniel Allen from Fort Worth District (CESWF). In addition, Sharon McCarthy from Louisiana Department of Natural Resources, Office of Coastal Management provided LDNR WVA models for addressing mitigation potentials on September 28, 2018.

Geographic Scope

The maximum area that the bottomland hardwood models should be applied is the coastal forested wetlands in the southeastern United States. These wetlands share similar community structure and function (Gosselink et al. 1990, Mitsch and Gosselink 2007, Mitsch et al. 2009). Coastal forests from South Carolina to east Texas share a similar climate and respond both positively and negatively to the same environmental conditions.

The WVA model examined herein was designed to capture habitat suitability of the flora and associated fauna that inhabit bottomland hardwood forests of coastal Louisiana. While these community assemblages are similar across the above mentioned geographical area, they vary widely in special case species such as Rafinesque's big-eared bat (*Corynorhinus rafinesquii rafinesquii*), the bald eagle (*Haliaeetus leucocephalus*), the Louisiana black bear (*Ursus americanus lutelous*), and a variety of neotropical migratory songbirds.

Geographic Range of Applicability

Figure 1 indicates the geographical range of applicability for the Wetland Value Assessment Bottomland Hardwoods Community Model. This model was developed for bottomland hardwoods habitats of coastal Louisiana, which share common functions, values, and habitats with the rest of the southern United States (Wharton et al. 1982). Four coastal level III ecoregions, 34, 73, 75, and 76, were initially used to focus on potential coastal habitats in the Southern U.S (Daigle et al., 2006; Griffith et al., 2007). Level IV ecoregions within these were screened for applicability based on their likelihood to contain bottomland hardwoods habitats. After screening, 26 level IV ecoregions remain as the geographic range of applicability (Table 1). Potential users outside of the geographical range of applicability presented here are encouraged to coordinate with ECO-PCX prior to applying this WVA community model for their project.

Table 1. Level IV ecoregions being considered for geographical range of applicability for the Wetland Value Assessment Bottomland Hardwoods Community Model for Civil Works (Version 1.2).

Northern Humid Gulf Coastal Prairies	Gulf Coast Flatwoods
Southern Subhumid Gulf Coastal Prairies	Southwestern Florida Flatwoods
Floodplains and Low Terraces	Eastern Florida Flatwoods
Coastal Sand Plain	Okefenokee Plains
Lower Rio Grande Valley	Sea Island Flatwoods
Lower Rio Grande Alluvial Floodplain	Okefenokee Swamp
Texas-Louisiana Coastal Marshes	Bacon Terraces
Lafayette Loess Plains	Floodplains and Low Terraces
Southern Holocene Meander Belts	Sea Islands/Coastal Marsh
Southern Pleistocene Valley Trains	Big Bend Coastal Marsh
Southern Backswamps	Everglades
Inland Swamps	Big Cypress
Deltaic Coastal Marshes and Barrier Islands	Miami Ride/Atlantic Coastal Strip

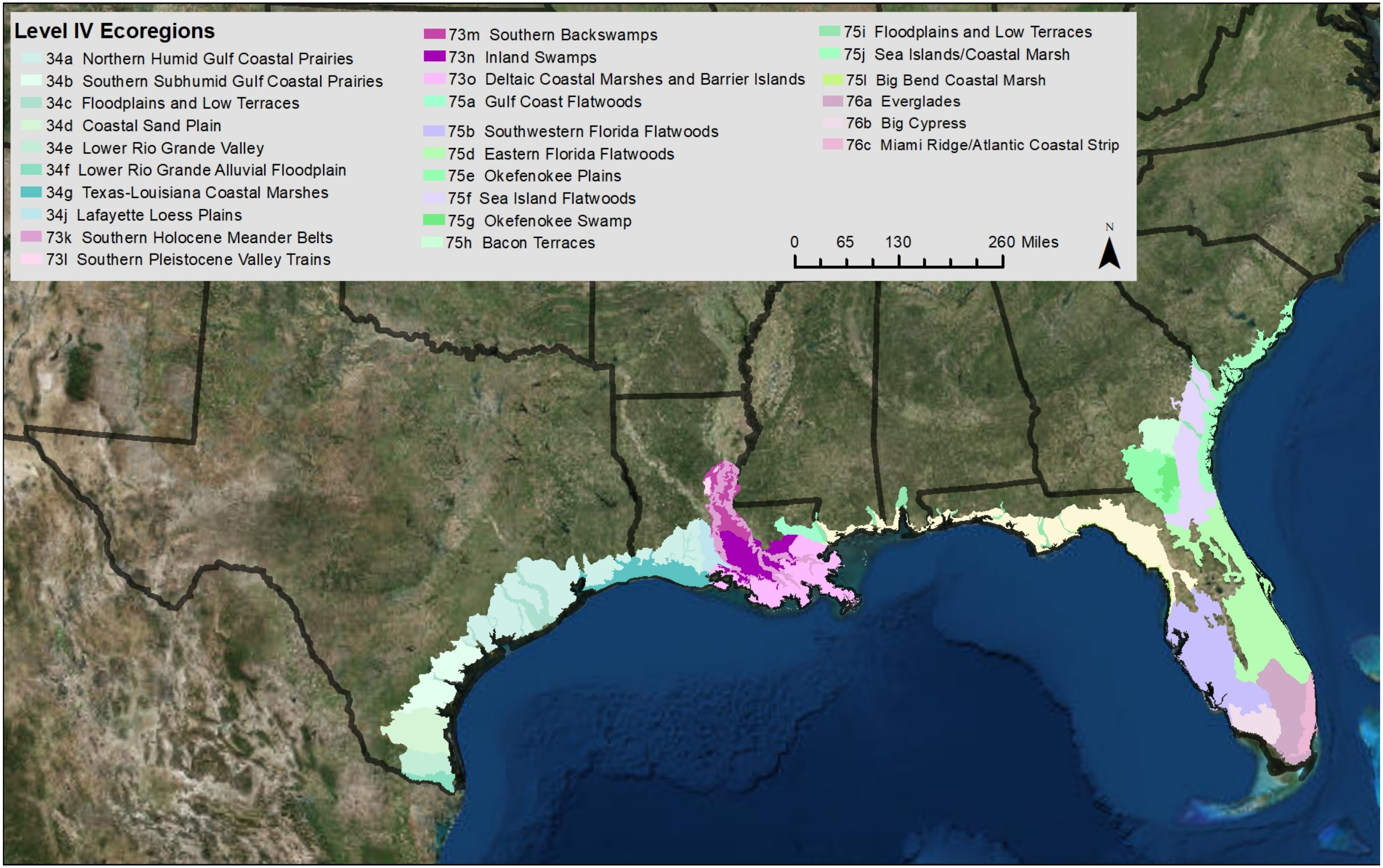


Figure 1. Geographic Range of Applicability for the WVA Bottomland Hardwoods Community Models.

Minimum Area of Application

The minimum area of application should be limited to an area that is large enough to be recognized as a bottomland hardwood site and provides some of the functions and values of the variables used to assess the site's condition. Various authors have concluded that even very small pieces of wooded habitat can be attractive to migrants (Skagen et al. 1998; Somershoe and Chanler 2004; Packett & Dunning 2009). Migrants were found in greater densities in smaller wooded hammocks in coastal South Carolina in a sample that ranged down to 7.9 acres, or 0.32 hectares (ha). Somershoe and Chandler 2004, and Skagen et al. (1998) concluded that riparian habitat patches were important to migrants in the southwestern USA no matter how small. Packett and Dunning (2009) found that migrant densities actually increased as woodlot size decreased, in wooded fragments in an agricultural landscape in Indiana. All their woodlots were less than 25 acres (10 ha) in size.

The value of tiny woodlots to migrant birds stems from the fact that migrants in an inhospitable landscape will gravitate to whatever forested habitat is available. It is quite possible that many of these small fragments are lower in quality than habitats in larger forested areas, but this is not a variable that can be reliably addressed by this model as data on food resources and predation threat are likely to be unavailable for most sites. Thus, this model can probably be profitably applied to even very small woodlot fragments less than 2.5 acres (1 ha) in size.

Field Investigations

The first step in evaluating candidate projects is to conduct a field investigation of the project area. This field investigation has several purposes: 1) familiarize the Interagency Review Team (IRT) with the project area, 2) visit the locations of project features, 3) determine habitat conditions in the project area, 4) compile a list of vegetative species and discuss habitat classification, and 5) collect data for the WVA (e.g., cover of submerged aquatics, water depths, salinities, etc.).

The primary purpose of the field investigation is to allow members of the IRT to familiarize themselves with the project area and project features in order to make informed decisions in the evaluation of the WVA. The interagency field investigation should not be treated as the only opportunity to conduct surveys or take measurements to develop designs and/or cost estimates for the project. That information could be obtained during previous field trips or should plan a follow-up field trip. In cases where the project area is very large, it may be necessary to divide the group into small work parties to collect WVA information across the project area or to allow some areas to be investigated by at least a subset of the entire group. However, an effort should be made to keep the group together to facilitate discussion about wetland conditions in the project area, the causes of habitat loss, the project features, and the effectiveness of the project features.

Project Boundary Determination

The project boundary is the area where a measurable biological impact, in regard to the WVA variables, is expected to occur with project implementation. The area must be divided into subareas based on habitat type so that the correct model can be applied. The most recent Vegetative Type Maps (Sasser et al. 2014) are typically used to delineate marsh areas from adjacent areas of forested wetlands. United States Geological Survey (USGS) Gap Analysis Project (GAP) data (USGS, 2011) is also utilized, particularly when forested wetlands are included. However, recent field investigations or other data (e.g., National Wetlands Inventory, www.fws.gov/wetlands) may be utilized to delineate habitat types within the project area. Reclassifying habitat should not be viewed as a means of reducing the number of subareas to simplify the project evaluation. Incorrect habitat classification can result in an inaccurate measure of project impacts. Reasons for habitat classification and/or reclassification should be documented.

In some instances, small areas of a particular habitat type may be combined with the more prevalent type within the project area. For example, a 100-acre area of bottomland hardwoods may be combined with an adjacent 5,000-acre tract of swamp. Determining the benefits for each individual small area could unnecessarily complicate the evaluation, be time-consuming, and may not significantly affect the overall project benefits. Any decision to combine a small area of one habitat type with a larger area of a different habitat type must be approved by the IRT.

Note: Remote sensing could also be determined through the use of aerial/satellite photographs, light imaging detection and ranging (LIDAR) information, USGS habitat and quadrangle maps and site visits. The boundary and revisions to the boundary are made by interagency group consensus. For non-restoration projects, boundaries are usually provided as areas designated for construction or clearing (typically to provide temporary or permanent rights-of-way) or areas that will experience changes in hydrology.

Selection of Target Years

In general, USACE Civil Works (CW) project WVAs are conducted for a period of 50 years which corresponds to the typical period of analysis of a CW Study (Table 2). Each project evaluation must include target years (TY) 0, 1, and 50 (or last year of the period of analysis). Target year 0 (TY0) represents baseline or existing conditions in the project area and TY50 (or last year of the period of analysis) represents the projected conditions at the end of the project life. A linear fit (over the project life) is used to make the projection unless there are expected changes that may occur in the intervening years. Examples of these changes include (but are not limited to):

1. Storm events: Storm frequencies for the Louisiana coast vary depending on the period of record analyzed but generally have been 8 to 10 years. For sites located along the shoreline, it may be necessary to select a target year which

corresponds to a storm event which is likely to occur within the project life in order to capture the effects of the storm. In forested wetlands, damaging winds from storms could cause tree mortality and reduce canopy cover by knocking trees down. Selection of a storm impact target year should be based on the storm return frequency that would result in substantial impact for the project vicinity. Climate change impacts to storm frequency and intensity varies spatially (Bender et al., 2010). It is not clear precisely how climate change will impact storm frequency and intensity, but many modelling results agree that we could expect decreased frequency and increased intensity (Walsh et al., 2015). However, an increase in frequency of tropical cyclonic storms was observed in the northern Atlantic in the recent past (1970-2005), which could, in part, have been due to a warming climate (Webster et al, 2005). Storm impact and return frequency by barrier system, should be used as justification when selecting target years (Stone et al. 1997). If the Future Without Project condition (FWOP) loss rates are based on data which include the effects of storm events then care must be taken to ensure that effects of storm events are not double counted.

2. Changes in frequency and duration of flooding: As relative sea level (RSL) rise continues, flooding frequency and duration may increase which could result in habitat loss and/or conversion. Project features could also decrease flooding frequency and duration or increase flooding duration if drainage is retarded by structures.

3. Salinity changes: Salinity may increase resulting in reduced tree growth or eventual mortality and subsequent conversion of habitat.

4. Project implementation: Additional CW (or non-CW) projects may be built which could influence the conditions in the current project area.

5. Maintenance events: These would include items such as phased vegetative plantings, replacement of hydrologic restoration structures, etc.

6. Increase or decrease in vegetative cover: These could be associated with project features (initial or phased) or environmental changes (see numbers 1 – 5).

Table 2. Summary of Target Years used for USACE Civil Works projects.

Project/Habitat Type	**Target Year**						
	0	**1**	**3**	**5**	**10, 20, 30, 40**	**50**	**>50**
Bottomland Hardwoods	Measured baseline		100% credit for marsh/dune plantings	100% credit for woody plantings	Storm Events (?)		Storm Event (?)

Use of the Community Habitat Models

Each community model contains a set of variables which is important in characterizing the habitat quality of several coastal wetland habitat types relative to the fish and wildlife communities dependent on those environments. Baseline (TY0) values are determined for each of those variables to describe existing conditions in the project area. Future values for those variables are projected to describe conditions in the area without the project and with the project. Projecting future values is the most complicated, and sometimes controversial, part of this process. It requires project sponsors to substantiate their claims with monitoring data, research findings, scientific literature, or examples of project success in other areas. Not all future projections can be substantiated by the results of monitoring or research, and, as with all wetland assessment methodologies, some projections are based on best professional judgment and can be subjective. It should be noted that future projections are not the sole responsibility of the project planner. It is the responsibility of the IRT (i.e., agency representatives, academics, and others) to use the best information available in developing those projections. Many times, the collective knowledge of the IRT is the only tool available to predict project impacts. Teams should be comprised of many individuals with diverse backgrounds and all project scenarios are discussed by the group and a final outcome is usually reached by consensus. The various workgroups are comprised of many individuals with diverse backgrounds and all project scenarios are discussed by the group and a final outcome is usually reached by consensus. Key assumptions made during the evaluation process, e.g., regarding the effects of climate change or storms, should be recorded on the Project Information Sheet (See Appendix III).

Model Application

Bottomland hardwoods are defined as an area supporting or capable of supporting a canopy of woody vegetation of which greater than 40% consists of tree species such as oaks, hickories, American elm, cedar elm, green ash, sweetgum, sugarberry, boxelder, common persimmon, honeylocust, red mulberry, eastern cottonwood, black willow, American sycamore, etc. (If 60% of the woody canopy consists of any combination of baldcypress, tupelogum, red maple, buttonbush, and/or water elm, the swamp community model should be applied).

Baseline Habitat Classification and Land/Water Data

Typically, the most recent habitat data provided by USGS are used to determine the areal extent of BLH within the project area. However, other datasets, e.g., Digital Orthophoto Quadrangles (DOQs; https://lta.cr.usgs.gov/DOQs), may be more appropriate for some applications. Upland and/or non-BLH habitats (e.g., open water, developed areas, cropland) should not be included within the project area. However, small areas of swamp, fresh marsh, or other habitats may be included within the project area. The insignificance of those areas will vary with the size of the project area. Any decision to combine a small area of one habitat type with a larger area of a different habitat type must be approved by the IRT.

Once all BLH subareas have been identified, USGS habitat data, National Oceanic and Atmospheric Administration (NOAA) land classification data, and aerial/satellite photographs should be used to further locate possible different BLH cover types in the area. Parish soil surveys may also provide useful information. Site visits for data gathering should be made to each cover type, if practicable. If sufficient variation exists in variable attributes or if significantly different responses to impacts are anticipated, separate analyses of different cover types may be warranted. Otherwise, combining cover types and sampling selected patches of each cover type is acceptable (Wakeley and O'Neil, 1988). Use of systematic sampling design (i.e., stratified random) rather than random to ensure each cover type is sampled may be necessary. Samples within each cover type (i.e., stratum) should be random and strata are classified on the basis of how well they represent the cover type and the variations within that cover type. These determinations are made by consensus. Once all data has been gathered, further combining of habitat types can be done as the values of individual variables and overall HSI are determined, but such combining must be coordinated with the interagency team.

In some areas, wetland loss is the conversion of emergent habitat to open water. However, in many areas, the historic loss of BLH has not resulted in a conversion to open water but conversion to marsh or swamp. Because much of the historic loss of BLH has not resulted in a conversion to open water, USGS habitat and land/water data generally do not allow the calculation of a "loss" rate for BLH habitat. However, habitat classification data and aerial/satellite photographs could be utilized to determine a "conversion" rate of BLH to other wetland types and that rate should be utilized in the WVA. These rates can be used in land loss spreadsheets to predict future conversion rates. In those instances, areas of BLH converting to other wetland types should be removed from the project area acreage. For areas undergoing land-use conversion (i.e., development) the same methodology should be used.

Whichever scenario exists for the project area, whether it is loss of habitat or conversion, the project planner should investigate the situation carefully and provide as much supporting documentation as possible to justify assumptions. Baseline habitat acreages must be adjusted from the habitat data being used to the current year.

Sampling Technique

The location and configuration of the area to be assessed direct the manner in which data are gathered. The plot size used by wetland forest ecologists of the southeastern United States is generally about 25 m x 25 m, or 625 m^2 (Conner et al. cites herein, Shaffer et al. 2003, 2009, Keim and King 2006). This plot size can be approximated by a circle constructed with a 41-foot (12.5 m) string which serves as the circle's radius. Perimeter trees can be flagged with survey tape to mark the plot while sampling. It is important to note that ecosystem function of forest interiors often is not reflected by forest edges (Gosselink et al. 1990, Llewellyn et al. 1996, Shaffer et al. 2009). Therefore, for larger forests data must be gathered at a distance (as much as 328 feet, 100 meters) from the edge that will minimize the edge's influence on the variables. Once the habitat of interest is reached, it may be necessary to sample several representative areas within it. Representative areas are generally reached by consensus and the process is operationally random. The center of each plot should be marked and the edge can be marked with string or flagging. Use of biodegradable string in hip chains to measure plot widths can be left in place during sampling; it provides a visible cue for the plot size and allows circular plots to be divided into quarters that aid in data gathering.

For mature even-aged forests with relatively few midstory trees, a factor 10 wedge prism may be utilized to gather data; however, data gathered for a project should utilize only one method. Because using a wedge prism can decrease the amount of time at a sample site, more sample sites can be measured. Proper techniques for using a wedge prism can be found in both the following US Forest Service and Corps publications: https://erdc-library.erdc.dren.mil/xmlui/bitstream/handle/11681/7195/TR%20EL-95-24.pdf?sequence=1&isAllowed=y and http://fia.fs.fed.us/library/field-guides-methods-proc/docs/core_ver_4-0_10_2007_p2.pdf.

There may be some situations (e.g., scientific research projects) when a more robust sampling scheme is necessary. In those situations, replicates of each forested habitat type (e.g., degraded, relict, throughput; Shaffer et al. 2009) should be located at least 1,640 feet (500 m) apart, yielding a theoretical equilateral triangle measuring 13.4 acres (5.4 ha) as the minimum area appropriate for data collection. The plot size used by wetland forest ecologists of the southeastern United States is generally about 25 m x 25 m, or 625 m^2 (Conner et al. cites herein, Shaffer et al. 2003, 2009, Keim and King 2006). This plot size can be approximated by a circle constructed with a 41-foot (12.5 m) string which serves as the circle's radius. Perimeter trees can be flagged with survey tape to mark the plot while sampling.

Variable Selection

The selection of variables was based on review of 1) Habitat Suitability Index models, published by the U. S. Fish and Wildlife Service (USFWS), for wood duck, barred owl, swamp rabbit, mink, downy woodpecker, and gray squirrel, 2) a community model for forest birds, published by USFWS, 3) "A Habitat Evaluation System for Water Resources Planning," published by USACE, and 4) a draft version of "A Community Habitat Evaluation Model for Bottomland Hardwood Forests in the Southeastern United States," coauthored by USACE and USFWS.

Several habitat variables appeared repeatedly in the various models reviewed. In general, it was concluded that those habitat variables which occurred most frequently in the various models were the most important for assessing habitat quality. The species-specific models concentrate on assessment of site-specific habitat quality features such as tree species composition, forest stand structure (understory, midstory, and overstory conditions), stand maturity, and hydrology. The other models rely heavily on how a site fits into the overall "landscape." Both approaches are important and warrant consideration. The model presented in this document attempt to incorporate both approaches.

Subsidence and Sea Level Change

At the time of publication, current guidance for incorporating the direct and indirect physical effects of projected future sea level change across the period of analysis cycle in managing, planning, engineering, designing, constructing, operating, and maintaining USACE projects and systems of projects can be found in Engineering Regulation 1100-2-8162 (Incorporating Sea level change in civil works programs). This Regulation discusses sea level change and subsidence. Please use current regulation concerning subsidence sea level change located in the Planning Community Toolbox (https://planning.erdc.dren.mil/toolbox/guidance.cfm?Option).

Suitability Index Graph Development

Each of the WVA community models developed for USACE CW projects includes SI graphs for each variable. Suitability Index graphs are unique to each variable and define the relationship between that variable and habitat quality. Suitability Index (SI) graph development for this model was very similar to the process used for other community models such as the coastal marsh community models. 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, published and unpublished data and studies, and personal knowledge of those involved in model development. A review of contemporary, peer-reviewed scientific literature was also conducted for each of the variables, providing ecological support for the form of the SI graph for each of the variables (Appendix I).

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

Variable V1 – Tree Species Composition

Wildlife species which utilize bottomland hardwoods depend heavily on mast, other edible seeds, and tree buds as primary sources of food. The basic assumptions for this variable are: 1) more production of mast (hard and/or soft) and other edible seeds is better than less production, and 2) because of its availability during late fall and winter and its high energy content, hard mast is more critical than soft mast, other edible seeds, and buds.

The baseline (TY0) value for this variable is usually determined during field investigations of the project area following the sampling technique previously discussed. Estimation of the canopy cover of each mast type is typically accomplished utilizing the "plant cramming" technique as presented by Hays, et al. 1981. Other methods can be utilized but the same technique must be used for all sample sites for that project.

Variable V2 – Stand Maturity

Prior to about Age 10, bottomland hardwood tree species provide only a very limited amount of wildlife food, in the form of buds and leaves. Accordingly, the SI for those early years shows a very small increase from 0.0 for a site with no trees to 0.1 for a site with 10-year-old trees. The production of soft mast and other edible seeds is expected to begin at about Age 10, increase with age, and reach maximum potential by approximately Age 50 (SI = 1.0). In general, hard mast production is expected to begin at about Age 20 (SI = 0.3), increase substantially by age 30 (SI = 0.6), and reach maximum potential by approximately Age 50. In addition to increased production of hard mast, soft mast, other edible seeds, and buds, older stands provide important wildlife requisites such as tree snags, nesting cavities, and the medium for invertebrate (wildlife food) production. Also, as the stronger trees establish themselves in the canopy, weaker trees are outcompeted and eventually die, forming additional snags and downed treetops that would not be present in younger stands. Another factor to be considered is the rarity (and associated ecological importance) of mature stands, due to man's historical conversion of bottomland hardwoods to agriculture and historical and ongoing timber harvesting. Because the average age of canopy-dominant and canopy-codominant trees is usually unknown, average tree diameter at breast height (dbh) can be used to determine the Suitability Index for this variable.

The baseline (TY0) value for this variable is usually determined during field investigations of the project area following the sampling technique previously discussed. All trees within the plot should have their dbh measured using Biltmore sticks or diameter tapes. For proper technique using Biltmore sticks refer to Hays, et al. 1981. Use of tapes is also addressed in that publication, however, more detailed techniques that are utilized are found in the U.S. Forest Services and Corps publications (see https://erdc-library.erdc.dren.mil/xmlui/bitstream/handle/11681/7195/TR%20EL-95-24.pdf?sequence=1&isAllowed=y and http://fia.fs.fed.us/library/field-guides-methods-proc/docs/core_ver_4-0_10_2007_p2.pdf)

Future projections should be supported by monitoring data, scientific literature, examples of project success in other areas, previous WVAs, or personal knowledge of the project area. A tree growth spreadsheet for coastal Louisiana was developed by FWS and USACE biologists. This can be used to assist with tree growth projections in coastal Louisiana. Other similar tree growth spreadsheets could be used or developed for other regions. Another reference to assist with tree growth projections is the U.S. Department of Agriculture's Silvics of North America (https://www.srs.fs.usda.gov/pubs/misc/ag_654/table_of_contents.htm).

Variable V3 – Understory/Midstory

The understory and midstory components of bottomland hardwoods provide resting, foraging, breeding, nesting, and nursery habitat. The understory and midstory provide soft mast, other edible seeds, and vegetation as sources of food. The understory and midstory also provide the medium for invertebrate production, an additional food source. The amount of understory coverage and the amount of midstory coverage are considered equally important and are given equal weight in determining the Suitability Index for this variable. The "plant cramming" technique is also used in determining this variable for 1/5 acre plots. For plots measured with the wedge prism, the trees most distant from the plot center should be used to determine the edge of the plot.

<u>Variable V4 – Hydrology</u>

Bottomland hardwood stands in the Louisiana Coastal Zone generally occur in one of four basic hydrology classes or water regimes: 1) efficient forced drainage system, 2) irregular periods of inundation due to an artificially lowered water table, 3) extended inundation or impoundment because of artificially raised water table, and 4) essentially unaltered. The optimum bottomland hardwood hydrology (SI = 1.0) is one that is essentially unaltered, allowing natural wetting and drying cycles which are beneficial to vegetation and associated fish and wildlife species. When a bottomland hardwood stand is part of an efficient forced drainage system, the vegetative component provides some habitat value, but wildlife species which are dependent on water would essentially be excluded year-round, and the area would not in any way serve to promote fish production (SI = 0.1). With a moderately lowered water table, the vegetative component of the site could provide excellent habitat for many wildlife species and temporary habitat for wildlife species which are dependent on water, but fish would generally be excluded (SI = 0.5). With a raised water table, fish habitat and habitat for water-dependent wildlife could be equivalent to an unaltered system; however, other wildlife species could be adversely affected because of water-related impacts to the vegetative components of the stand (SI = 0.5).

This variable considers the duration and amount/degree of water flow/exchange. Four flow/exchange and four flooding duration categories are described to characterize the water regime. The optimal water regime is assumed to be temporary flooding with abundant and consistent riverine input and water flow-through (SI = 1.0). Temporary flooding is assumed to contribute to increased nutrient cycling (primarily through oxidation and decomposition of accumulated detritus), increased vertical structure complexity (due to growth of other plants on the forest floor), and increased recruitment of dominant overstory trees. In addition, consistent input and water flow-through is optimal, because under that regime the full functions and values of a BLH in providing fish and wildlife habitat are assumed to be maximized. Seasonal flooding is also assumed to be desirable. Habitat suitability is assumed to decrease as water exchange between the forest and adjacent systems is reduced. The combination of permanently flooded conditions or no water exchange (e.g., an impounded bottomland where the only water input is through rainfall and the only water loss is through evapotranspiration and ground seepage) is assumed to be equivalent to areas that may be placed under a forced drainage system; either scenario is least desirable.

Water level gauges in combination with elevation data from USGS quadrangle maps or LIDAR data can be used to determine flood duration and frequency. Aerial/satellite photographs can also be used to determine duration, frequency and areal extent if the data of the photograph can be obtained and compared to gauge data. If gauge data are not available, aerial/satellite photographs, soil conditions, vegetative indicators and high water marks can be used to estimate flooding conditions. Also, high water marks can be measured from the ground surface and compared to gauge data.

Variable V5 – Size of Contiguous Forested Area

Although edge and diversity, which are dominant features of small forested tracts, are important for certain wildlife species, it is important to understand four concepts: 1) species which thrive in edge habitat are highly mobile and presently occur in substantial numbers, 2) because of forest fragmentation and ongoing timber harvesting by man, edge and diversity are quite available, 3) most species found in "edge" habitat are "generalists" in habitat use and are quite capable of existing in larger tracts, and 4) those species in greatest need of conservation are "specialists" in habitat use and require large forested tracts. Therefore, the basic assumption for this variable is that larger forested tracts are less common and offer higher quality habitat than smaller tracts. For this model, tracts greater than 500 acres in size are considered large enough to warrant being considered optimal.

Use of geographic information system (GIS) and satellite photographs is the primary method of determining the contiguous forested area. DOQs provide the best resolution for this variable; more than one year can be utilized to verify any breaks in contiguity.

Variable V6 – Suitability and Traversability of Surrounding Land Uses

Many wildlife species commonly associated with bottomland hardwoods will often use adjacent areas as temporary escape or resting cover and seasonal or diurnal food sources. Surrounding land uses which meet specific needs can render a given area of bottomland hardwoods more valuable to a cadre of wildlife species. Additionally, the type of surrounding land use may encourage, allow, or discourage wildlife movement between two or more desirable habitats. Land uses which allow such movement essentially increase the amount of habitat available to wildlife populations. The weighting factor assigned to various land uses reflects their estimated potential to meet specific needs and allow movement between more desirable habitats.

The most recent aerial/satellite photographs and habitat/land classification databases should be used for this variable. A 0.5 mile buffer should be delineated around the project area (use of a buffer tool in GIS simplifies this step) and within that buffer, the land cover types designated in V6 should be identified and acreage determined. Land loss rates and/or habitat conversion rates should be applied to these areas provided that the land cover type percentages will change enough to change this variable's value.

Variable V7 – Disturbance

Human-induced disturbance can displace individuals, modify home ranges, interfere with reproduction, cause stress, and force animals to use important energy reserves. The effects of disturbance are a factor of the distance to disturbance and the type of disturbance. A separate suitability graph was developed for each of those factors and the results are combined to yield a single Suitability Index for Disturbance. If the source of disturbance is located beyond 500 feet from the perimeter of the site, or if the type of disturbance is "insignificant," the effects of disturbance are assumed to be negligible and SI = 1.0. If the source of disturbance is located within 50 feet of the perimeter of the site and the disturbance is "Constant or Major," the effects of disturbance are assumed to be maximum and SI = 0.1. Other combinations of distance to, and type of, disturbance yield moderate SI's of 0.26, 0.41, 0.5, and 0.65.

Use of GIS and satellite photographs is the primary method of determining the type of possible disturbance such as highways, industrial areas, waterways, agriculture, homes, etc. Because this variable does not need as fine a resolution as V5, the use of aerial/satellite photographs other than DOQs may be sufficient.

Habitat Suitability Index Formulas

Within the HSI formula, any Suitability Index can be weighted by various means to increase the power or "importance" of that variable relative to the other variables in determining the HSI. Any variable's Suitability Index can be weighted, by raising its exponent, to increase the importance of that variable relative to the other variables in the HSI formula. A larger exponent will increase the influence of that variable on the resultant HSI. The model attempts to incorporate site-specific habitat quality features (tree species composition, forest stand structure, stand maturity, and hydrology) and landscape variables (forest size, surrounding habitat, and disturbance). Because the primary application of these models is to quantify the loss of ecological values due to small and site-specific activities, the site specific variables (V_1, V_2, V_3, and V_4) are considered more important and have been given more weight than the landscape variables.

The site specific variables V_1 (Tree Species Composition) and V_2 (Standard Maturity) are considered to be of greatest importance; they are weighted to the power of four. Variables V_3 (Understory/Midstory) and V_4 (Hydrology) are weighted to the power of two. The "landscape" variables (V_5, V_6, and V_7) are not weighted. In some cases, data for Variable V_3 (Understory/Midstory) may not be readily available; in those instances that variable can be deleted from the HSI formula as indicated below.

Stands less than 7 years of age generally do not 1) exhibit distinguishable understory, midstory, and overstory components, 2) produce substantial mast, or 3) function as part of a forested landscape; hence, the variables Stand Structure, Tree Species Composition, Size of Contiguous Forest, and Understory/Midstory are not incorporated into the HSI formulas until the stand reaches 7 years of age.

The HSI formulas bottomland hardwoods are:

1. If Age < 7 (or dbh < 5 in), then:
HSI = $(SI_{v2}^4 \times SI_{v4}^2 \times SI_{v6} \times SI_{v7})^{1/8}$, or

2. If Age > 7 (or dbh > 5 in) and V3 (Understory/Midstory) data is available, then:
HSI = $(SI_{v1}^4 \times SI_{v2}^4 \times SI_{v3}^2 \times SI_{v4}^2 \times SI_{v5} \times SI_{v6} \times SI_{v7})^{1/15}$, or

For project areas where surrounding land use (V_6) will not change over the project life or the site is (or will) not be adversely impacted by changing land uses or where disturbances associated with human activities (V_7) are determined to be insignificant to the value of the habitat the following formulas may be used:

1. If Age < 7 (or dbh < 5 in), then:

HSI = $(SI_{v2}^4 \times SI_{v4}^2)^{1/6}$, or

2. If Age > 7 (or dbh > 5 in) and V3 (Understory/Midstory) data is available, then:

HSI = $(SI_{v1}^4 \times SI_{v2}^4 \times SI_{v3}^2 \times SI_{v4}^2 \times SI_{v5})^{1/13}$

BOTTOMLAND HARDWOODS

Variable V_1 Tree Species Association (see following section for scientific names).

Non-mast / inedible seed producers: eastern cottonwood, black willow, American sycamore.
Hard mast producers: oaks, sweet pecan, other hickories.
Soft mast and other edible seed producers: red maple, sugarberry, green ash, boxelder, common persimmon, sweetgum, honeylocust, red mulberry, American elm, cedar elm

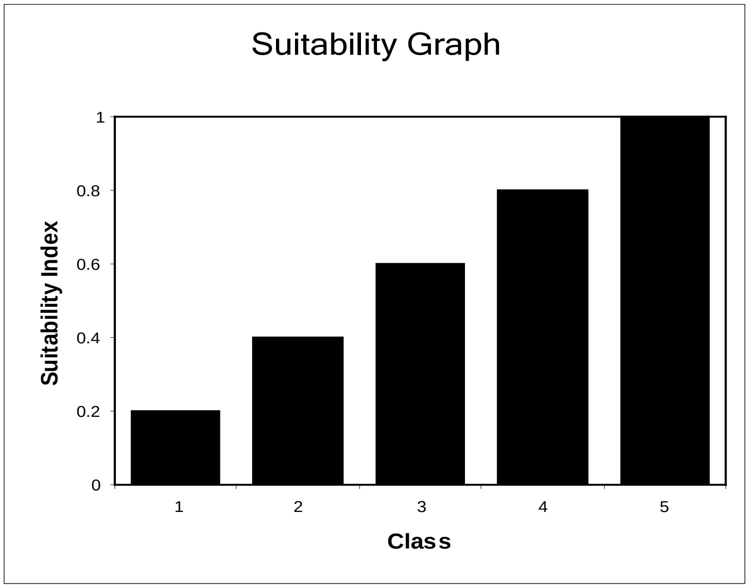
Class 1: Less than 25% of overstory canopy consists of mast or other edible-seed producing trees or more than 50% of soft mast present but no hard mast.

Class 2: 25% to 50% of overstory canopy consists of mast or other edible-seed producing trees, but hard mast producers constitute less than 10% of the canopy

Class 3: 25% to 50% of overstory canopy consists of mast or other edible-seed producing trees, and hard mast producers constitute more than 10% of the canopy.

Class 4: Greater than 50% of overstory canopy consists of mast or other edible-seed producing trees, but hard mast producers constitute less than 20% of the canopy.

Class 5: Greater than 50% of overstory canopy consists of mast or other edible-seed producing trees, and hard mast producers constitute more than 20% of the canopy.



BOTTOMLAND HARDWOODS

Variable V_2 Stand Maturity

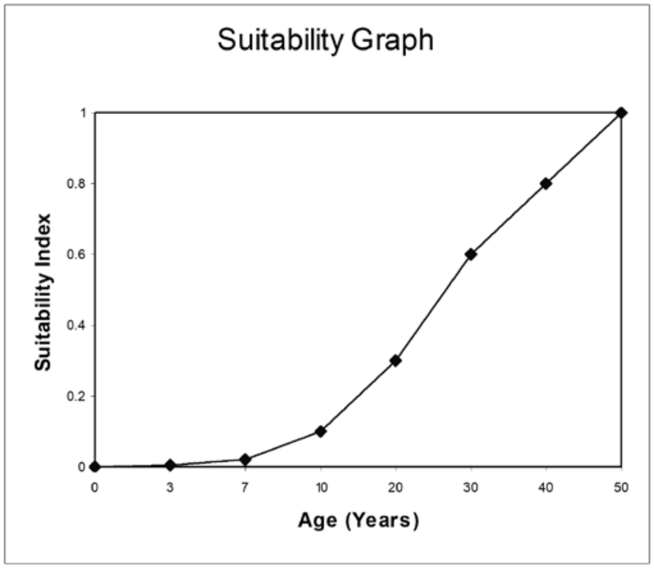
[i.e., average age of canopy-dominant and canopy-codominant trees].

Notes:

1. When the average age of canopy-dominant and canopy-codominant trees is unknown, average tree diameter at breast height (dbh) can be used to determine the Suitability Index for this variable.
2. Canopy-dominant and canopy co-dominant trees are those trees whose crown rises above or is an integral part of the stand's overstory.
3. For trees with buttress swell, dbh is the diameter measured at 12" above the swell.

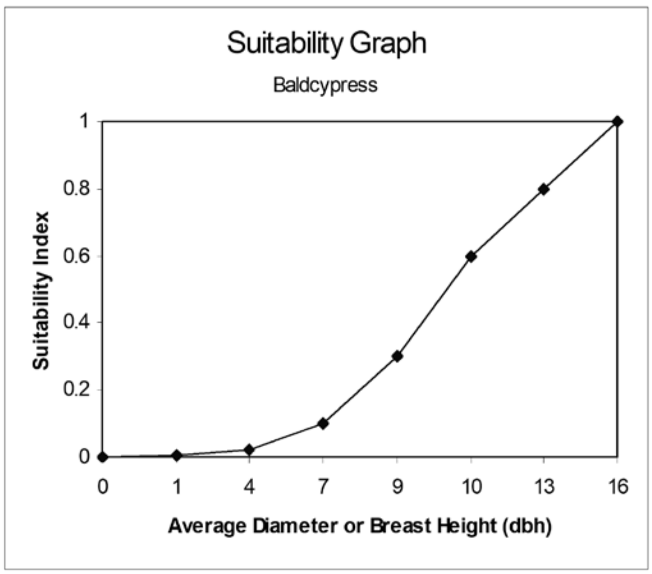
Line Formulas, when age is known:

If age = 0 then SI = 0
If 0 < age $\leq$ 3 then SI = .0033 * age
If 3 < age $\leq$ 7 then SI = (.01 * age) - .02
If 7 < age $\leq$ 10 then SI = (.017 * age) - .07
If 10 < age $\leq$ 20 then SI = (.02 * age) - .1
If 20 < age $\leq$ 30 then SI = (.03 * age) - .3
If 30 < age $\leq$ 50 then SI = .02 * age
If age 50 > then SI = 1.0



Line Formulas for bottomland hardwoods, when age is unknown:

If dbh = 0 then SI = 0
If 0 < dbh $\leq$ 5 then SI = .01 * dbh
If 5 < dbh $\leq$ 8 then SI = (.017 * dbh) - .035
If 8 < dbh $\leq$ 11 then SI = (.067 * dbh) - .436
If 11 < dbh $\leq$ 14 then SI = (.1 * dbh) - .8
If 14 < dbh $\leq$ 20 then SI = (.067 * dbh) - .338
If dbh > 20 then SI = 1.0

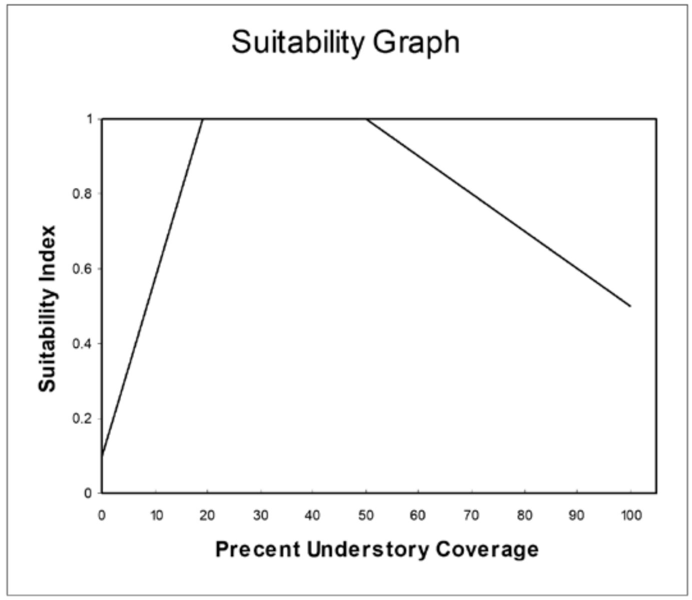


BOTTOMLAND HARDWOODS

Variable V_3 Understory / Midstory

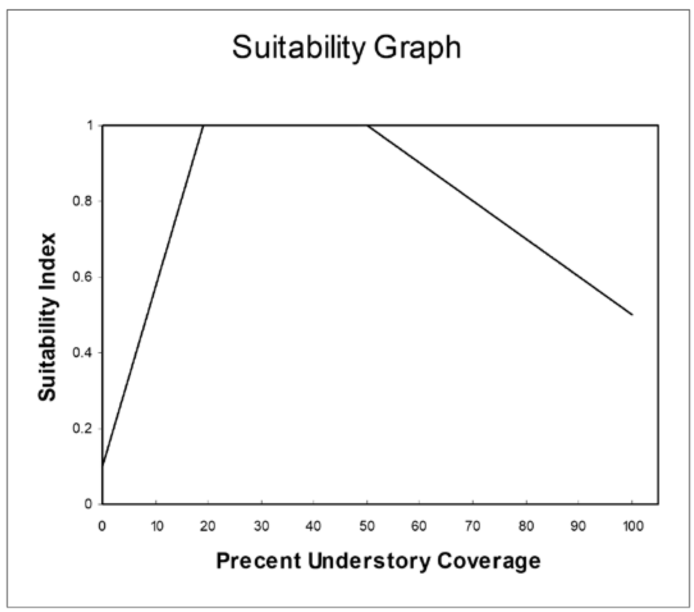
Line Formulas for Understory Coverage:

If understory % = 0 then SI = .1
If 0 < un. % ≤ 30 then SI = 0.03 * un. % + .1
If 30 < un. % ≤ 60 then SI = 1.0
If un. % > 60 then SI = (-.01 * un. %) + 1.6



Line Formulas for Midstory Coverage:

If midstory % = 0 then SI = 0.1
If 0 < mid % ≤ 20 then SI = 0.45 * mid % + .1
If 20 < mid % ≤ 50 then SI = 1.0
If mid % > 50 then SI = (-.01 * mid %) + 1.5



Understory / Midstory SI = Understory SI + Midstory SI / 2

BOTTOMLAND HARDWOODS

Variable V_4 Hydrology

		Flow/Exchange			
		High	Moderate	Low	None
Flooding Duration	Temporary	1.00	0.85	0.70	0.50
	Seasonal	0.85	0.75	0.65	0.40
	Semi-Permanent	0.75	0.65	0.45	0.25
	Permanent/Dewatered	0.65	0.45	0.30	0.10

Flooding Duration

1. Permanently Flooded/Dewatered: Water covers the substrate throughout the year in all years or no longer covers the substrate except in major flood events.
2. Semipermanently Flooded: Surface water is present throughout the growing season and may extend beyond the growing season in most years.
3. Seasonally Flooded: Surface water is present for extended periods, especially in the growing season, but is absent by the end of the growing season in most years.
4. Temporarily Flooded: Surface water is present for brief periods during the growing season, but the water table usually lies below the surface for most of the season.

Flow/Exchange

1. High: Receives abundant and consistent riverine input and through-flow.
2. Moderate: Moderate water exchange, through riverine and/or tidal input.
3. Low: Limited water exchange through riverine and/or tidal input, or just rainfall on an area that is not efficiently drained. This can include pumps that are maintaining some exchange or through flow.
4. None: No water exchange (stagnant, impounded), or no natural water exchange (i.e., forced drainage or pumping as only drainage mechanism). This would include forced drainage and/or pumping without any through flow.

BOTTOMLAND HARDWOODS

Variable V_5 Size of Contiguous Forested Area.

Note: Corridors less than 75 feet wide do not constitute a break in the forested area contiguity.

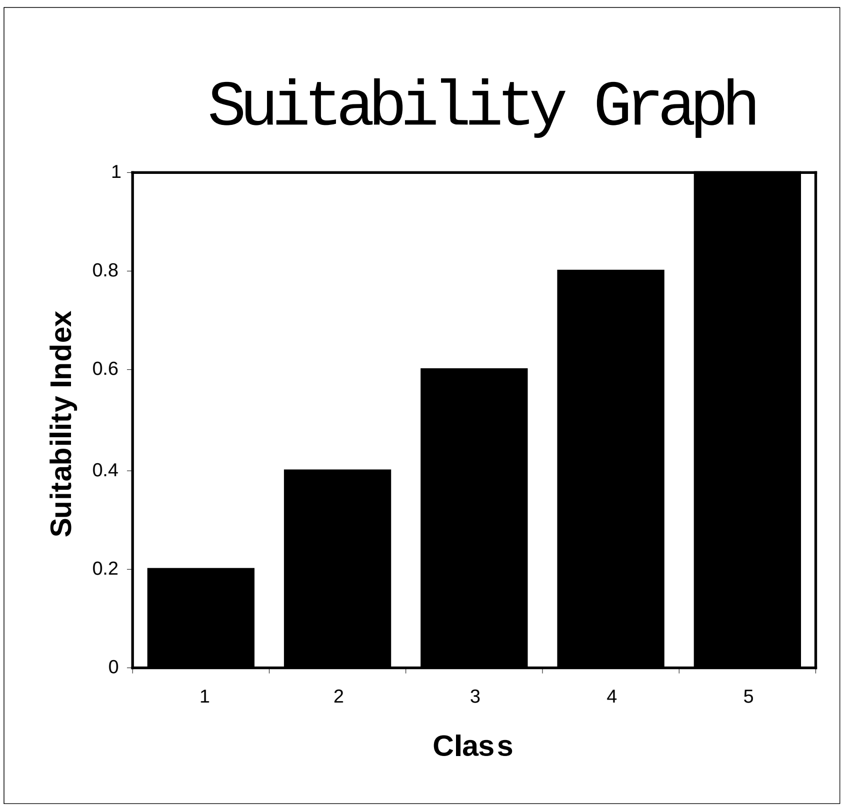
Class 1. 0 to 5 acres

Class 2. 5.1 to 20 acres

Class 3. 20.1 to 100 acres

Class 4. 100.1 to 500 acres

Class 5. > 500 acres



BOTTOMLAND HARDWOODS

Variable V_6 – Suitability and Traversability of Surrounding Land Uses.

Within a 0.5 mile of the perimeter of the site, determine the percent of the area that is occupied by each of the following land uses (must account for 100 percent of the area). Multiply the percentage of each land use by the suitability weighting factor shown below, add the adjusted percentages and divide by 100 for a suitability index for this variable.

Land Use	**Weighting Factor**		**% of 0.5 mile circle**		**Weighted Percent**
Bottomland hardwood, other forested areas, marsh habitat, etc.	1.0	X		=	
Abandoned agriculture, overgrown fields, dense cover, etc.	0.6	X		=	
Pasture, hayfields, etc.	0.4	X		=	
Active agriculture, open water	0.2	X		=	
Nonhabitat: linear, residential, commercial, industrial development, etc.	0.01	X		=	
					___ /100 = SI

Variable V_7 Disturbance

The effect of disturbance is a factor of the distance to, and the type of, disturbance, hence both are incorporated in the SI formula.

Note: Linear and/or large project sites may be exposed to various types of disturbances at various distances. The SI for this variable should be weighted to account for those variances.

Distance Classes	**Type Classes**
Class 1. 0 to 50 ft.	**Class 1.** Constant/Major. (Major highways, industrial, commercial, major navigation.)
Class 2. 50.1 to 500 ft.	**Class 2.** Frequent/Moderate. (Residential development, moderately used roads, waterways commonly used by small to mid-sized boats).
Class 3. > 500 ft.	**Class 3.** Seasonal/Intermittent. (Agriculture, aquaculture.)
	Class 4. Insignificant. (Lightly Used roads and waterways, individual homes, levees, rights of way).

Suitability Indices for Distance/Type Class

	Type Class				
		1	2	3	4
Distance Class	1	.01	.26	.41	1
	2	.26	.50	.65	1
	3	1	1	1	1

Common Names/Scientific Names

Common Names	**Scientific Names**
American elm	*Ulmus americana*
American sycamore	*Plantanus occidentalis*
Baldcypress	*Taxodium distichum*
Black willow	*Salix nigra*
Boxelder	*Acer negundo*
Buttonbush	*Cephalanthus occidentalis*
Cedar elm	*Ulmus crassifolia*
Common persimmon	*Diospyros virginiana*
Eastern cottonwood	*Populus deltoides*
Green ash	*Fraxinus pennsylvanica*
Hickories	*Carya spp.*
Honeylocust	*Gleditsia triacanthos*
Oaks	*Quercus spp.*
Water elm	*Planera aquatica*
Red maple	*Acer rubrum*
Red mulberry	*Morus rubra*
Sugarberry	*Celtis laevigata*
Sweet pecan	*Carya illinoensis*
Sweetgum	*Liquidambar styraciflua*
Tupelogum	*Nyssa aquatica*

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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 V1 – Tree Species Composition

Unlike Louisiana coastal swamps, bottomlands contain species (mostly oaks and hickories) that produce substantial quantities of hard mast. Unlike most soft mast, hard mast is available to wildlife during the winter and the seeds are large and contain abundant amounts of highly nutritious endosperm (Allen 1997, King and Keeland 1999). In general, it is assumed that light-seeded species will establish naturally through wind or water dispersal (Allen and Kennedy 1989, Allen 1990). Clear relationships exist between the quantity and quality of hard and soft mast and the fauna that rely on these resources (Gosselink et al. 1990a, Chambers et al. 2005).

The diverse vegetation composition, vertical and horizontal heterogeneity, and seasonal pulses of resources create many different niches and foods for animals (Fredrickson 1979, Junk et al. 1989, Harris and Gosselink 1990). Bottomland trees produce large crops of hard and soft mast (acorns, drupes, and samaras) with production being highly seasonal and can vary among years in relation to climate, flooding, and nutrient availability (Heitmeyer et al. 2005). The distribution and abundance of forest vegetation within bottomland hardwood forests also influence the distribution and abundance of organisms. Fredrickson (1979) and Wharton et al. (1982) have described the distribution of various organisms in relationship to forest zones in bottomland sites. Shrub-scrub habitats, for example, provide seeds, browse, and insects for feeding wildlife as well as dense cover for nesting, roosting sites, and thermal refugia (Fredrickson and Heitmeyer 1988). Overcup and pin oak forests are important for wintering waterfowl because of acorns and invertebrates (Heitmeyer 1985). Red oaks (pin, Nuttall, cherrybark, and willow) are of special interest because they produce acorns suitable for consumption by waterfowl and other wildlife (Barras et al. 1996) and also provide important invertebrate foods (Bateman 1987, Wehrle et al. 1995).

Variable V2 – Stand Maturity

The healthiest bottomland hardwood forests in coastal Louisiana are those characterized by high basal area and large trees (Conner and Day 1976, Nessel 1982; 1984 Conner et al. 1981, Muzika et al. 1987, Megonigal et al. 1997, Shaffer et al. 2009). Certain species of special interest, such as the Louisiana black bear and the Rafinesque big-eared bat frequently use hollows of large trees for nesting (Taylor 1971, Weaver et al. 1990, Cochran 1999, Hoffman 1999, Hightower et al. 2002, Gooding and Langford 2004). Large hollow hardwoods characteristic of older bottomlands appear particularly important to the Rafinesque big-eared bat (Cochran 1999, Lance et al. 2001, Gooding and Langford 2004).

Variable V3 – Understory/Midstory

In general, healthy bottomland hardwood forests in coastal Louisiana are dominated by overstory canopy consisting of oaks (*Quercus sp.*) and other hardwoods. Dominant midstory species include red maple (*Acer rubrum*), ash (*Fraxinus sp*.), and many other species. Herbaceous ground cover is highly variable and can be nearly absent in a mature BLH because of light limitation, or seasonal during periods of overstory dormancy. As bottomland hardwood forests degrade, generally due to altered hydrologic conditions, localized droughts, or major storms (Chambers et al. 2005) the canopy begins to open and groundcover often increases. This can lead directly to the formation of an immature swamp habitat creating a mixed community of more flood tolerant BLH species, herbaceous cover and emergent swamp species. Therefore, it is the combination of overstory, midstory, and ground cover that best indicate BLH stand structure. These stand structure components are sensitive to Future With Project condition (FWP) vs. FWOP conditions.

From a community perspective, a bottomland containing overstory and midstory trees, as well as herbaceous ground cover, in roughly even amounts, offers the highest degree of food and shelter for a diverse assemblage of wildlife (Brokaw and Lent 1999, Haila 1999, Bodie and Semlitsch 2000, Chambers et al. 2005). Healthy mature BLH will likely have low cover of herbaceous vegetation, due to light limitation (Chambers et al. 2005). Conversely, as bottomlands degrade, generally due to altered hydrologic conditions, the canopy begins to open allowing midstory, shrub-scrub and groundcover vegetation to increase (Allen 1958; Allen 1962, Conner et al. 1981, White 1983, Barras et al. 1994, Allen et al. 1996, Aust et al. 1998, Thomson et al. 2002, Conner and Inabinette 2003, Shaffer et al. 2009).

Variable V4 – Hydrology

Floodplain hydrology controls vegetation composition and productivity in bottomland hardwood forests. Flooding results in seasonal pulses of nutrient flow and food resources, and it is these pulses that have been a key factor influencing organismal adaptations and strategies for colonizing and exploiting bottomland resources (Heitmeyer et al. 2005). Even modest changes in the timing of flood events can be devastating to birds and mammals. Extended spring flooding can destroy annual production of most ground-nesting species or plant food supplies for herbivores. Delayed flooding in late fall or early winter can delay and decrease invertebrate populations that are critical for important functions of many species: prebasic molt of mallards, egg-laying in night herons and hooded mergansers, embryo development in raccoons, and storage of nutrient reserves by hibernating black bear (Heitmeyer et al. 2005). Waters flood bottomland hardwood forests from a variety of sources including rainfall, head- and backwater flooding from rivers and streams, and groundwater flows (Heitmeyer et al. 2005). The seasonal and long-term dynamics of this surface flooding help determine the structure, function, and value of the system. Almost all bottomland hardwood forests are flooded for some portion of the year with the timing, extent, depth, duration, and source of floodwaters varying among locations. The relative flooding patterns are what determine habitat types in bottomland hardwood forests. Heitmeyer et al. (1989) have broken these forests into sites of low elevation (dominated by overcup oak), intermediate elevation (significant amounts of Nuttall, willow, or pin oaks, sweetgum, and green ash), high elevation (cherrybark oak, water oak, sugarberry, and hickory), or scrub/shrub-cypress/tupelo elevation.

Because of their location and connection to rivers, bottomland hardwood forests introduce organic material as well as nutrients of terrestrial origin into aquatic dimensions of the ecosystem (Junk et al. 1989, Sparks 1995). Once river waters overtop the main channel banks, invertebrates and fishes colonize inundated areas to take advantage of resources (Jackson 2005). This aquatic/terrestrial interface is particularly important because this ephemeral environment promotes faunal interactions biotically as well as abiotically, and rapid nutrient exchanges (Goulding 1980, Bayley 1989). Fishes exploit the spatially complex floodplain for spawning and nursery habitat as well as for refuge and feeding (Risotto and Turner 1985, Bayley 1989, Ward and Stanford 1989). Because flooded bottomland areas are shallower than the main river channel, water in flooded backwater locations tends to be warmer earlier in the year which promotes biological activity of invertebrates and fishes in these systems (Rutherford et al. 1995). The presence of aquatic invertebrates encourages spawning of fishes, and the earlier the spawning occurs, the longer the fish can remain on the floodplain, leading to higher recruitment potentials for the river’s fish stocks (Ye 1996).

Variable V5 - Size of Contiguous Forest

Whereas single blocks of BLH used to cover hundreds of thousands of hectares in the Mississippi Alluvial Plain, there now remain only isolated fragments, most less than 250 acres (100 ha) in size and most of these are surrounded by agricultural fields (Gosselink et al. 1990b). Certain species of neotropical migratory birds require a minimum of 6,900 acres (2,800 ha) of forest interior to sustain viable populations (Robbins et al. 1989, Twedt and Loesch 1999). In their plan to restore large tracks of BLH, The Nature Conservancy focuses on three migratory-bird guilds, namely Bachman’s warbler which requires 9,880 acres (4,000 ha) of forest interior for successful breeding habitat, the Cerulean warbler requiring 19,770 acres (8,000 ha) of forest interior, and the swallowtail kite requiring 98,840 acres (40,000 ha) of interior forest (Shaffer et al. 2005, Weitzell et al. 2003). Gosselink and Lee (1989) estimate that 494,200 acres (200,000 ha) of forested habitat is required to sustain a viable population of the Louisiana black bear. In general, ecosystem function of forest interiors often is not reflected by forest edges (Gosselink et al. 1990a,b, Llewellyn et al. 1996, Saunders et al. 1991, Shaffer et al. 1992, 2009). To date, the bottomland hardwood forest of coastal Louisiana have been reduced by over 80% (Llewellyn et al. 1996, Shaffer et al. 2005, Weitzell et al. 2003), rendering large patches of contiguous BLH extremely valuable for floral and faunal species diversity (Gosselink et al. 1990). The decrease in BLH area has been correlated with a decrease in the species richness of migratory birds (Burdick et al. 1989). Furthermore, there exists a significant relationship between decreases in BLH area and decreases in forest bird abundance and densities (Burdick et al. 1989).

Variable V6 - Suitability and Traversability of Surrounding Habitat

The quality of a bottomland hardwood forest patch is clearly associated with the type of habitat that surrounds it (Gosselink and Lee 1989, Rudis 1995). Certain species of birds and mammals will not traverse other types of habitats, especially those developed by humans, to move from one patch of BLH to another (Gosselink and Lee 1989, Gosselink et al. 1990b). Clearly habitat types such as abandoned agricultural fields or pastures are of higher habitat value than cultivated fields, residential areas, or busy streets.

Variable V7 – Disturbance

Human-induced disturbance can displace individuals, modify home ranges, interfere with reproduction, cause stress, and force animals to use important energy reserves. Clearly, the effect of a disturbance is a function of the type of disturbance and the distance of the disturbance to the habitat in question (Rudis 1995). Many species of birds and mammals are highly sensitive to disturbance (Twedt et al. 1999, Wigley and Roberts 1997). As described above, animals have different habitat requirements from 6,900 acres (2,800 ha) for certain neotropical migrants to 494,200 acres (200,000) ha for the Louisiana black bear. In general, ecosystem function of forest interiors often is not reflected by forest edges prone to disturbance (Gosselink et al. 1990a, b, Llewellyn et al. 1996, Shaffer et al. 1992, 2009a). Furthermore, as patch size increases, the effects of outside disturbances have been shown to decrease (Rudis 1993, 1995).

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<u>Appendix II</u>
Document Revisions

Version 1.0 – April 2010 document developed via the Corps' WVA certification process

Version 1.1 – April 2012
1) Pertinent sections from the Procedural Manual incorporated

Version 1.2 – November 2018
1) Manual updated, including additional language for V4.

Appendix III

Project Information Sheet Format

Project Name:

Sponsoring Agency: List Environmental and Engineering Work Group Contacts

Project Location and Description: Describe project location (Coast 2050 region, basin, parish, nearby cities, important bodies of water, total acres, wetland type, etc.). Include a project map.

Problem: Discuss the major causes (historical and current) of habitat loss/degradation in the project area.

Objectives: How will the project address the major causes of habitat loss/degradation in the project area? What are the specific objectives of the project?

Project Features: List all project features including their locations, dimensions, etc. The project map should include the locations of all project features.

Monitoring and Modeling Results for Similar Projects: Relevant monitoring reports and modeling studies should be discussed.

Miscellaneous: As necessary, discuss the following subjects as they relate to the project.
Climate change
Off site disturbances – these are generally the same FWOP and FWP.
Any project risks or uncertainties

V1 – Tree Species Association

1) Discuss the historical and current vegetative community and any trends noted for the area.

2) Discuss the methods used to determine the percentage of hard mast, soft mast, and non-mast producing species in the overstory.

TY 0 – Existing class of Tree Species Association (percentages of hard mast, soft mast, and non-mast producing species).

FWOP – Provide percentages and class value for each target year (TY) and include all assumptions. Use as many TYs as necessary and justify each.
TY 1 –
TY X –
TY Y –

TY 50 –

FWP – Provide percentages and class value for each target year (TY) and include all assumptions. Use as many TYs as necessary and justify each.
TY 1 –
TY X –
TY Y –
TY 50 –

V2 – Stand Maturity

1) Discuss the methods used to collect dbh values or determine the age of canopy-dominant and canopy-codominant trees for the baseline condition.

TY 0 – Average dbh or age for canopy-dominant and canopy-codominant trees.

FWOP – Provide average dbh or age for canopy-dominant and canopy-codominant trees for each target year (TY) and include all assumptions. Use as many TYs as necessary and justify each.
TY 1 –
TY X –
TY Y –
TY 50 –

FWP – Provide average dbh or age for canopy-dominant and canopy-codominant trees for each target year (TY) and include all assumptions. Use as many TYs as necessary and justify each.
TY 1 –
TY X –
TY Y –
TY 50 –

V3 – Understory / Midstory Coverage

1) Discuss the methods used to determine the understory and midstory cover values for the baseline condition.

TY 0 – Understory and midstory cover values.

FWOP – Provide cover values for each target year (TY) and include all assumptions. Use as many TYs as necessary and justify each.
TY 1 –
TY X –
TY Y –
TY 50 –

FWP – Provide cover values for each target year (TY) and include all assumptions. Use as many TYs as necessary and justify each.
TY 1 –
TY X –
TY Y –
TY 50 –

V4 – Hydrology

1) Discuss the methods used to determine the flooding duration and degree of flow/exchange for the baseline condition.

TY 0 – Flooding duration and degree of water flow/exchange.

FWOP – Determine flooding duration and degree of exchange for each target year (TY) and include all assumptions. Use as many TYs as necessary and justify each.
TY 1 –
TY X –
TY Y –
TY 50 –

FWP – Determine flooding duration and degree of exchange for each target year (TY) and include all assumptions. Use as many TYs as necessary and justify each.
TY 1 –
TY X –
TY Y –
TY 50 –

V5 – Size of Contiguous Forested Area

1) Discuss the methods used to determine the size of the contiguous forested area for the baseline condition.

TY 0 – Class value for the size of the contiguous forested area.

FWOP – Determine the class value for each target year (TY) and include all assumptions. Use as many TYs as necessary and justify each.
TY 1 –
TY X –
TY Y –
TY 50 –

FWP – Determine the class value for each target year (TY) and include all assumptions. Use as many TYs as necessary and justify each.
TY 1 –

TY X –
TY Y –
TY 50 –

V6 – Suitability and Traversability of Surrounding Land Uses

1) Discuss the methods used to determine the surrounding land uses for the baseline condition.

TY 0 – Percentage values for each surrounding land use.

FWOP – Determine the percentage values for each surrounding land use for each target year (TY) and include all assumptions. Use as many TYs as necessary and justify each.
TY 1 –
TY X –
TY Y –
TY 50 –

FWP – Determine the percentage values for each surrounding land use for each target year (TY) and include all assumptions. Use as many TYs as necessary and justify each.
TY 1 –
TY X –
TY Y –
TY 50 –

V7 – Disturbance

1) Discuss the methods used to determine the distance class and the type class for disturbances surrounding the project area for the baseline condition.

TY 0 – Distance class and type class for disturbances around the project area.

FWOP – Determine the distance class and type class for disturbances surrounding the project area for each target year (TY) and include all assumptions. Use as many TYs as necessary and justify each.
TY 1 –
TY X –
TY Y –
TY 50 –

FWP – Determine the distance class and type class for disturbances surrounding the project area for each target year (TY) and include all assumptions. Use as many TYs as necessary and justify each.
TY 1 –

TY X –
TY Y –
TY 50 –

Literature Cited

Other Supporting Information

Part 5: Memo - Regional Use Re-approval of the WVA Coastal Barrier Headland, Barrier Island, Bottomland Hardwood, Coastal Chenier and Swamp Models

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

CEMVD-PDP 06 December 2018

MEMORANDUM FOR

Commander, Fort Worth District, Regional Planning and Environmental Center, U.S. Army Corps of Engineers (Attn: Mr. Rob Newman, CESWF-PEC)

Commander, New Orleans District, Regional Planning and Environmental Division South, U.S. Army Corps of Engineers (Attn: Mr. Troy Constance, CEMVN-PD)

Commander, St Paul District, Regional Planning and Environmental Division North, U.S. Army Corps of Engineers (Attn: Mr. Terry Birkenstock, CEMVP-PD)

SUBJECT: Regional Use Re-approval of the Wetland Value Assessment (WVA) Coastal Barrier Headland, Barrier Island, Bottomland Hardwood, Coastal Chenier and Swamp Models

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

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

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

   d. Memorandum to Director of the National Ecosystem Restoration Planning Center of Expertise - Subject: Recommend Regional Use Re-approval of the Wetland Value Assessment (WVA) Coastal Barrier Headland, Barrier Island, Bottomland Hardwood, Coastal Chenier and Swamp Models, 03 December 2018. (Encl 1)

2. The National Ecosystem Restoration Planning Center of Expertise evaluated the results of an independent review managed by a team of experts from the New Orleans District for the subject models. The models are used to evaluate and compare alternatives for habitat restoration or other civil works project activities.

3. The models are re-approved for regional use within the range of applicability defined for each model. Independent technical review of the tools is complete and the models meet the criteria contained in References 1.a. and 1.b. There are no

unresolved issues stemming from the review. This re-approval will expire on 06 December 2025.

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

Encl

CF
CEMVD-PDP (Lawton, Mallard, Miller)
CEMVP-PD (Birkenstock)
CEMVP-PD-F (Knollenberg, Mesko, Richards, Sparks)
CEMVP-PD-P (Creswell, McCain, Runyon)
CEMVP-PD-C (Johnson, Jordan)
CEMVN-PD (Constance)
CEMVN-PM-P (Inman)
CEMVN-PM-W (Broussard)
CEMVN-PD-P (Axtman)
CEMVN-PDN (Harper)
CEMVN-PDN-CEP (Klein, Smith)
CEMVN-PDN-UDP (Meden)
CELRH-PX-NC (Cade)
CENAD-PD-X (Cocchieri)
CESAM-PD-D (Otto)
CESPD-PDS-P (Thaut)

Part 6: WVA Coastal Marsh Community Models for Civil Works Version 2.1

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

Wetland Value Assessment Coastal Marsh Community Models for Civil Works (Version 2.1)

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

November 2024

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US Army Corps of Engineers
New Orleans District

WETLAND VALUE ASSESSMENT METHODOLOGY
Coastal Marsh Community Models (Version 2.1)

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 U.S. Army Corps of Engineers (USACE) civil works planning models.

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 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 current version discussed in this manual is version 2.1. Version 2.1 of the WVA Marsh Models is substantively the same as Version 2.0. Updates to model spreadsheets were made to increase useability by

1. allowing decimal entries for V1 and V2, and
2. allow user entry for marsh and open water acres

Additional explanation was provided in the user manual for V1 and V3.

A major update to the models were established in version 2.0 (approved 4 NOV 2017). Incorporation of Battelle's recommendations specific to Comment 10 (Battelle Memorial Institute 2010) provided guidance for some aspects of the WVA Marsh Models version 2.0. 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 54-57 for Battelle's Comment 10 from the WVA Marsh Model Review.

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. Consequently, the model is applicable from Galveston Bay, TX through coastal Louisiana. Use of the model outside of this area is not recommended as it may not adequately represent the community dynamics.

Minimum Area of Application

Numerous 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 should accurately depict the 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 49-53 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 1). 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 1. 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	
	roseate spoonbill	
Reptiles and Amphibians		
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 49-53).

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.

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 54-57) for supporting information and a literature review.

For all coastal marsh WVAs, V1 (Percent of wetland area covered by emergent vegetation) considers emergent vegetation cover at the landscape or project spatial scale, similar to a land cover classification. That is, the percentage entered should estimate the percentage of the project area that has established emergent vegetation. V1 should not be based on percent ground cover of emergent vegetation that is often estimated by quadrat in the field. Estimating percent cover of emergent vegetation for V1 could be completed in a similar manner to a land cover analysis using various remotely sensed techniques, field data, and imagery.

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

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 54-57) for supporting information and a literature review.

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

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 31-37) 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 (see V3 in Appendix I for more details). 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.

Interspersion classification for V3 is inherently subjective and Figures on pages 31-37 should be used as a guideline and reference. End users with limited WVA experience are encouraged to discuss assumptions and estimates for V3 through discussion with more experienced WVA practitioners and experts seeking consensus for this variable. It is important to note that carpet marsh should be treated as Classification 3 for this variable, as noted in the sample illustrations on pages 31-37 of this User Guide.

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

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.

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 38-41). 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 2). 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 2 shows the overall value of each of the variables after weighting.

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

Brackish Marsh: 2.6(Marsh AAHUs) + Open Water AAHUs

3.6

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

Table 2. 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.

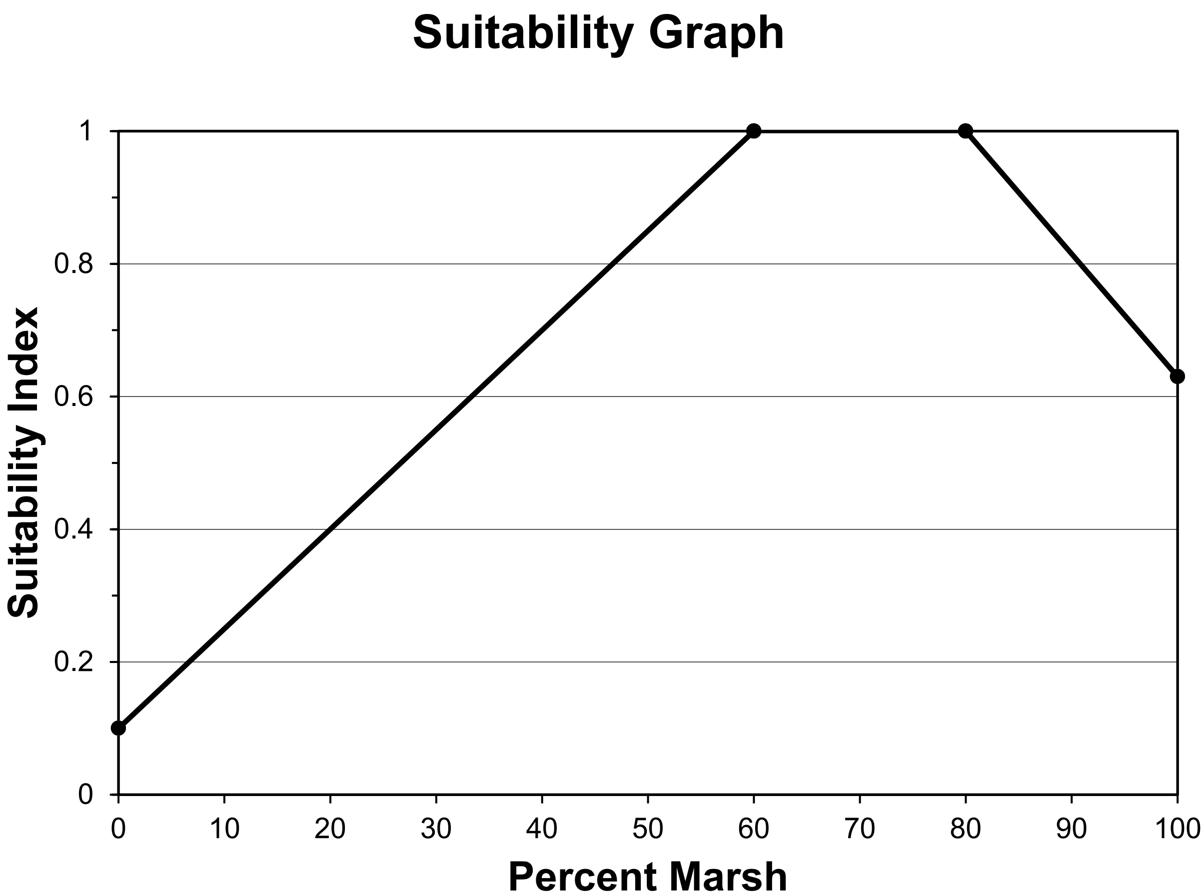
HSI Calculations:

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

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

FRESH/INTERMEDIATE MARSH

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



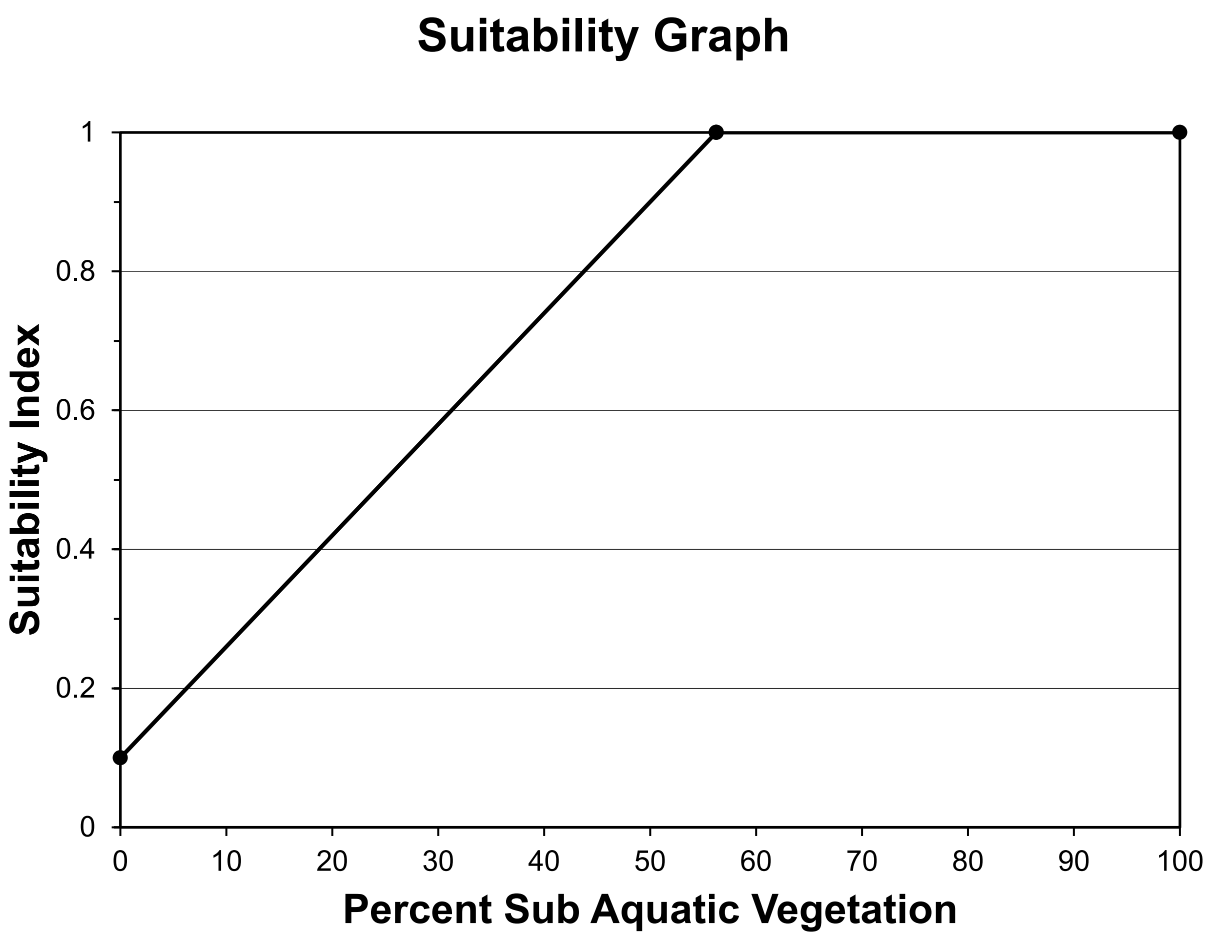
Line Formula

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

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

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

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

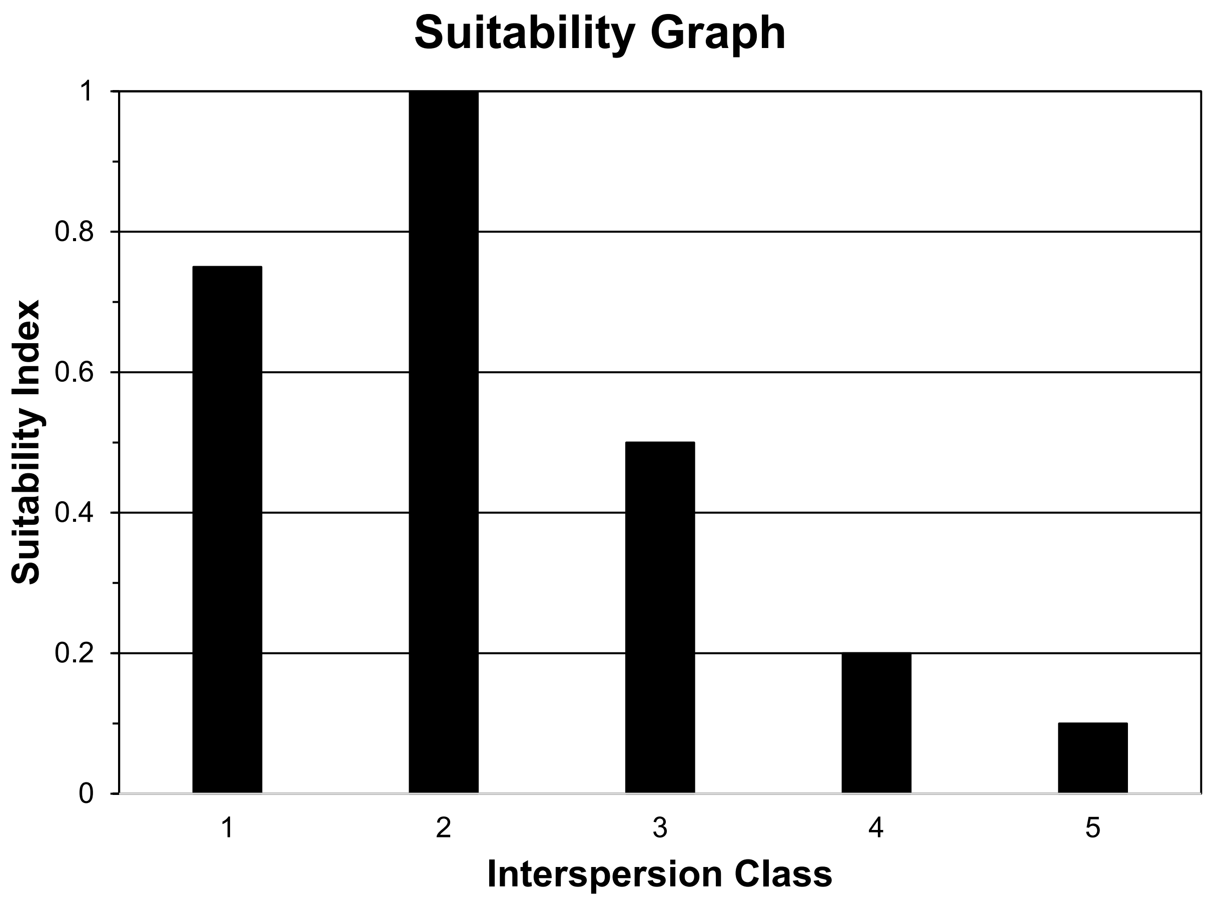


Line Formula

If 0 ≤ % < 56.25%, then SI = (0.016 * %) + 0.1

If % ≥ 56.25%, then SI = 1

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

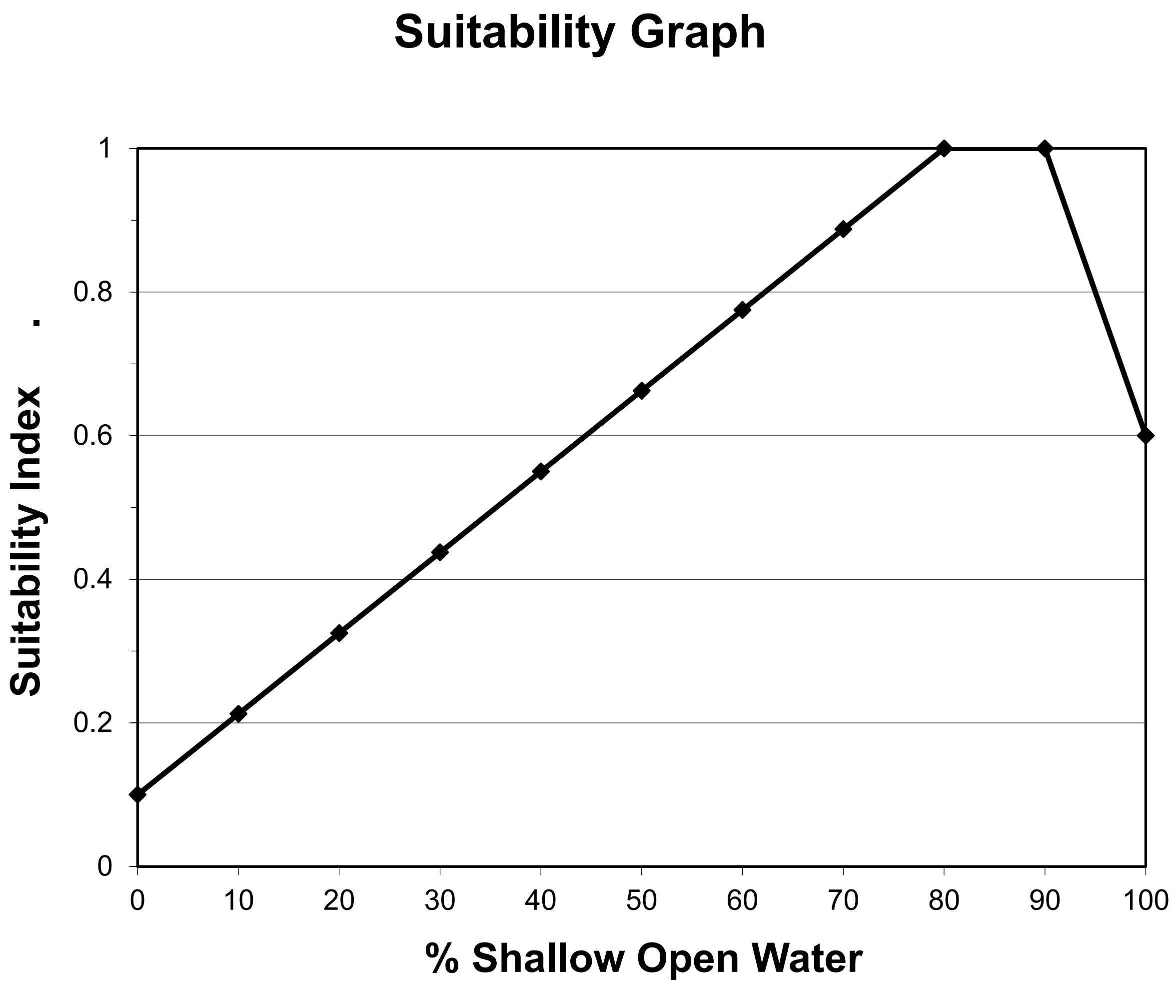


Instructions for Calculating the SI for Variable V_3:

1. Refer to pages 31-37 for examples of the different interspersion classes.

2. Estimate percent of project area in each class.

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



Line Formulas

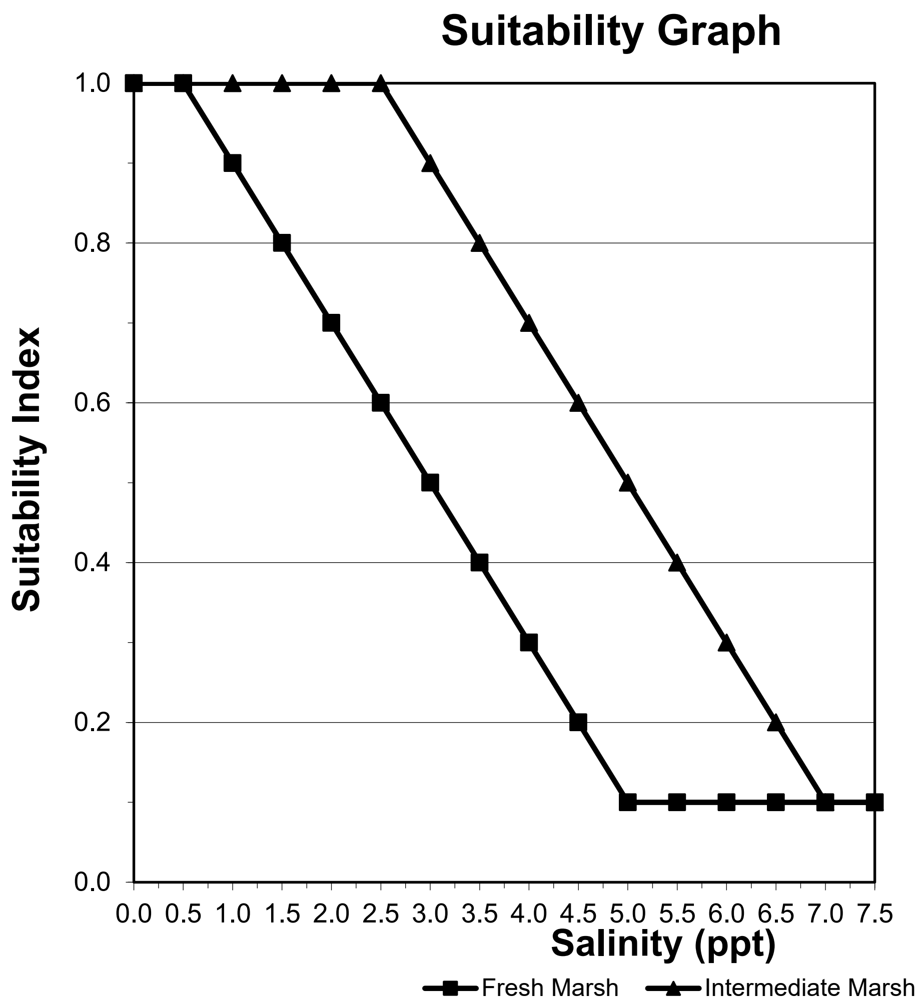
If 0 ≤ % < 80, then SI = (0.01125 * %) + 0.1

If 80 ≤ % ≤ 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).

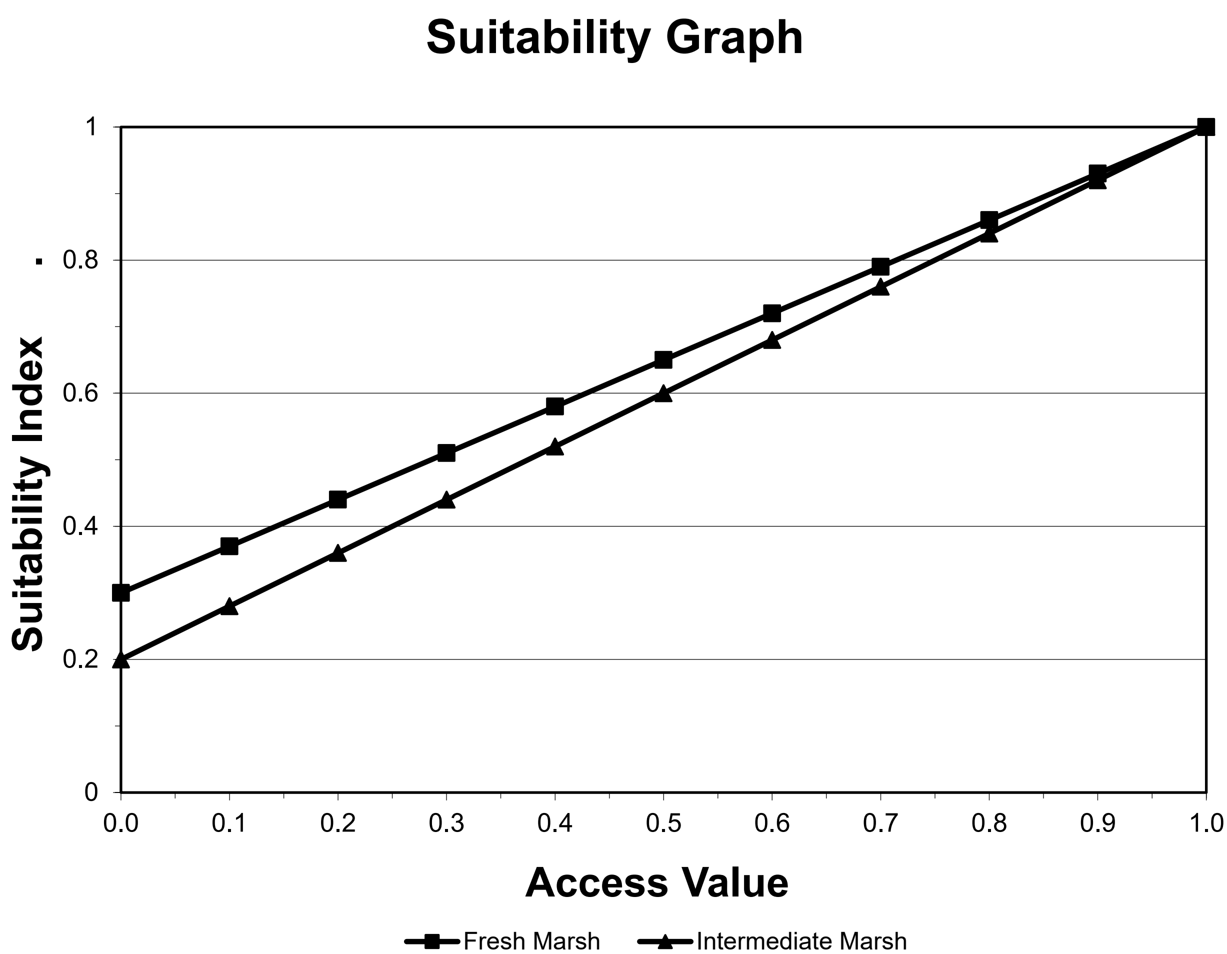


Line Formulas

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

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 38-41 for complete information on calculating the Access Value.

WETLAND VALUE ASSESSMENT COASTAL MARSH COMMUNITY MODEL

Brackish 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.

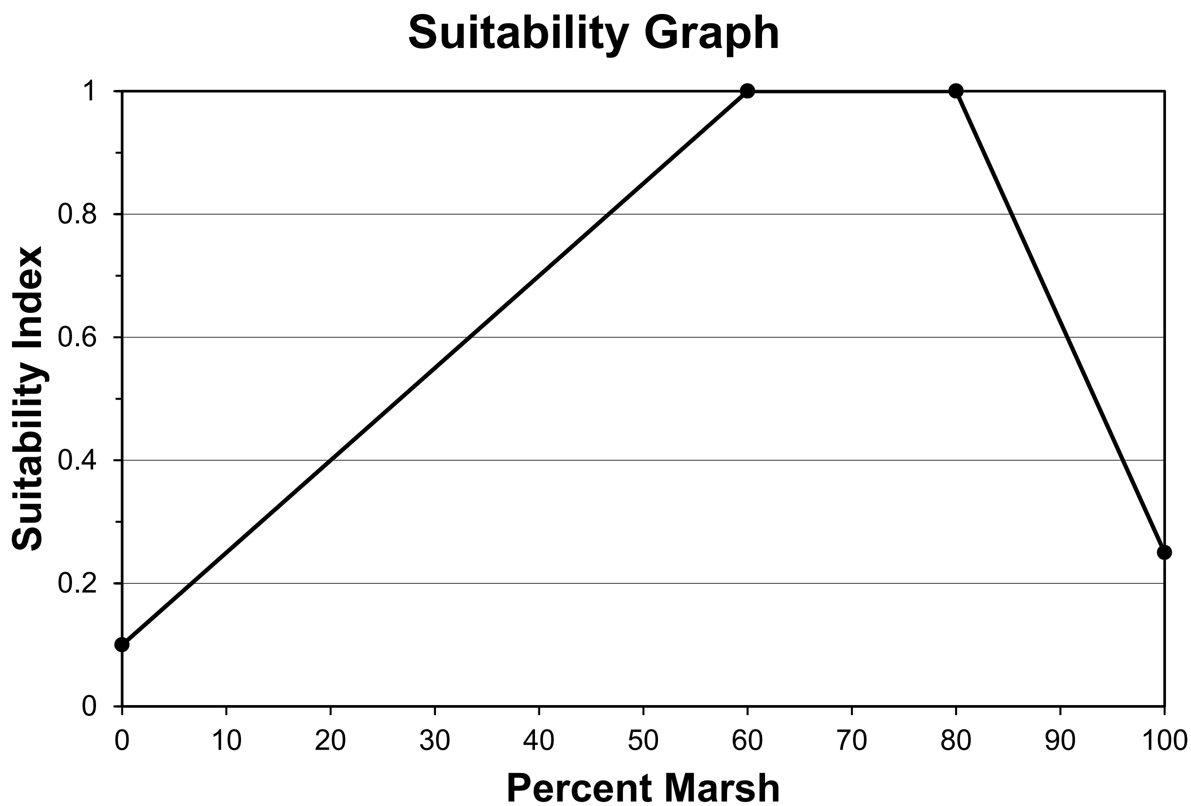
HSI Calculations:

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

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

BRACKISH MARSH

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



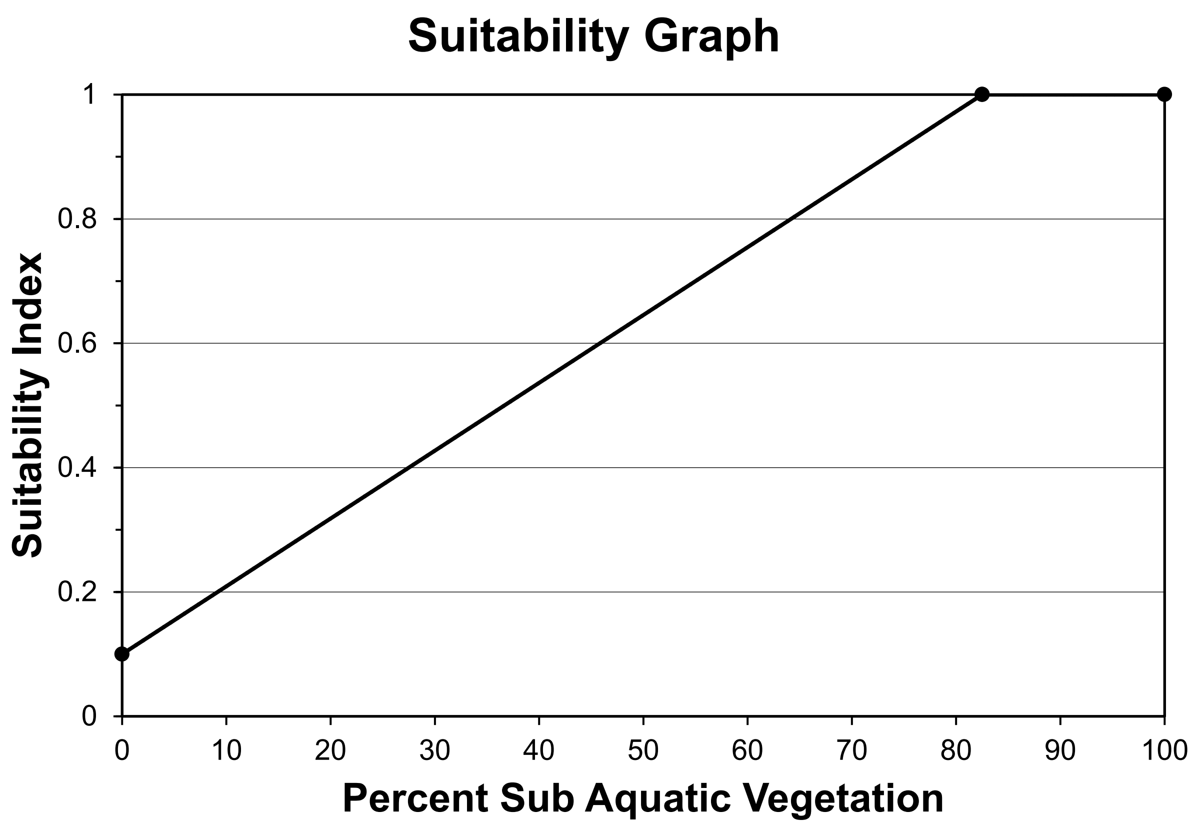
Line Formula

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

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

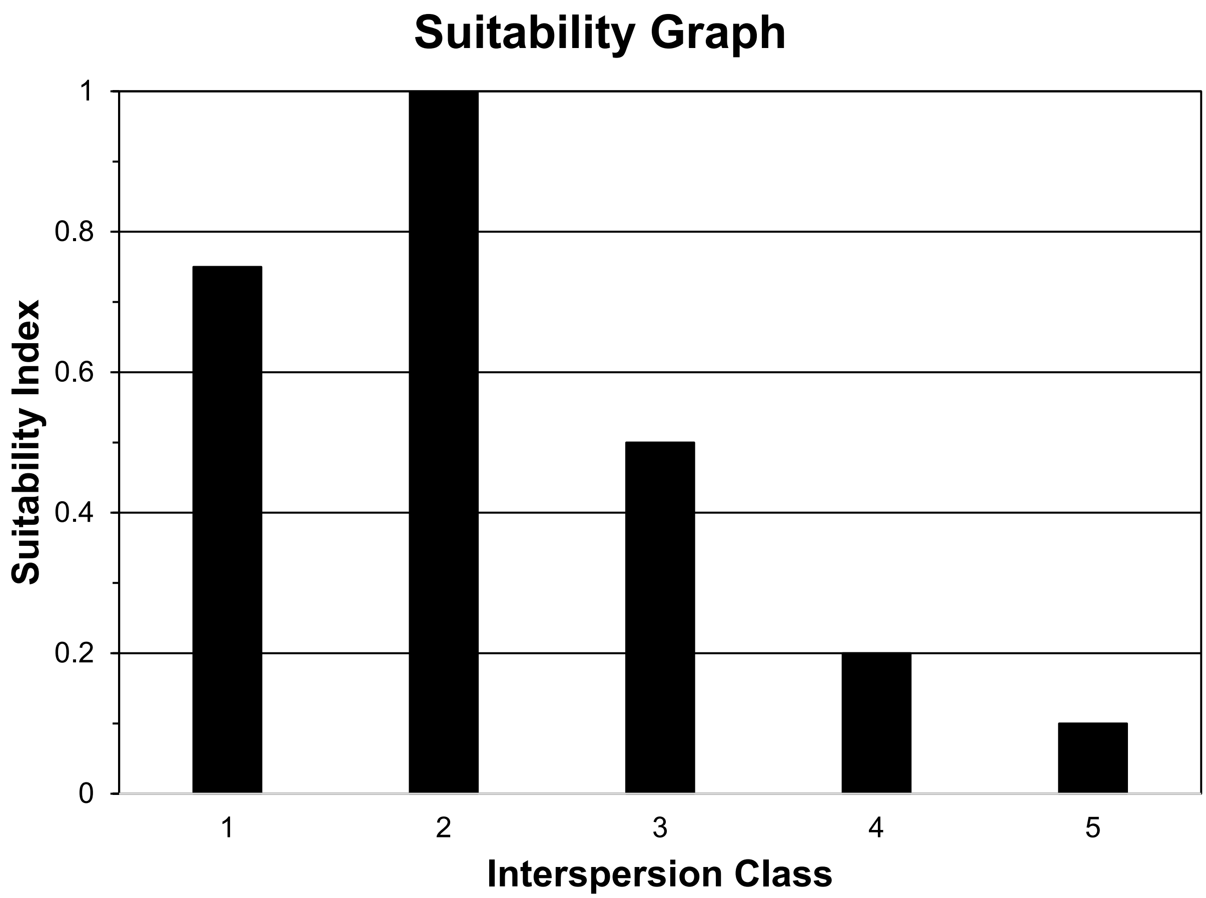


Line Formula

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).

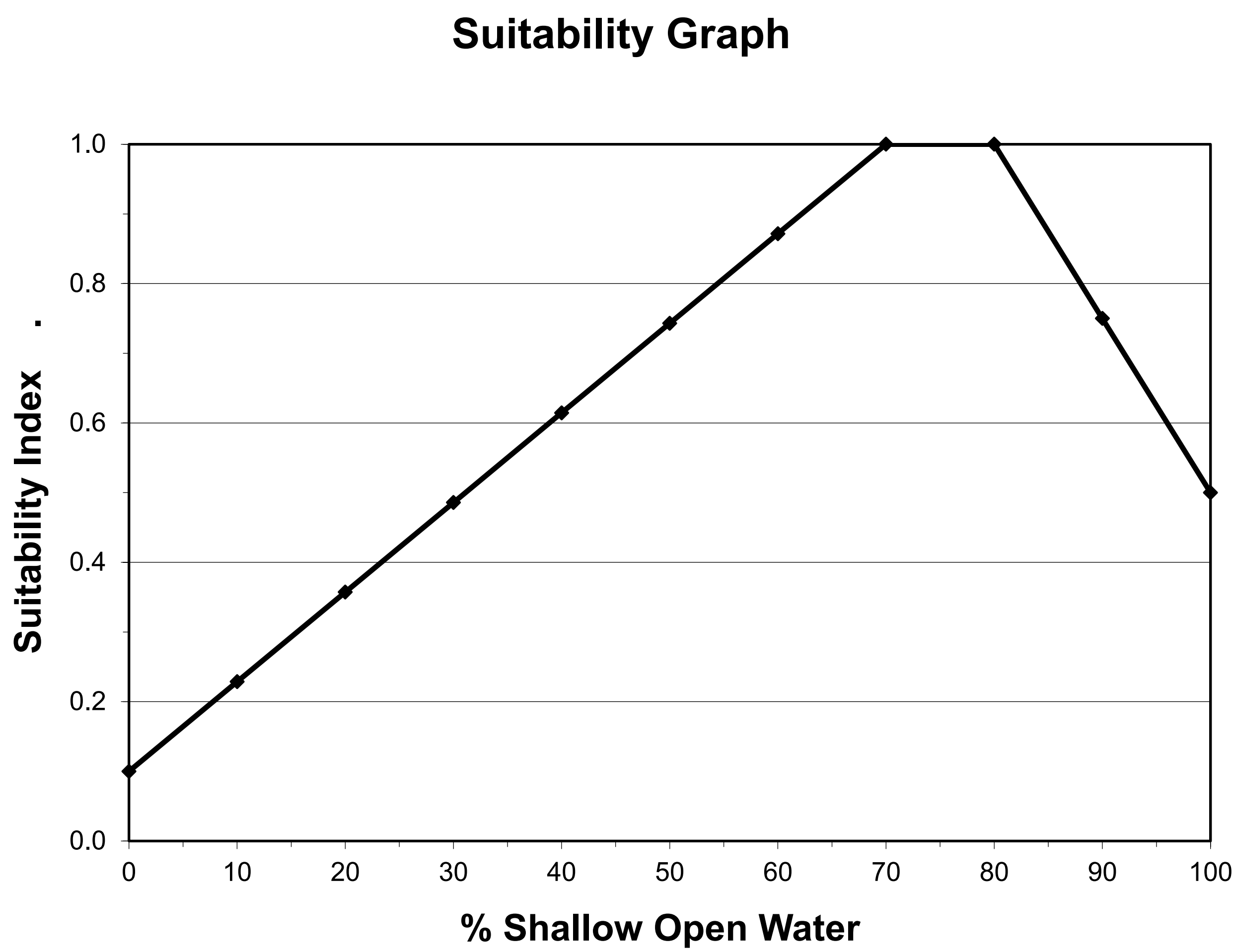


Instructions for Calculating SI for Variable V_3:

1. Refer to pages 31-37 for examples of the different interspersion classes.

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

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



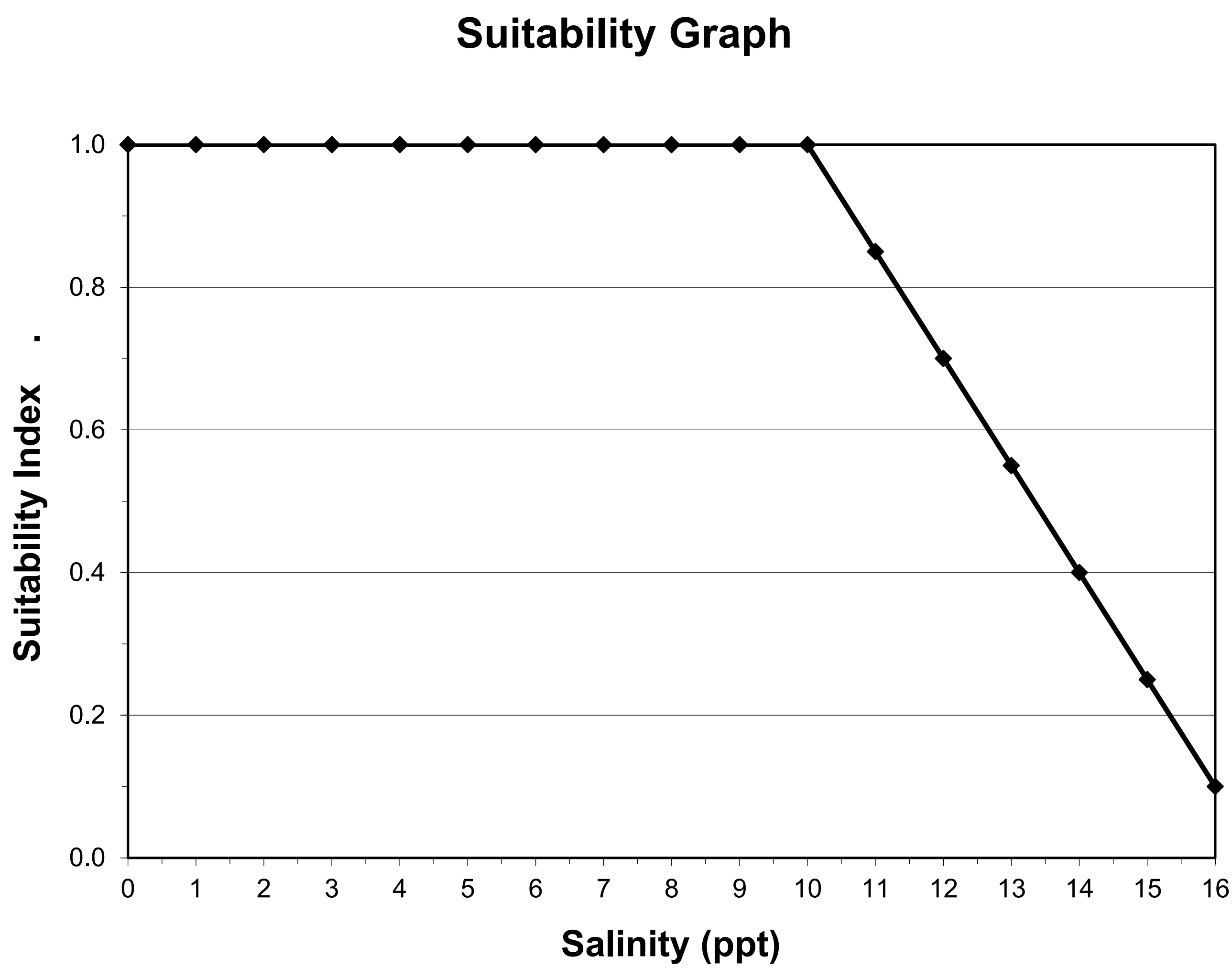
Line Formulas

If 0 ≤ % < 70, then SI = (0.01286 * %) + 0.1

If 70 ≤ % ≤ 80, then SI = 1.0

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

Variable V_5 Average annual salinity.

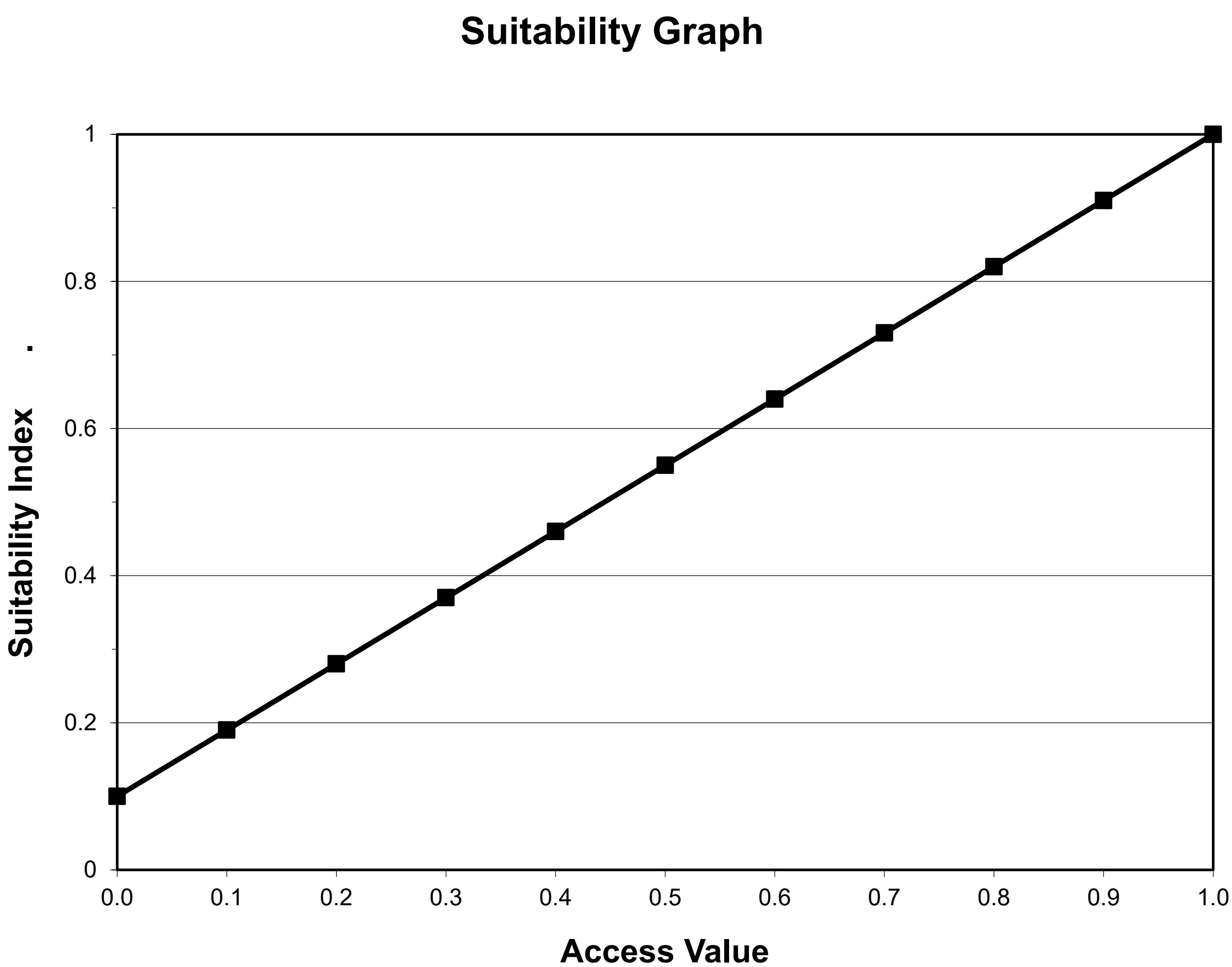


Line Formulas

If $0 \leq \text{ppt} \leq 10$, 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

<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 38-41 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:

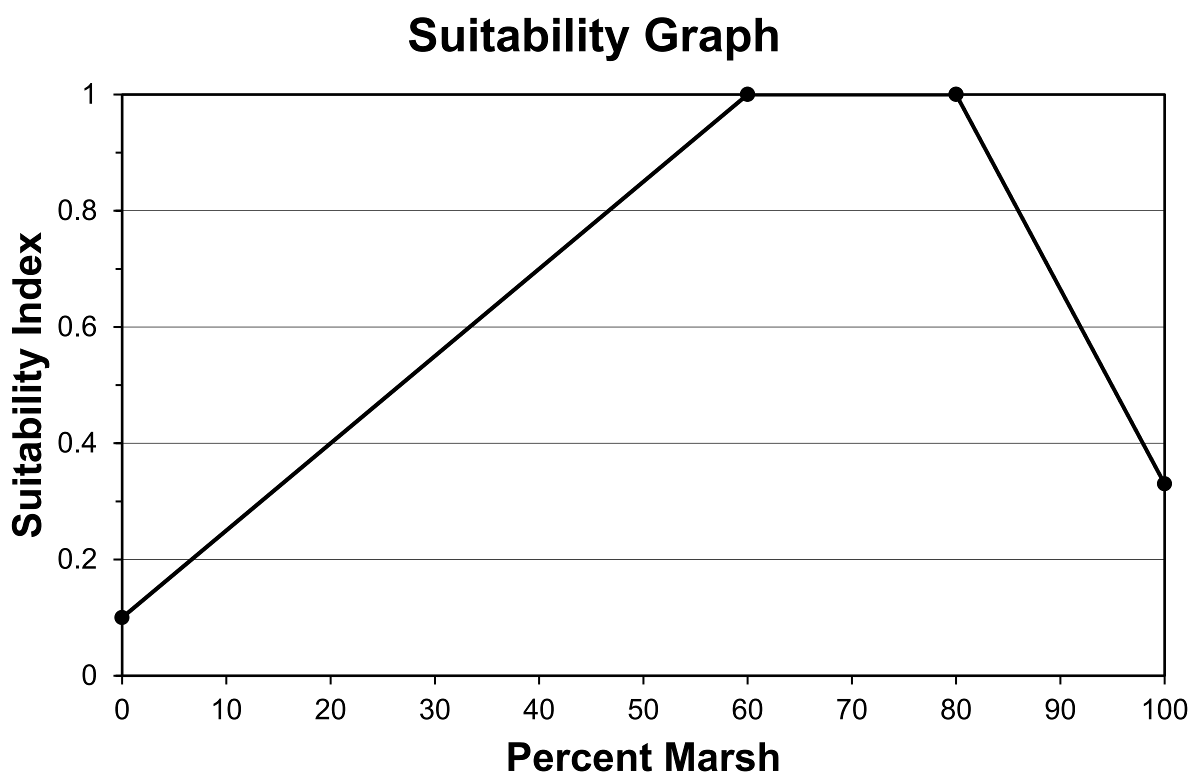
Variable V_6 Aquatic organism access.

HSI Calculation:

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

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

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



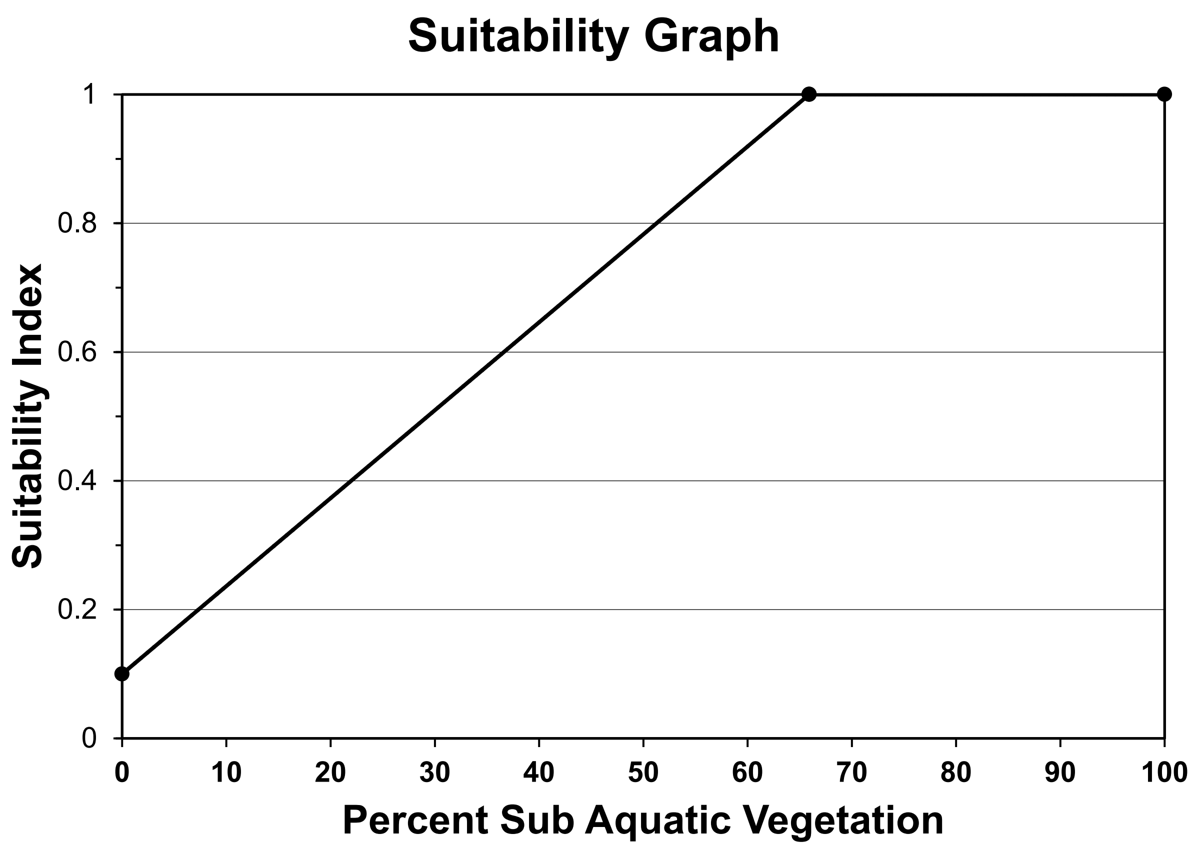
Line Formula

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).

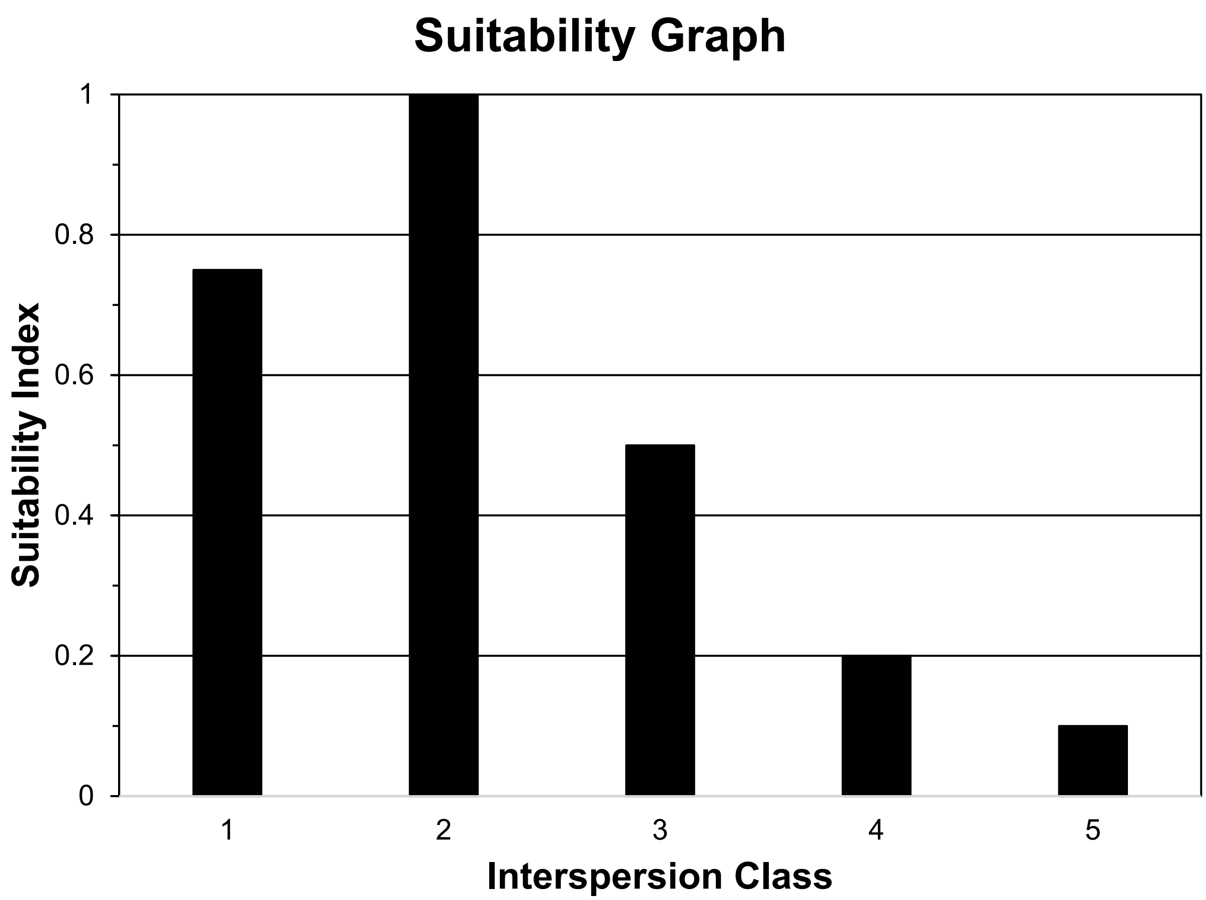


Line Formula

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).



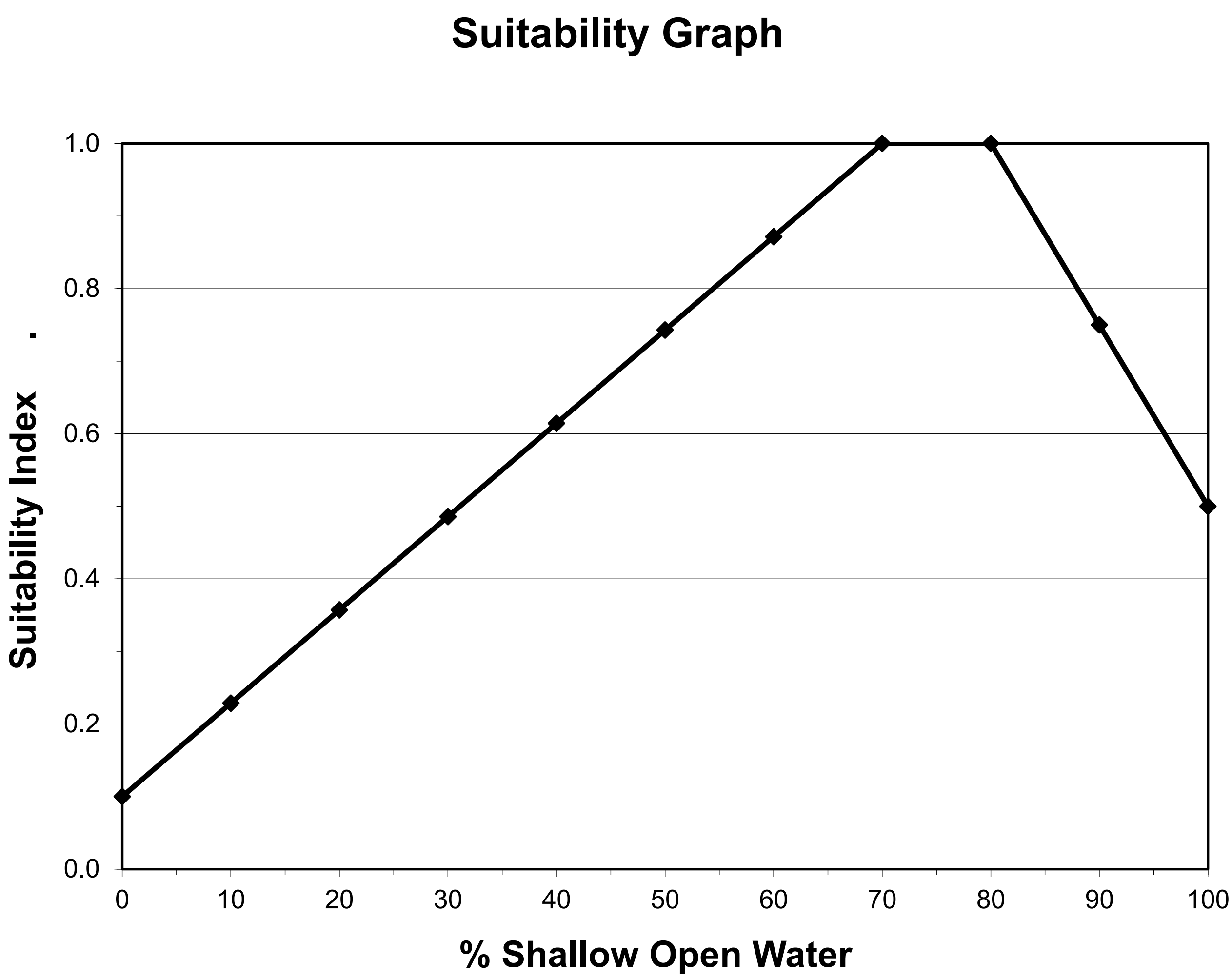
Instructions for Calculating SI for Variable V_3:

1. Refer to pages 31-37 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 ≤ 1.5 feet deep, in relation to marsh surface.



Line Formulas

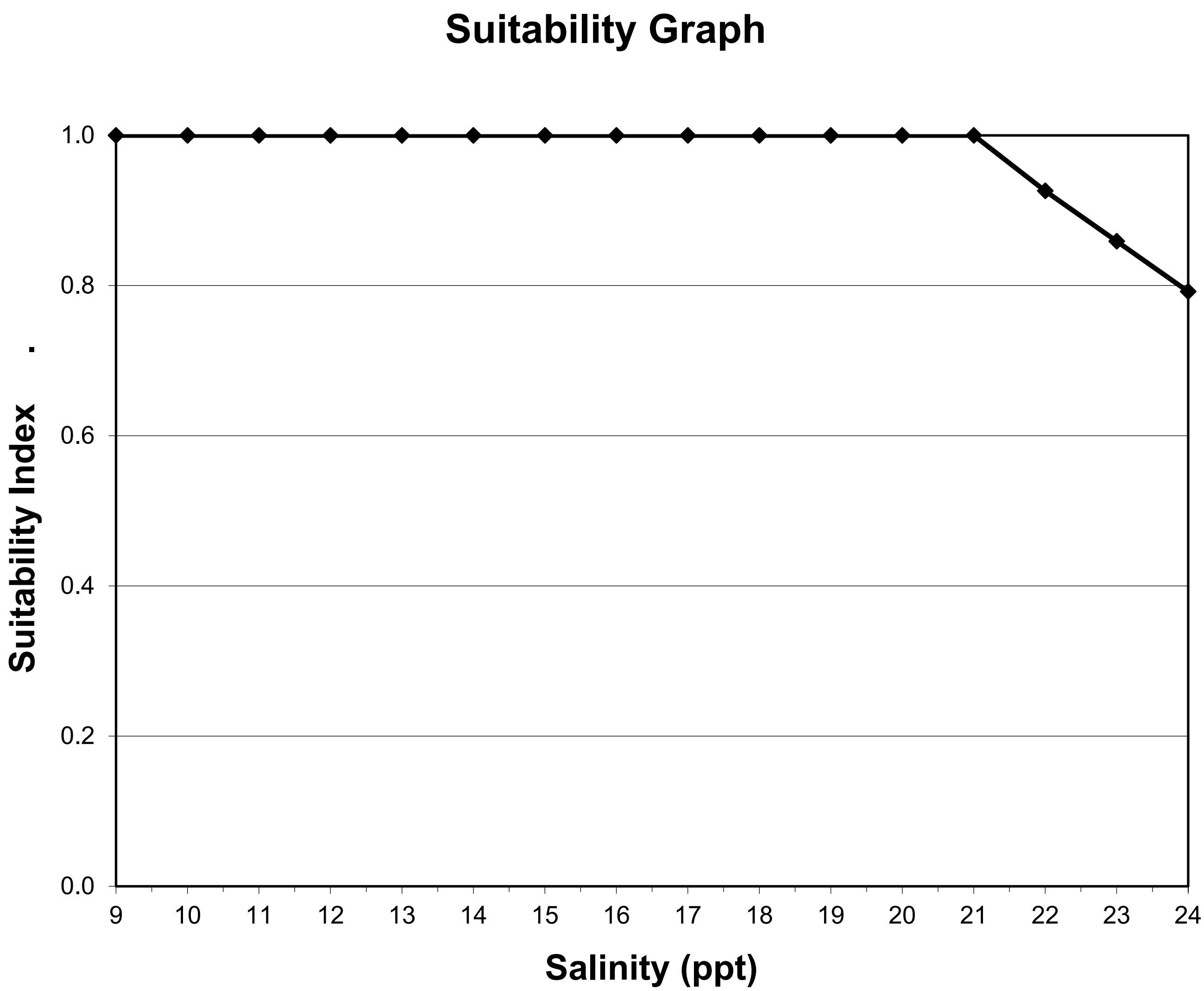
If 0 ≤ % < 70, then SI = (0.01286 * %) + 0.1

If 70 ≤ % ≤ 80, then SI = 1.0

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

SALINE MARSH

Variable V_5 Average annual salinity.



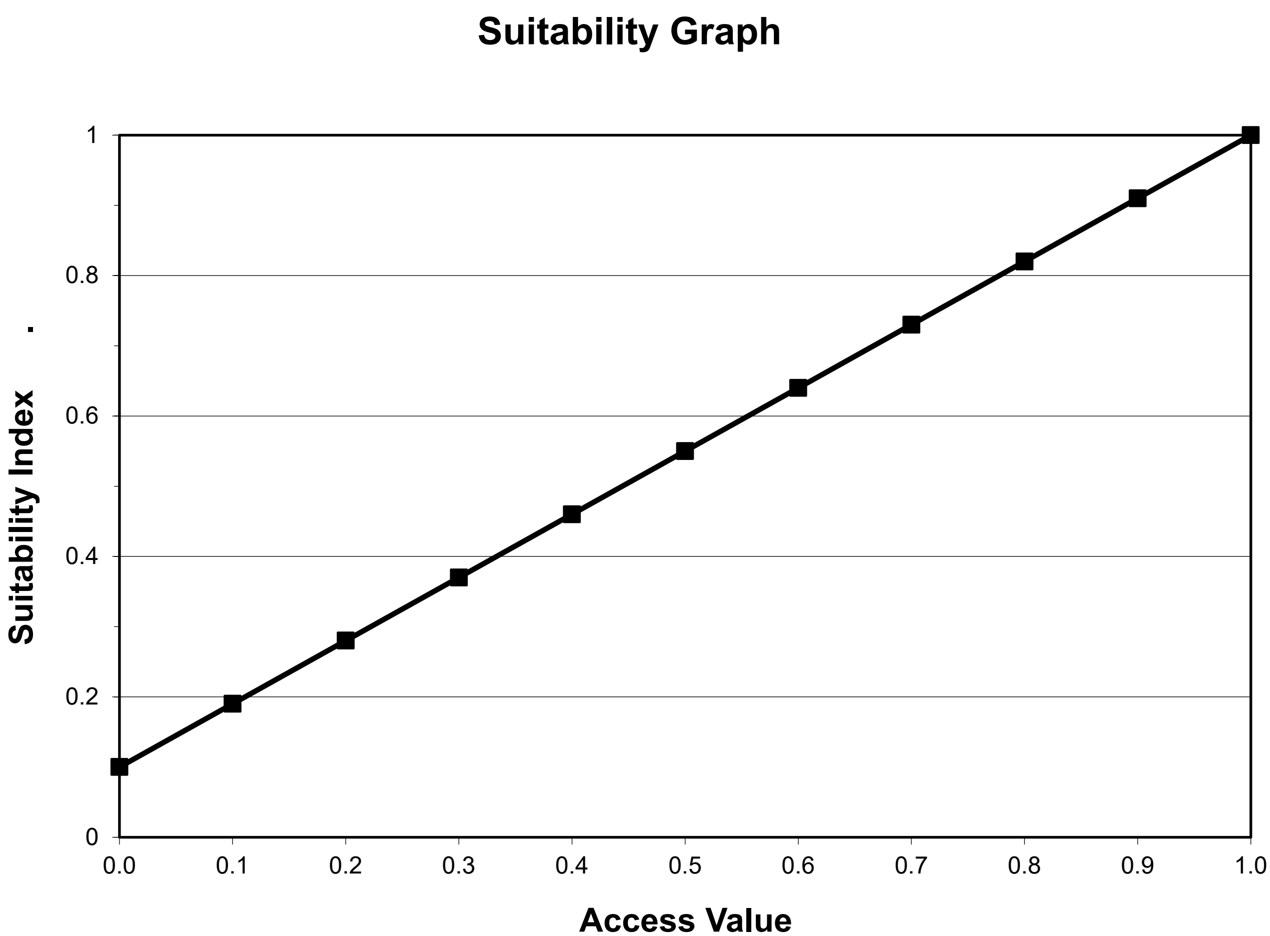
Line Formulas

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

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

SALINE MARSH

Variable V_6 Aquatic organism access.



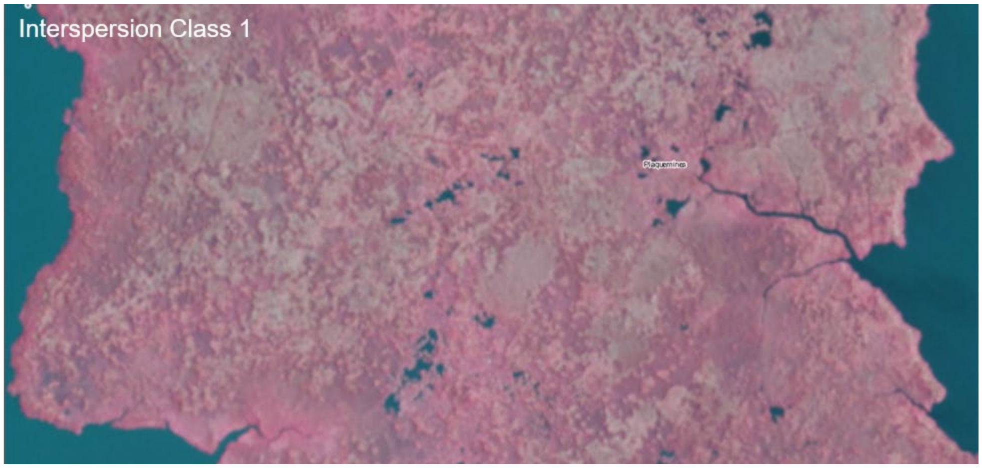
Line Formula

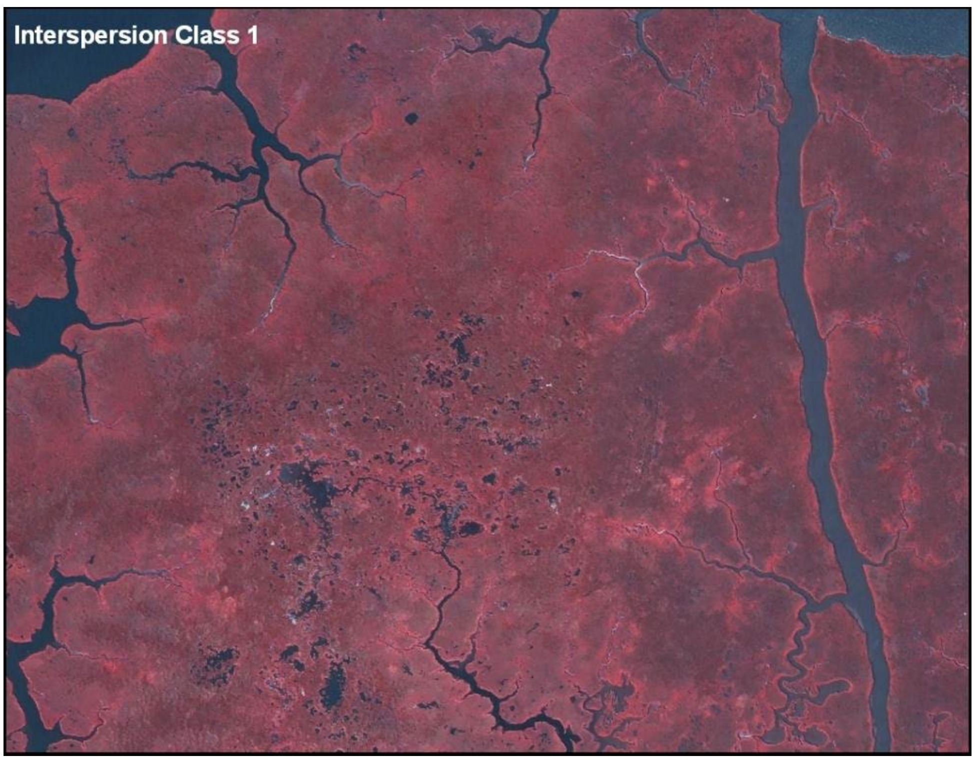
SI = (0.9 * Access Value) + 0.1

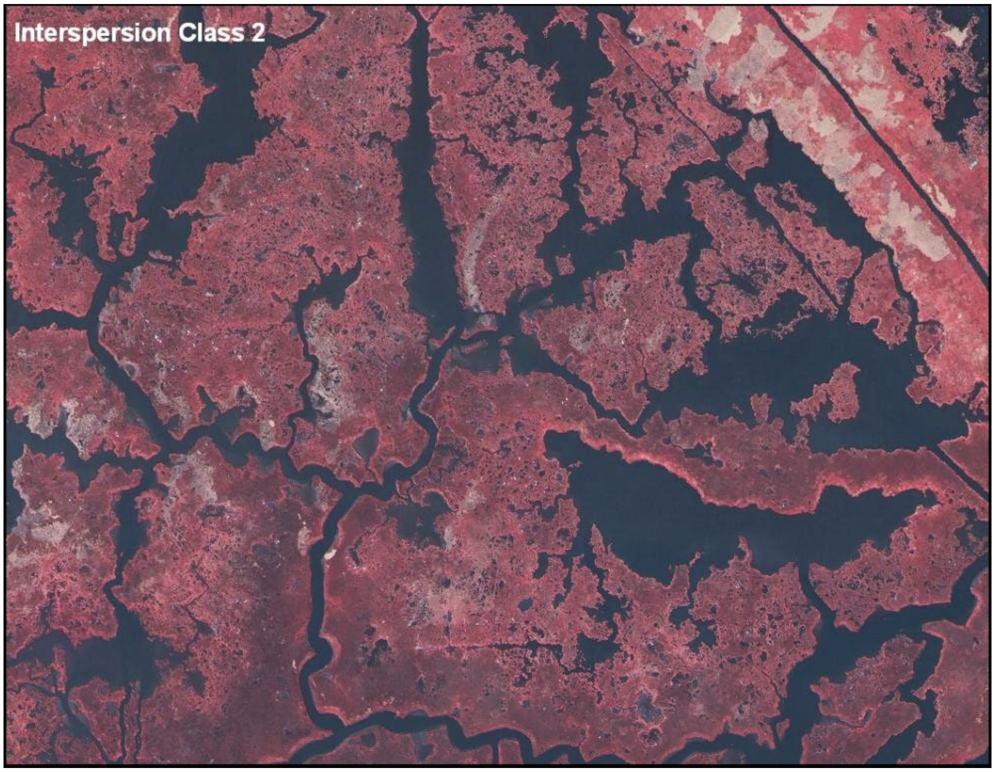
<u>**Note**</u>: Access Value = P * R, where "P" = percentage of wetland area considered accessible by estuarine organisms during normal tidal fluctuations, and "R" = Structure Rating.

Refer to pages 38-41 for complete information on calculating the Access Value.

Examples of Marsh Edge and Interspersion Classes

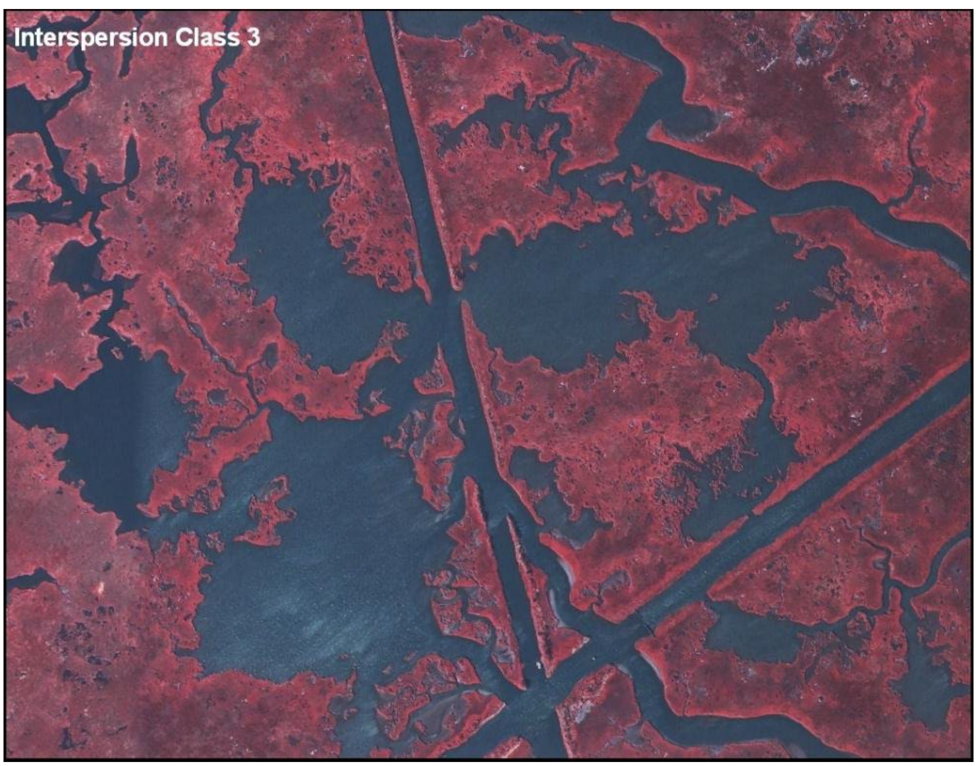





Interspersion Class 2

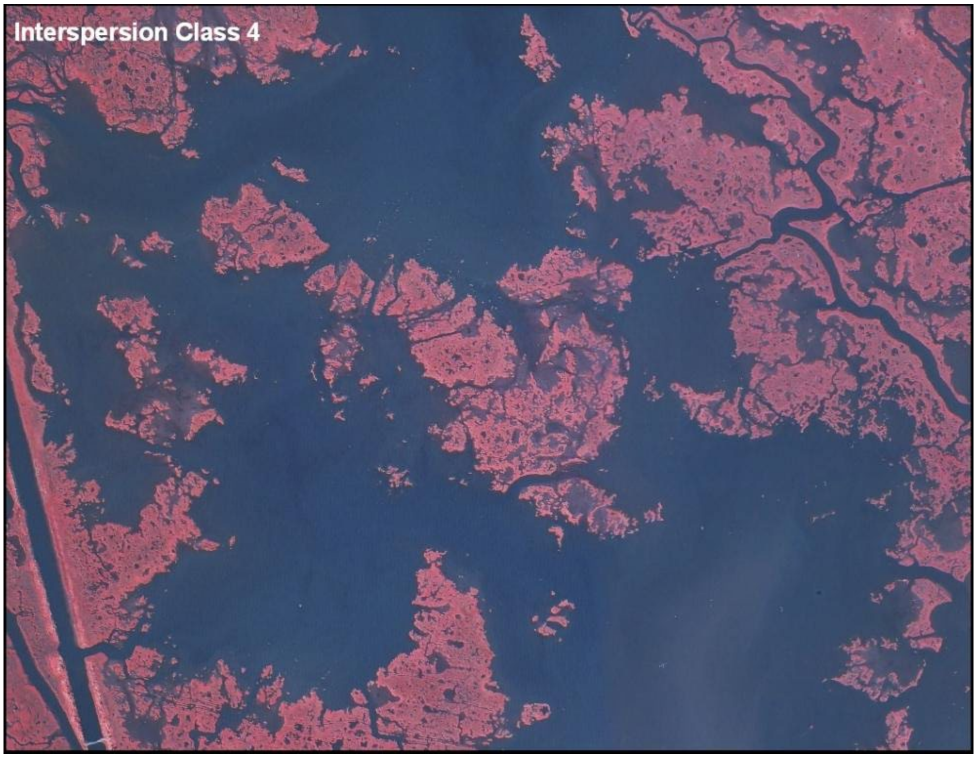

Interspersion Class 2


Interspersion Class 3


Interspersion Class 3


Interspersion Class 3
"Carpet Marsh"


Interspersion Class 4


Interspersion Class 4


Interspersion Class 5


Interspersion Class 5


Interspersion Class 5
Marsh Creation Platform


Interspersion Class 5
Marsh Creation Platform

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.

3. Determine the Access Value. Where multiple openings equally affect a common "accessible unit", the Structure Rating (R) of the structure proposed for the "major" access point for the unit will be used to calculate the Access Value. The designation of "major" will be made by the HET.

An "accessible unit" is defined as a portion of the total accessible area that is served by one or more access routes (canals, bayous, etc.), yet is isolated in terms of estuarine organism access to or from other units of the project area. Isolation factors include physical barriers that prohibit further movement of estuarine organisms, such as natural levee ridges, and spoil banks; and dense marsh that lacks channels, trenasses, and similar small connections that would, if present, provide access and intertidal refugia for estuarine organisms.

Access Value should be calculated according to the following examples (Note: for all examples, P for TY0 = 90%. That designation is arbitrary and is used only for illustrative purposes; P could be any percentage from 0% to 100%):

a. One opening into area; no structure.

Access Value = P
= .90

b. One opening into area that provides access to the entire 90% of the project area deemed accessible. A flap-gated culvert with slotted weir is placed across the opening.

Access Value = P * R
= .90 * .35
= .32

c. Two openings into area, each capable by itself of providing full access to the 90% of the project area deemed accessible in TY0. Opening #2 is determined to be the major access route relative to opening #1. A flap-gated culvert with slotted weir is placed across opening #1. Opening #2 is left unaltered.

Access Value = P
= .90

Note: Structure #1 had no bearing on the Access Value calculation because its presence did not reduce access (opening #2 was determined to be the major access route, and access through that route was not altered).

d. Two openings into area. Opening #1 provides access to an accessible unit comprising 30% of the area. Opening #2 provides access to an accessible unit comprising the remaining 60% of the project area. A flap-gated culvert with slotted weir is placed across #1. Opening #2 is left open.

Access Value = weighted avg. of Access Values of the two accessible units
= $([P_1*R_1] + [P_2*R_2])/(P_1+P_2)$
= ([.30*0.35] + [.60*1.0])/(.30+.60)
= (.11 + .60)/.90
= .71/.90
= .79

Note: $P_1 + P_2 = .90$, because only 90 percent of the study area was determined to be accessible at TY0.

e. Three openings into area, each capable of providing full access to the entire area independent of the others. Opening #3 is determined to be the major access route relative to openings #1 and #2. Opening #1 is blocked with a solid plug. Opening #2 is fitted with a flap-gated culvert with slotted weir, and opening #3 is left open.

$$\text{Access Value} = P = .90$$

Note: Structures #1 and #2 had no bearing on the Access Value calculation because their presence did not reduce access (opening #3 was determined to be the major access route, and access through that route was not altered).

f. Three openings into area, each capable of providing full access to the entire area independent of the others. Opening #2 is determined to be the major access route relative to openings #1 and #3. Opening #1 is blocked with a solid plug. Opening #2 is fitted with a flap-gated culvert with slotted weir, and opening #3 is fitted with a fixed crest weir.

$$\text{Access Value} = P * R_2 = .90 * .35 = .32$$

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 route; thus, it was the flap-gated culvert with slotted weir across that opening that actually served to limit access.

g. Three openings into area. Opening #1 provides access to an accessible unit comprising 20% of the area. Openings #2 and #3 provide access to an accessible unit comprising the remaining 70% of the area, and within that area, each is capable by itself of providing full access. However, opening #3 is determined to be the major access route relative to opening #2. Opening #1 is fitted with an open culvert, #2 with a flapgated culvert with slotted weir, and #3 with a fixed crest weir.

$$\text{Access Value} = ([P_1*R_1] + [P_2*R_3])/(P_1+P_2)$$

$$= ([.20*.5]+[.70*.35])/(.20+.70)$$
$$= (.10 + .25)/.90$$
$$= .35/.90$$
$$= .39$$

h. Three openings into area. Opening #1 provides access to an accessible unit comprising 20% of the area. Opening #2 provides access to an accessible unit comprising 40% of the area, and opening #3 provides access to the remaining 30% of the area. Opening #1 is fitted with an open culvert, #2 a flap-gated culvert with slotted weir, and #3 a fixed crest weir.

Access Value $= ([P_1*R_1]+[P_2*R_2]+[P_3*R_3])/(P_1+P_2+P_3)$

$= ([.20*.5]+[.40*.35]+[.30*.1])/(.20+.40+.30)$
$= (.10+.14+.03)/.90$
$= .27/.90$
$= .30$

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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.
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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.

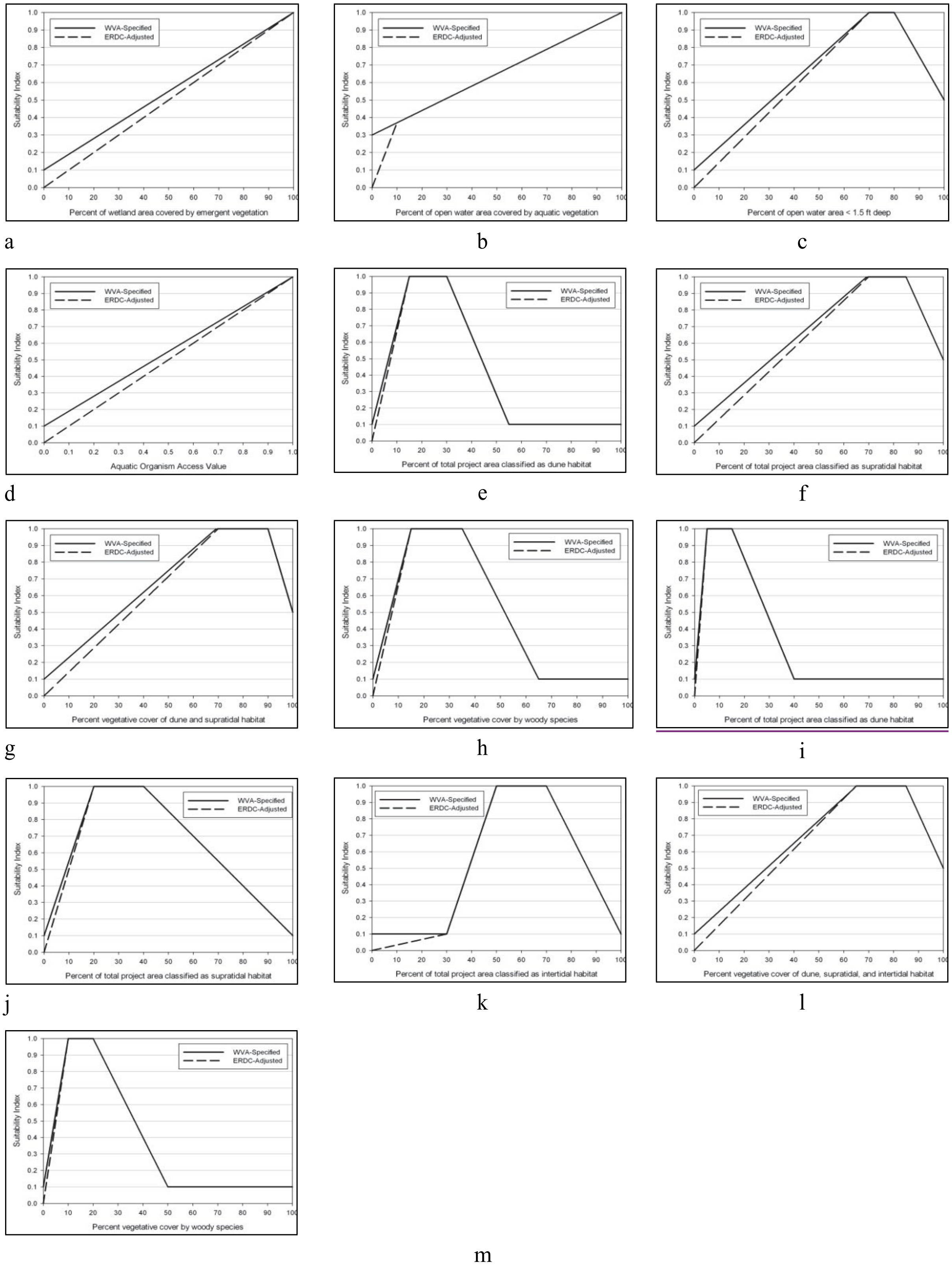

Figure 1. Suitability index curves as specified by WVA (solid lines) and adjusted by ERDC (dashed lines) to address review comments. (a-d) saline marsh (SIV_1, SIV_2, SIV_4, SIV_6); (e-h) barrier headland (SIV_1, SIV_2, SIV_3, SIV_4); and (i-m) barrier island (SIV_1, SIV_2, SIV_3, SIV_4, SIV_5).

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 Island
WVA Specified	$\frac{3.5\sqrt[4]{SIV_1^3 + SIV_6} + \frac{SIV_3 + SIV_5}{2}}{4.5}$	$\frac{3.5\sqrt[7]{SIV_2^2\, SIV_6^5} + \frac{SIV_3 + SIV_4 + SIV_5}{3}}{4.5}$	$0.23SIV_1 + 0.23SIV_2 + 0.18SIV_3 + 0.18SIV_4 + 0.18SIV_5$	$0.14SIV_1 + 0.14SIV_2 + 0.17SIV_3 + 0.20SIV_4 + 0.10SIV_5 + 0.15SIV_6 + 0.10SIV_7$
Geometric Mean	$\sqrt[4]{SIV_1 SIV_3 SIV_5 SIV_6}$	$\sqrt[5]{SIV_2 SIV_3 \ldots SIV_6}$	$\sqrt[5]{SIV_1 SIV_2 \ldots SIV_5}$	$\sqrt[7]{SIV_1 SIV_2 \ldots SIV_7}$
Arithmetic Mean	$\frac{SIV_1 + SIV_3 + SIV_5 + SIV_6}{4}$	$\frac{SIV_2 + SIV_3 + \ldots + SIV_6}{5}$	$\frac{SIV_1 + SIV_2 + \ldots + SIV_5}{5}$	$\frac{SIV_1 + SIV_2 + \ldots + SIV_7}{7}$
Harmonic Mean	$\frac{4}{\frac{1}{SIV_1} + \frac{1}{SIV_3} + \frac{1}{SIV_5} + \frac{1}{SIV_6}}$	$\frac{5}{\frac{1}{SIV_2} + \frac{1}{SIV_3} + \ldots + \frac{1}{SIV_6}}$	$\frac{5}{\frac{1}{SIV_1} + \frac{1}{SIV_2} + \ldots + \frac{1}{SIV_5}}$	$\frac{7}{\frac{1}{SIV_1} + \frac{1}{SIV_2} + \ldots + \frac{1}{SIV_7}}$

[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.

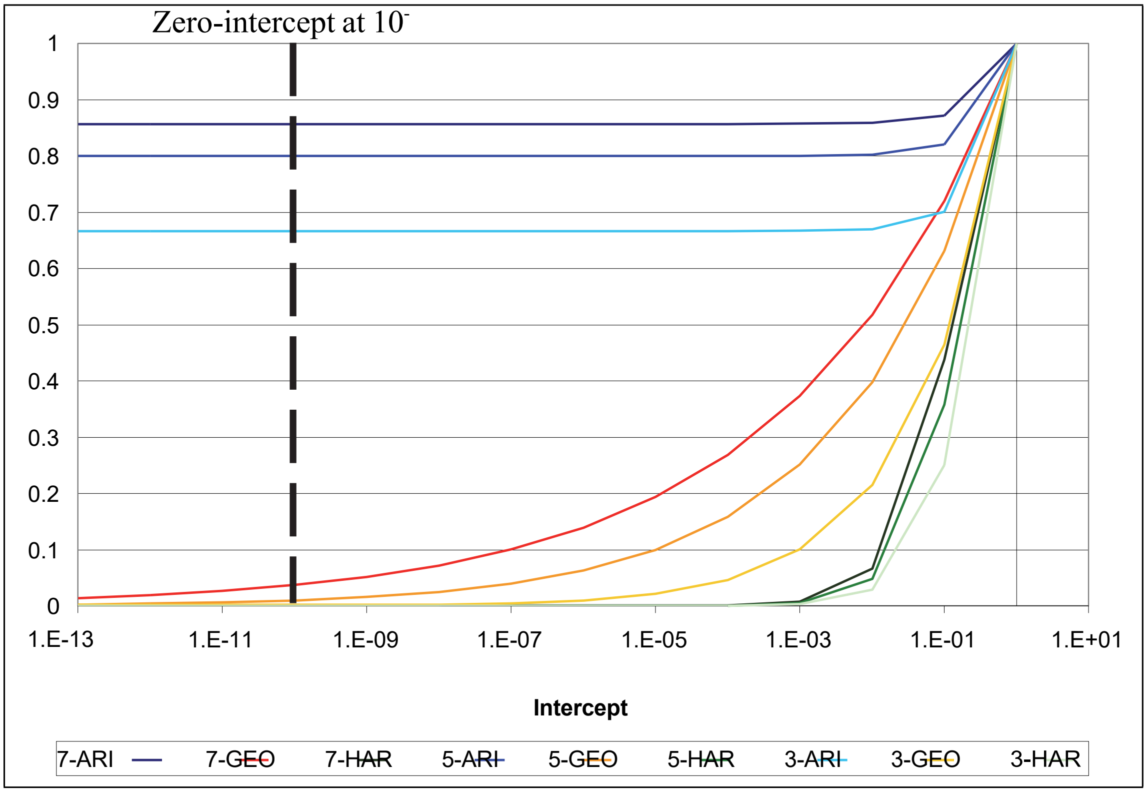

Figure 2. Combined habitat suitability indices (HSI) for "near-zero" intercepts with seven-, five-, and three-factor analyses and arithmetic (ARI), geometric (GEO), and harmonic (HAR) means.

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:

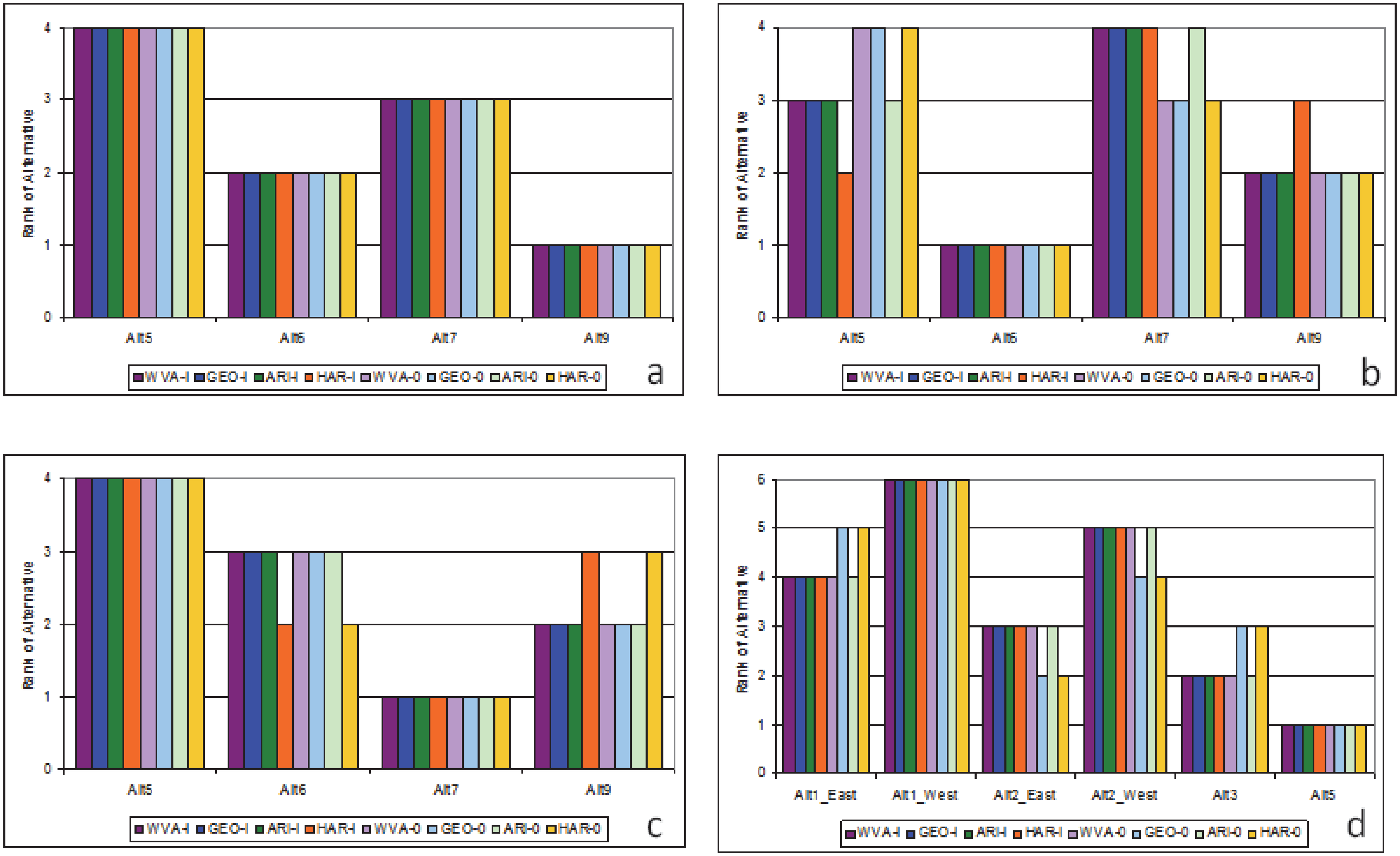

Figure 3. Relative rank of alternatives under different sensitivity scenarios (Refer to Table 3 for naming system) for each WVA model: (a) saline direct; (b) saline indirect; (c) barrier headlands; and (d) barrier islands.

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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________. 2011. *Assuring quality of planning models*. Engineer Circular 1105-2-412. Washington, DC: Headquarters, USACE.

Schmolke A., P. Thorbek, D.L. DeAngelis, and V. Grimm 2010. Ecological models supporting environmental decision making: A strategy for the future. *Trends in Ecology and Evolution*. Vol. 25, pp. 479-486.

Schultz M.T., K.N. Mitchell, B.K. Harper, and T.S. Bridges 2010. *Decision making under uncertainty.* ERDC TR- 10-12. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

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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 loss 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.

Part 7: Memo - Regional Use Rea-approval of the Wetland Value Assessment Coastal Marsh Community Models Version 2.1

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
MISSISSIPPI VALLEY DIVISION
1400 WALNUT STREET
VICKSBURG MS 39180-3262

CEMVD-PD 4 December 2024

MEMORANDUM FOR Commander, New Orleans District, U.S. Army Corps of Engineers (Attn: Mr. Troy Constance, CEMVN-PD)

SUBJECT: Regional Use Reapproval of the Wetland Value Assessment Coastal Marsh Community Models, Version 2.1

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

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

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

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

    e. Memorandum from the Director of the Ecosystem Restoration Planning Center of Expertise – Subject: Recommend Streamlining Planning Model Certification Process for the Ecosystem Restoration Planning Center of Expertise (ECO-PCX), 20 November 2024.

    f. Memorandum to Operating Director of the Ecosystem Restoration Planning Center of Expertise - Subject: Recommend Regional Use Reapproval of the Wetland Value Assessment Coastal Marsh Community Models, Version 2.1, 2 December 2024.

2. A review by the Ecosystem Restoration Planning Center of Expertise evaluated the subject model for regional use. The model is technically sound, computationally correct, usable for Civil Works planning, and policy compliant using appropriate functional assessment procedures.

3. The Wetland Value Assessment Coastal Marsh Community Models, Version 2.1, are reapproved for regional use. The models meet the criteria contained in References 1.a. and 1.b. There are no unresolved issues.

4. Appropriate Use and Quality Control. The appropriateness of the models and their variables must be checked by experienced modeler(s) and biologist(s) before each

application of the models. The application of the models will also be described in the Review Plan for studies or similar decision-making efforts. The Review Plan will identify District Quality Control and technical review requirements for the models and their application, per current review guidance. Regarding the individuals who apply the models, Districts are entrusted to confirm that the modeler(s) and biologist(s) who are using the models have the experience needed to apply the models correctly and interpret the model outputs.

5. This certification expires 4 December 2031.

Kathryn McCain, PhD
Operating Director, Ecosystem
Restoration Planning Center
of Expertise

CF
CEMVD-PDP (Keefe, Lawton, Mallard, Mickal, McGuire)
CEIWR-WRC-S (Runyon)
CELRB-PML-P (Unghire)
CEMVN-PDN-CEP (Smith)
CEMVN-PDS (Butcher, Sevick, Udoff)
CEMVN-PD (Constance)

Part 8: Indirect Impacts

Assessment of Potential Indirect Impacts Associated with Changes in Hydrology and Hydraulics for the Morganza to the Gulf Draft Supplemental Environmental Impact Statement

November 2025

1 Background

The Morganza to the Gulf of Mexico, Louisiana, Hurricane and Storm Damage Risk Reduction Project (MTG Project) is located in Terrebonne and Lafourche Parishes, Louisiana. The MTG Project would reduce risks associated with storm surge and flooding in Houma, Louisiana, and surrounding communities for storms up to a 1 percent Annual Exceedance Probability (AEP) (sometimes referred to as a “100-year level of risk reduction”) by constructing approximately 98 miles of levee system and associated structures (Figure 1).

2 Purpose

Construction of the MTG Project has the potential to cause indirect impacts due to changes in hydrologic and hydraulic (H&H) conditions outside of its footprint. Four modeling efforts were completed to estimate potential negative impacts to habitat, water quality (salinity), and larval marine species transport (Table 1). Habitats assessed include forested, bottomland hardwoods (BLH) and swamp, and herbaceous, fresh, intermediate, brackish and saline marsh. Potential impacts associated with structure operation is also investigated.

3 Status

This version was created for the Draft Supplemental Environmental Impact Statement (DSEIS) and is not complete. Impacts to Salinity and Larval Transport are substantively complete and revisions would not be required unless comments are made during the public review process of the DSEIS. Impacts to forested and marsh habitats are incomplete, and this document would be updated prior to review of the Final Supplemental Environmental Impact Statement. The current version only includes estimates of acres of impacts by forested and fresh, intermediate, brackish, and saline marshes based on the 2025 HEC-RAS modeling (Table 1, Appendix E of the DSEIS), available imagery (Maxar imagery, 2023 using ArcGIS Pro), and available remotely sensed land use data sets (USGS, 2022 and USGS, 2023). A supervised habitat classification incorporating field data and completed Wetland Value Assessments for each habitat type would be completed prior to review of the Final Environmental Impact Statement. This document would be updated with those details and be made publicly available.

All modeling for potential indirect impacts in this document has all structures open, except for specific modeling assessing how the closure of the HNC would affect relative salinity and transport of larval marine organisms. Annual reporting of structure closures would be required after construction to determine if an additional assessment for potential indirect impacts would be required.

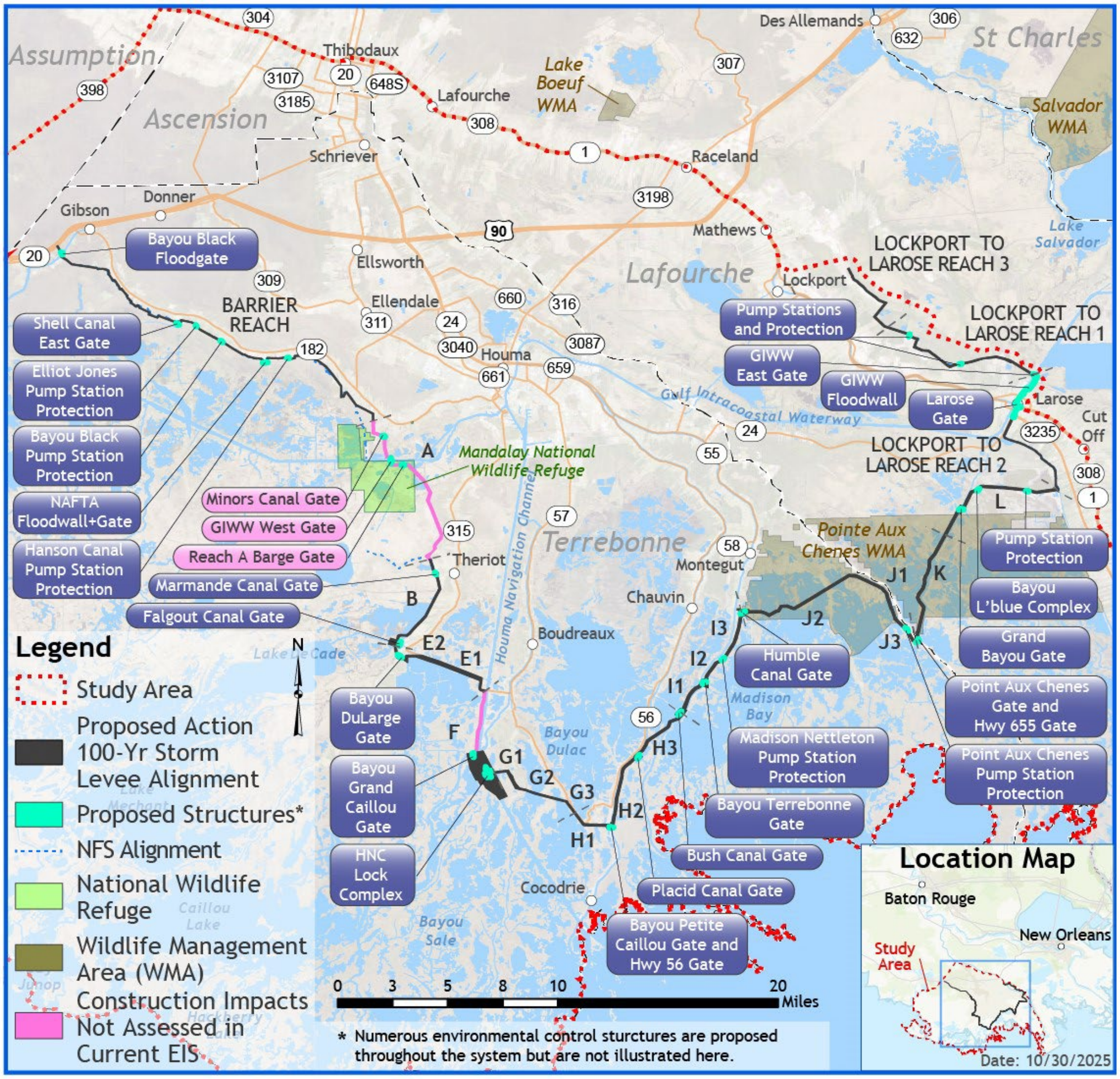

Figure 1: Morganza to the Gulf Project Study Area with associated levee reaches and structures.

Table 1. Summary of Modeling Conducting for Indirect Impact Analysis. Appendix E of the DSEIS includes reports for each of the models discussed below.

Model	Description	Purpose
Adaptive Hydraulics Modelling (AdH)	Finite Element based model that can be used in combination with PTM (described below). Update of McAlpin et al., 2013.	Assess for salinity and discharge for historic (2004), existing (2020, but structures up to 2015), and future conditions (2035, 2085). Due to model domain constraints, only relative changes in salinity were used to inform impact analysis on biological/ecological resources in the SEIS
Particle Tracking Model (PTM)	PTM is a Lagrangian particle tracker that facilitates the simulation of particle transport processes. For this study, AdH hydrodynamic output served as the input for PTM. PTM specifically characterizes larval marine species particles as neutrally buoyant (passive particles) while integrating distinct behaviors.	Two month-long periods— March and September—were chosen. The goals were to address the questions below: 1. How does the updated proposed design impact larval aquatic organism recruitment? 2. How does the updated proposed design impact larval aquatic organism transport through the proposed structures? 3. How will this assessment differ if seal level change is considered?
Hydrologic Engineering Center's River Analysis System (HEC-RAS 2025) (Indirect Impacts)	A series of two-dimensional unsteady flow simulations using Hydrologic Engineering Center's River Analysis System (HEC-RAS) version 6.6 were completed.	Determine the resulting hydrologic and hydraulic changes in typical conditions that could have impacts to significant habitats. Two (2) observed tidal periods were assessed. December 2023 was assessed because it had typical cold front patterns, and April 2023 was assessed because it had typical spring tidal signals. Observed precipitation and wind were applied to both. The probabilistic 4%, 10%, and 20% AEP rainfall events were assessed.

4 Salinity (AdH)

4.1 Methods

The Engineering Research and Development Center (ERDC) conducted Adaptive Hydraulics Modelling (AdH) modeling in 2024 with multiple year-long simulations using observed data from 2004. The purpose was to simulate hydrodynamic and salinity conditions for the historic (2004), existing (2020) but with structures up to 2015 and Proposed Action Alternative conditions for two sea level change scenarios (2035 and 2085). It also assessed for effects of HNC Lock operation by modeling it as open or closed for existing and Proposed Action Alternative modeling, resulting in 10 model scenario runs. All structures other than the HNC Lock Complex were open in all model scenarios. The model domain did not allow for an accurate assessment of potential project impacts east of Bayou Lafourche. This modeling was used to assess indirect impacts by comparing FWOP and FWP salinities for the different modeling scenarios. Actual salinity outputs are not likely to be very accurate, but the relative difference between runs is assumed to reflect differences in salinity. The model report is included in Appendix E of the DSEIS.

4.2 Results

Overall, the project is expected to cause only negligible to minor changes in salinity, which in turn would have negligible to minor effects on marsh vegetation in the study area. This is because estuarine marsh habitats—including fresh, intermediate, brackish, and saline marshes—are naturally adapted to changing salinity levels due to both freshwater inflows and saltwater from the Gulf. Marsh habitats are anticipated to be resilient to modeled salinity changes. However, swamp and particularly BLH wetlands are less tolerant to increases in salinity and could decline in areas where even small (1-2 ppt) increases are anticipated, hastening conversion to other habitat types or open water.

5 Larval Transport (PTM)

5.1 Methods

ERDC completed modeling to assess impacts to larval aquatic organism transport using the Particle Tracking Model (PTM) based on WSEs and velocity input from AdH modeling. Larval transport impacts were compared for historic conditions, the No Action Alternative, and the Proposed Action Alternative with the HNC Lock Complex either open or closed. All model scenarios assumed that all other structures and environmental control structures were open. This modeling was used to assess Proposed Action indirect impacts to aquatic resources (see Section 6.4). The model report is included in Appendix E.

5.2 Results

Organism access to marsh and open-water areas within and outside of the proposed levee system would be impeded when proposed structures are closed during storm and flood events (see Section 6 and Appendix M for information about the draft water control plan). When all structures are open, variation between the No Action and Proposed Action alternatives would be minor. The overall recruitment of larval organism into the system would not change significantly when the structures, including the HNC Lock Complex, is closed. The HNC Lock Complex operations would be based not only on water level conditions but also based on salinity conditions (see Draft Water Control Manual Plan in Appendix M). When the HNC Lock Complex is closed (due to salinity triggers) and the other proposed structures are open, particles would be able to enter the system through Bayou Grand Calliou, bypassing the HNC Lock Complex. See Appendix E for the Particle Tracking Model.

6 Significant Habitats (HEC-RAS)

6.1 Methods

A series of two-dimensional unsteady flow simulations aimed at understanding potential changes in WSEs, drainage, and flow during typical tidal and meteorological conditions were modeled to assess if there would be any changes in tidal signals or water levels that could have impacts to significant habitats. HEC-RAS version 6.6 model runs were completed for typical observed data and probabilistic rainfall events. The probabilistic 4%, 10%, and 20% AEP rainfall events, cold front, and spring tidal conditions were modeled for the 2035 and 2085 SLC condition.

The probabilistic AEP rainfall events are standard for assessment of hurricane and storm damage risk reduction projects and are explained in Appendix E. The 4%, 10%, and 20% AEP rainfall events were used for this analysis, because they represent relatively high frequency events that when FWP and FWOP are compared could indicate areas with reduced drainage or alterations in water levels.

For both the Spring and Cold Front events, observed daily flows from the USGS gage Atchafalaya River at Simmesport, LA (USGS 07381490, https://nwis.waterdata.usgs.gov/nwis/uv?cb_00060=on&cb_00065=on&format=gif_default&site_no=07381490&legacy=1&period=&begin_date=2023-12-01&end_date=2023-12-31), observed European Centre for Medium-Range Weather Forecast atmospheric reanalysis (ECMWF-ERA5) hourly winds, observed hourly precipitation from NOAA, and observed hourly water surface elevations from the CRMS 0347 gage were used for both the month scenarios and SLC conditions (https://www.lacoast.gov/crms_viewer).

Cold front conditions were assessed, because these are regular, recurring meteorological events that cause dramatic exchange of water from bays to shelfs and water surface elevations in coastal Louisiana. Additionally, water levels in coastal Louisiana are, on average, lower in the winter. April 2023 was selected, because it had a typical solar-lunar tidal signal, higher average water levels than December 2023 (average of 1.5 feet vs 1.3 feet for December), and the Atchafalaya River at Simmesport had higher flows (Figures 2-5).

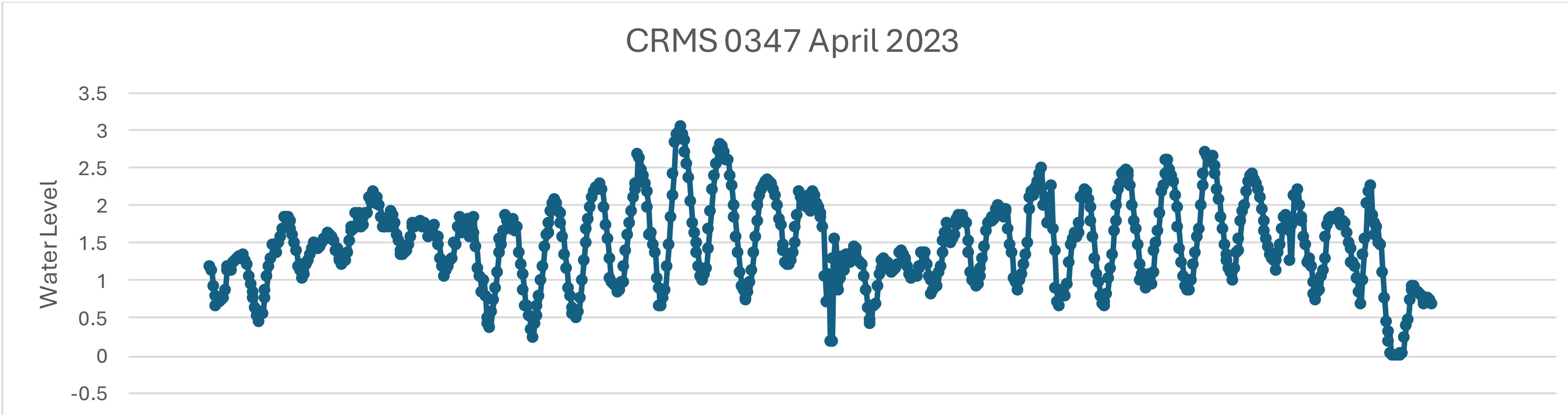

Figure 2: Hourly water level data for CRMS 0347 from April 2023.

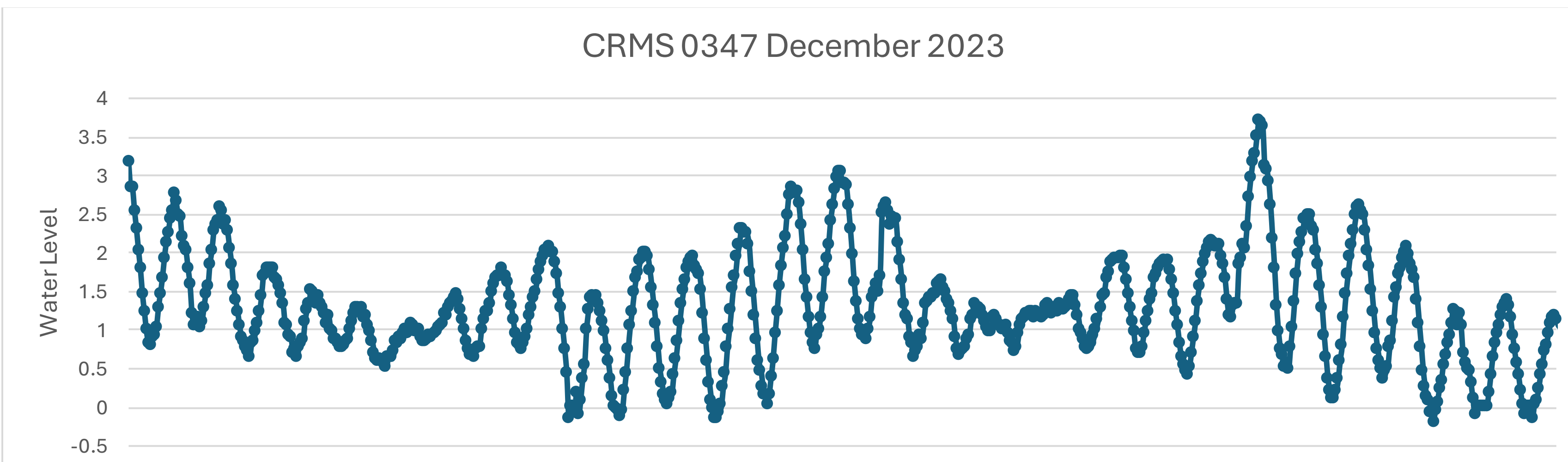

Figure 3: Hourly water level data for CRMS 0347 from December 2023.

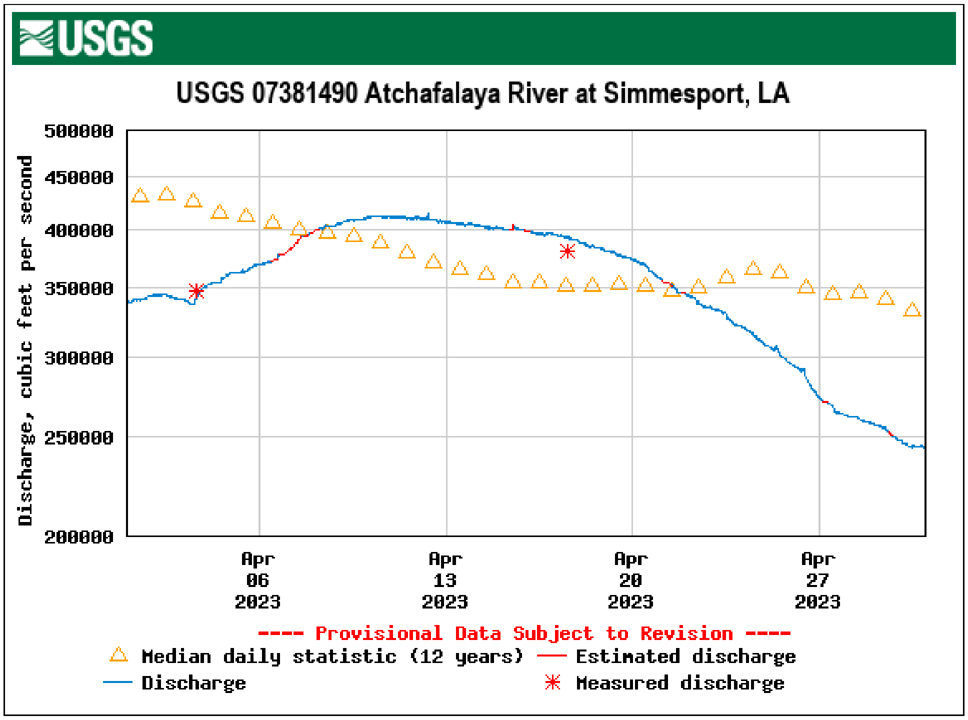

Figure 4: Daily discharge of the Atchafalaya River an Simmesport, LA for the April 2023 Spring modeling scenario.

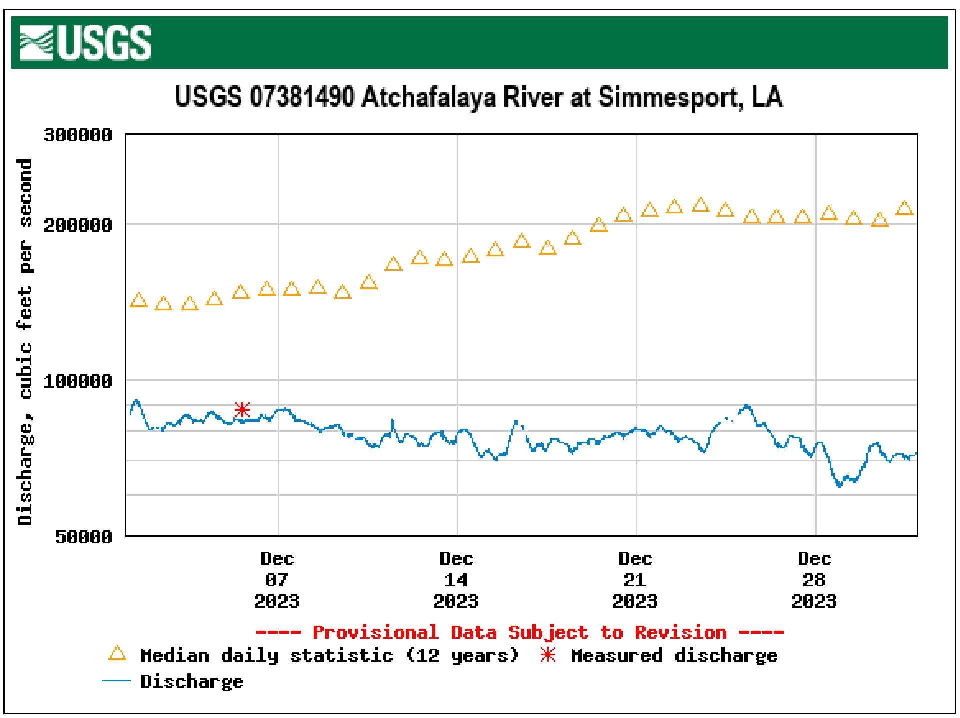

Figure 5: Daily discharge of the Atchafalaya River an Simmesport, LA for the December 2023 Spring modeling scenario.

6.2 Results

Maximum WSE differences between FWP and FWOP conditions were calculated for each modeled scenario. Differences were mapped and areas that had a difference of 0.2 feet or greater were further investigated by generating one or more time series plot(s) comparing WSEs between the FWP and FWOP runs (Figure 6). Time series plots were assessed and discussed with an interagency group to determine if modeling results indicated a potential for indirect impacts. If this two-step process that included interagency coordination and consensus resulted in a potential for indirect impacts, acres by habitat type were estimated using the best available remotely sensed data (USGS, 2022 and USGS, 2023).

Approximately 1,059 acres of potential indirect impacts were identified to forested, and fresh, intermediate, brackish and saline marshes (Table 2). These impacts are likely associated with construction of new levee features (e.g., Reach L and L2L) or changed structure configurations (areas surrounding Lake Quitman and the Barrier Reach) (Figure 6). Time series plots for these areas are shown in Figures 7-11.

Table 2. Acres by habitat type of potential indirect impacts associated with construction of the MTG Project

Habitat	**Acres**
Forested (combination of BLH and Swamp)	179
Fresh Marsh	214
Intermediate Marsh	621
Brackish Marsh	23
Saline Marsh	22
Total Marsh	**880**
Total Habitat	**1059**

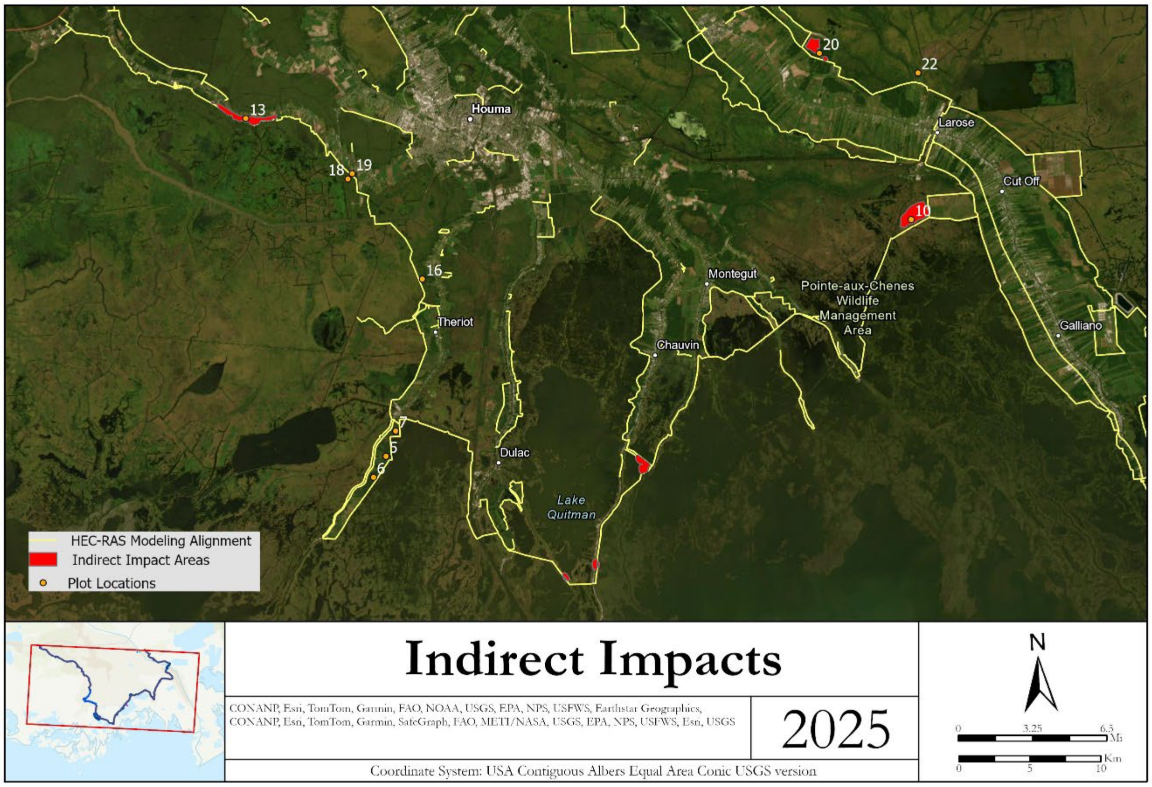

Figure 6: Areas of potential indirect impacts for the MTG project and locations for WSE time series plots.

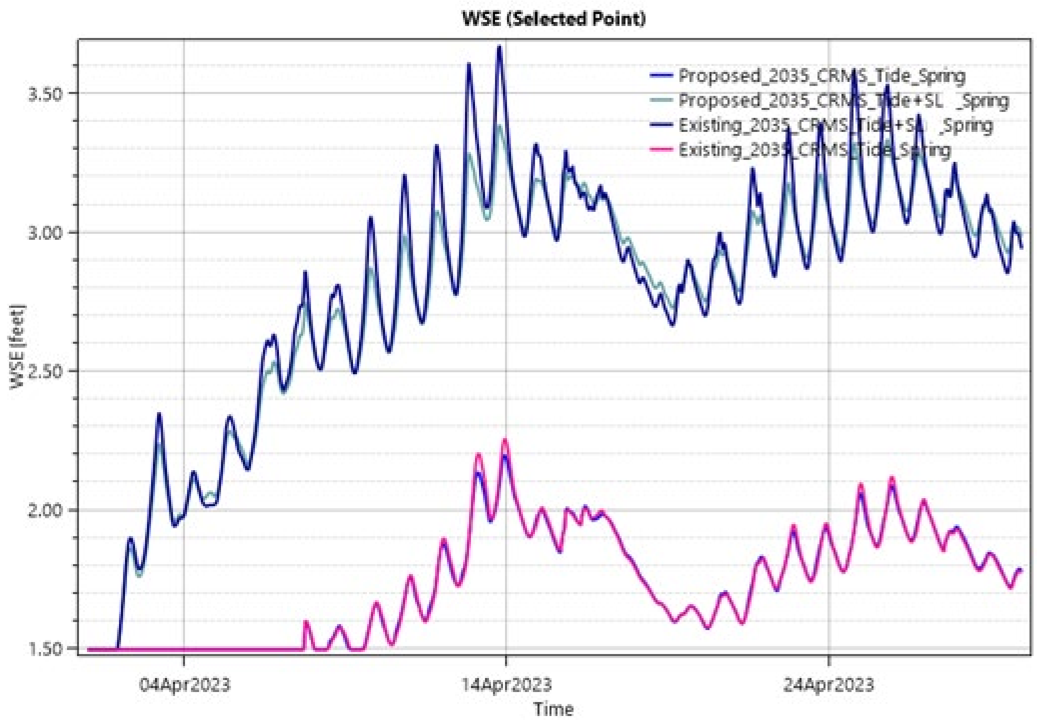

Figure 7: WSE in feet at plot 10 for the 2035 with and without SLC spring tide model run.

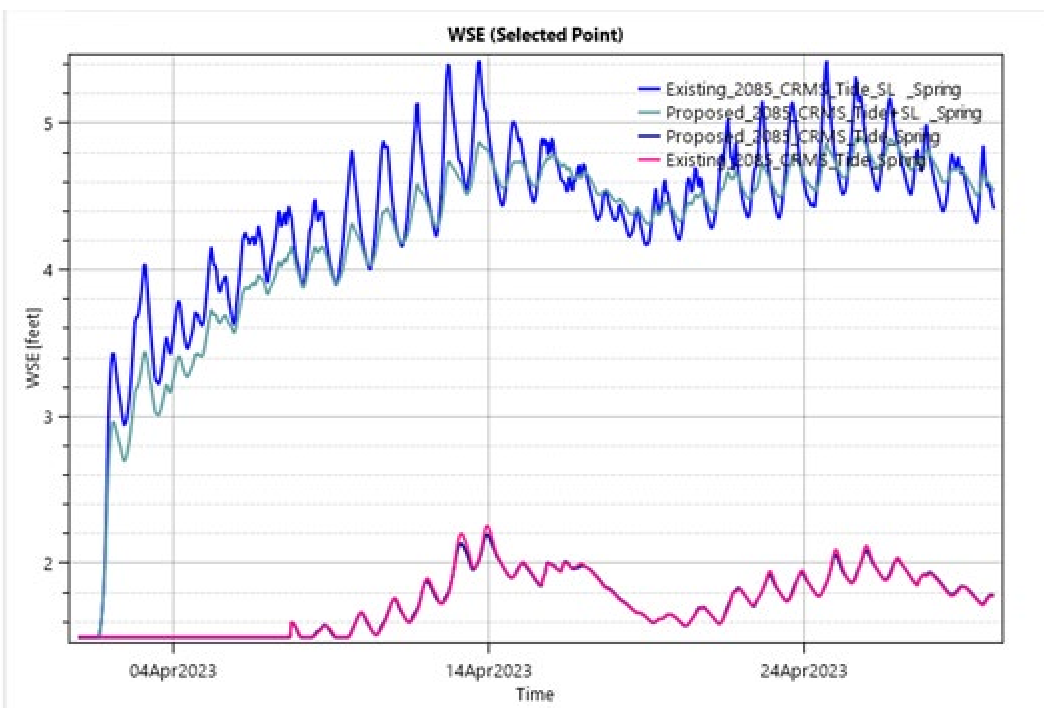

Figure 8: WSE in feet at plot 10 for the 2085 with and without SLC spring tide model run.

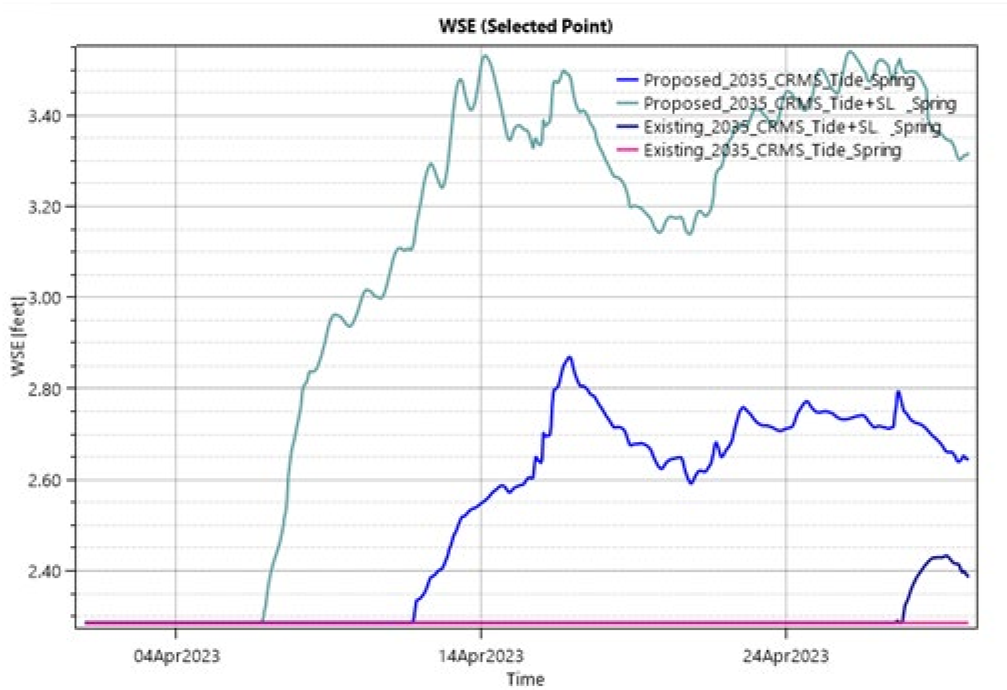

Figure 9: WSE in feet at plot 13 for the 2035 with and without SLC spring tide model run

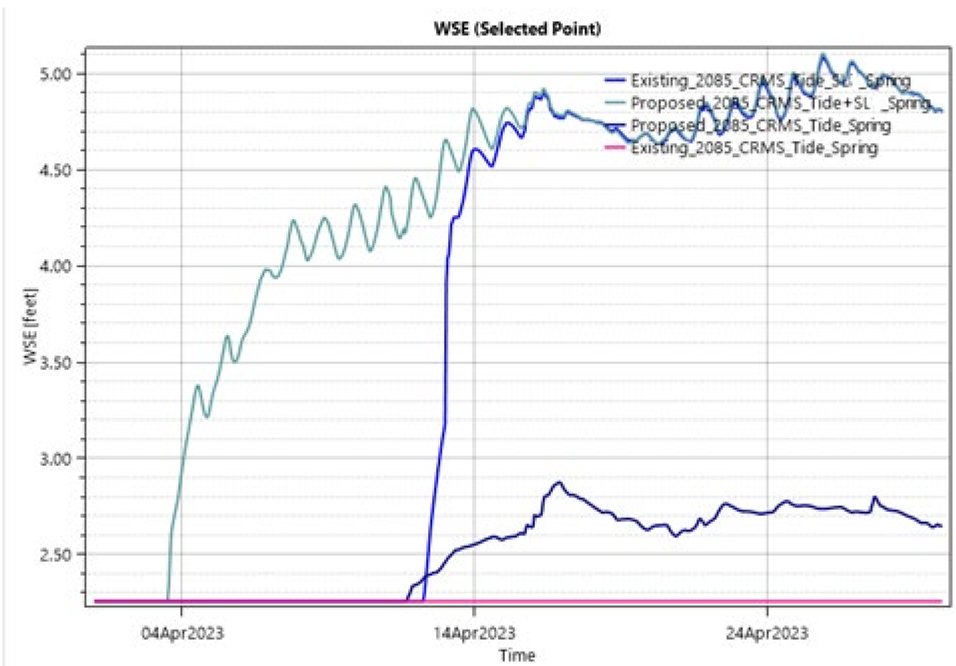

Figure 10: WSE in feet at plot 13 for the 2085 with and without SLC spring tide model run.

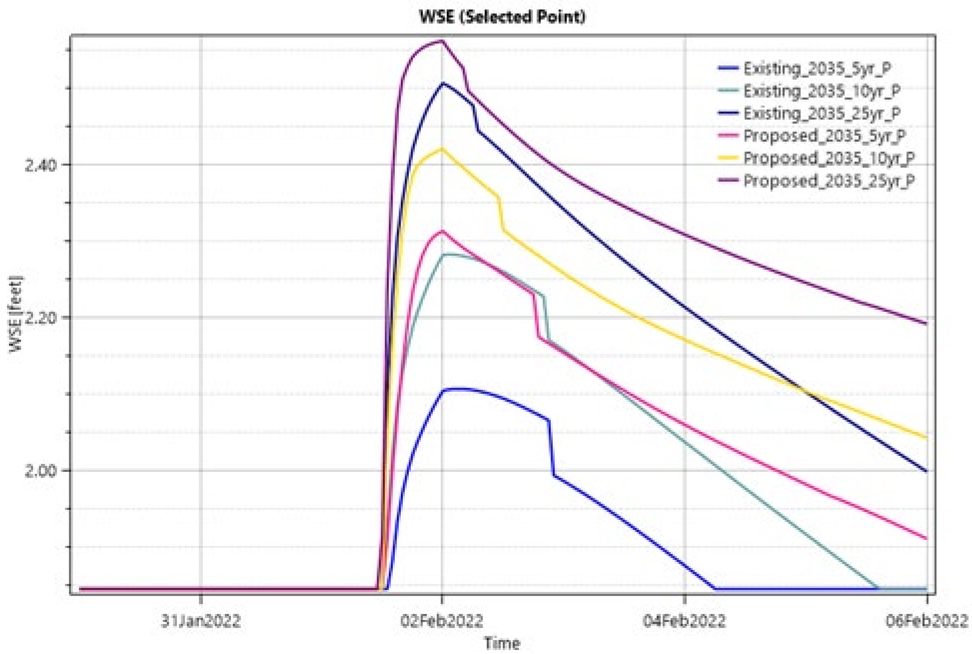

Figure 11: WSE in feet at plot 20 for the 2035 rainfall events model runs.

7 Structure Operations

7.1 Methods

A preliminary draft water control plan was prepared for all structures under the Proposed Action Alternative that directs operators to close structures under specific water level conditions outside of storm events (see Appendix M for the preliminary draft plan). The USACE is responsible for completing the water control plan in accordance with ER 1110-2-24, EM 1110-2-3600, DIVR 1110-2-240, and ER 1165-2-240. The USACE, Mississippi Valley Division would review the water control plans and/or manual, and approval would be required within 1 year after full-scale operations of the proposed structures.

Historic gage data from the USGS, USACE, and CRMS was utilized to approximate appropriate water surface elevation triggers for structure closures. The selected trigger water surface elevations (2.5 and 3.0 ft. NAVD88) correspond to annual exceedance probabilities that lie between those of 50% (2-year) and 20% (5-year) AEPs, as estimated using CHS-LA (Coastal Hazards System – Louisiana) for storm surge probabilities in the basin. Table 3 summarizes the trigger conditions by reach and structure.

Table. 9¿Morganza. to.the.Gulf.Structure. Operation. Guidance. from.DSEIS.Appendix. M

Reach Name	Structures/Gates	Closure Conditions[3]	Reopening Conditions
Barrier Reach	Bayou Black Floodgate Shell Canal West Floodgate (Stoplog Gate) Shell Canal East Floodgate NAFTA Canal Environmental Control Structures	1. A named storm is in the Gulf of Mexico that is threating the Louisiana coast, OR 2. The water surface elevation measured at the gate/structure location reaches **+3.0 ft NAVD88**	1. The water surface elevation on the outside of the gate/environmental control structure drops below **+3.0 ft NAVD88**, AND (for ONLY Navigation Gates) 1. The NHC small craft advisory no longer applies to the area, 2. The channel has been cleared of debris or obstructions so that navigation can safely resume.
Reach A North of GIWW	Environmental Control Structures		
Reach A South of GIWW	Minors Canal Floodgate GIWW West[1] Environmental Control Structures		
Reach B	Marmande Canal Floodgate (Stoplog Gate) Falgout Canal Floodgate[1]	1. A named storm is in the Gulf of Mexico that is threating the Louisiana coast, OR (for ONLY Navigation Gates) 2. The water surface elevation measured at the gate location reaches **+2.5 ft NAVD88**, OR (for ONLY Environmental Control Structures) 2. The water surface elevation measured at the structure location (or nearest approved instantaneous gage) reaches **+3.0 ft NAVD88**.	1. The water surface elevation measured on the exterior of the System at the gate location drops below **+2.5 ft NAVD88**, OR 1. The water surface elevation measured on the exterior of the System at the environmental control structure location drops below **+3.0 ft NAVD88**, AND (for ONLY Navigation Gates) 1. The NHC small craft advisory no longer applies to the area, 2. The channel has been cleared of debris or obstructions so that navigation can safely resume.
Reach E (1&2)	Bayou Dularge Floodgate Environmental Control Structures		
Reach F (1&2)	Bayou Grand Caillou Floodgate[1] HNC Lock Complex[2]		
Reach G (1-3)	Four Point Bayou Floodgate (Stoplog Gate) Environmental Control Structures		
Reach H (1-3)	Bayou Petit Caillou Floodgate[1] Placid Canal Floodgate[1] Environmental Control Structures		
Reach I (1-3)	Bush Canal Floodgate[1] Bayou Terrebonne Floodgate Humble Canal Floodgate		
Reach J (1-3)	Bayou Pointe Aux Chenes Floodgate[1] Environmental Control Structures		
Reach K	Environmental Control Structures		
Reach L	Grand Bayou Floodgate[1] Proposed Structure at Bayou Blue		
GIWW Reach	Larose Floodgate	1. A named storm is in the Gulf of Mexico that is threating the Louisiana coast, OR 2. The water surface elevation measured at the gate/structure location reaches **+3.0 ft NAVD88**	1. The water surface elevation on the outside of the gate/environmental control structure drops below **+3.0 ft NAVD88**, AND (for ONLY Navigation Gates) 1. The NHC small craft advisory no longer applies to the area, 2. The channel has been cleared of debris or obstructions so that navigation can safely resume.
Lockport Reach A	GIWW East[1]		
Lockport Reach B	Environmental Control Structures		
Reach J	Environmental Control Structure #1 and #2	Managed according to current LA Wildlife and Fisheries Permit.	Managed according to current LA Wildlife and Fisheries Permit.

Notes:

1. Structure contains culverts within or adjacent to the floodgate for continued flow passage when the gate is closed. Most culverts include a flap gate and/or sluice gate that can also be closed if the closure conditions are reached.
2. HNC Lock Complex has additional criteria for acceptable closure, see "Error! Reference source not found." section.
3. All water surface elevations should be read at the gate or structure location to satisfy closure conditions. If the gate or structure does not have a gage on location, the water surface elevation must be taken from an approved gage. See "Acceptable Use" section, above, for approved gages.
4. NHC = National Hurricane Center

All modeling for potential indirect impacts in this document have all structures open, except for specific modeling assessing how the closure of the HNC would affect relative salinity and transport of larval marine organisms. To estimate potential indirect impacts that would occur immediately upon construction and operation, an analysis was completed to determine if closures would have been triggered by this plan in the past 5 years. This analysis used triggers for structures from Table 3 and compered them to nearby WSEs from long term water levels from nearby CRMS stations (Table 4, Figures 12-18).

7.2 Results

Results from this analysis indicate that structures would have been closed between 0 and 2.5 days per year, therefore only minor, temporary changes in hydrology would be expected. However, with sea level change, it is anticipated that structure closures outside of storm events would become more common. Sea level change is an uncertain phenomenon, both temporally and in magnitude. For example, navigation structures associated with I and J would be closed for less than 1% of the time from October 2020 through October 2025, but if there is +2.5 feet of RSLC then it would be approximately 80% of the time. The operator of each structure would be required to submit an annual report of daily operations that would be reviewed by USACE to be able to assess and monitor how future sea level changes may be affecting closure rates. Once a threshold of 30 total days per year of operation is met, this would trigger a re-analysis of potential impacts to hydrology in non-storm conditions. If this re-analysis finds a potential for additional indirect impacts, a determination if adaptive management actions, such as changes in operations, could be instituted to avoid impacts or if additional mitigation actions would be necessary. This re-analysis would involve coordination with resource agencies and could require additional WVAs.

Table 4: Assessment of WSE data from CRMS stations to determine how often structure closures would have been required from October 1, 2020 through October 1, 2025. Note this analysis does not remove periods where tropical cyclones could have affected WSEs.

DATES	REACH	CRMS STATION	CLOSE LEVEL ECS (ft)	PERCENTAGE TIME OVER ECS LVL	CLOSE LEVEL NAVIGATION (ft)	PERCENTAGE TIME OVER NAV LVL
OCT 1 2020 - OCT 1 2025	BARRIER/A	CRMS0381-H01	3	0.000%	3	0.000%
	B	CRMS0381-H01	3	0.000%	2.5	0.000%
	EF	CRMS0434-H01	3	0.000%	2.5	0.058%
	GH	CRMS0369-H01	3	0.098%	2.5	0.282%
	IJ	CRMS0315-H01	3	0.210%	2.5	0.684%
	KL	CRMS0312-H01	3	0.095%	2.5	0.266%
	L2L GIWW	CRMS2991-W01	3	0.194%	3	0.194%

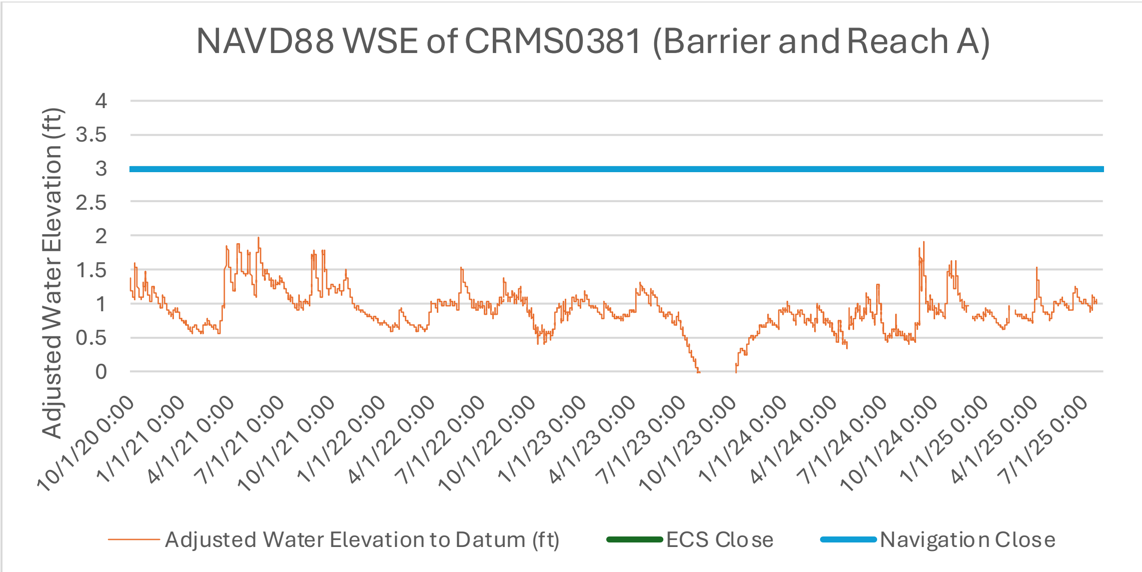

Figure 12: Graph of WSE at CRMS 0381, adjusted to NAVD88, plotted against proposed closure thresholds at Barrier and Reach A

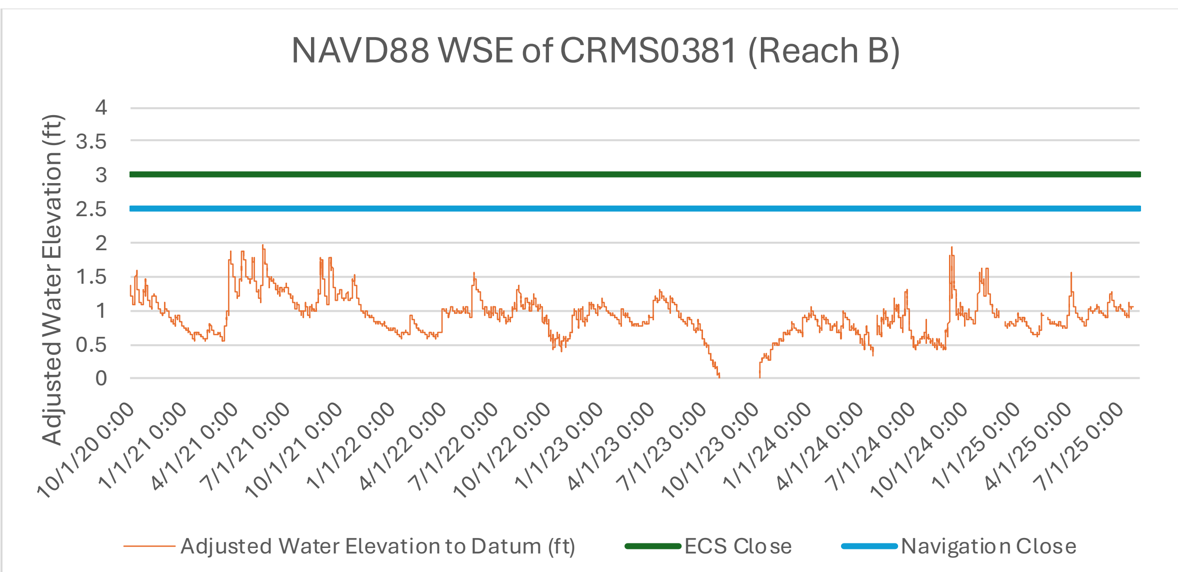

Figure 13: Graph of WSE at CRMS 0381, adjusted to NAVD88, plotted against proposed closure thresholds at Reach B

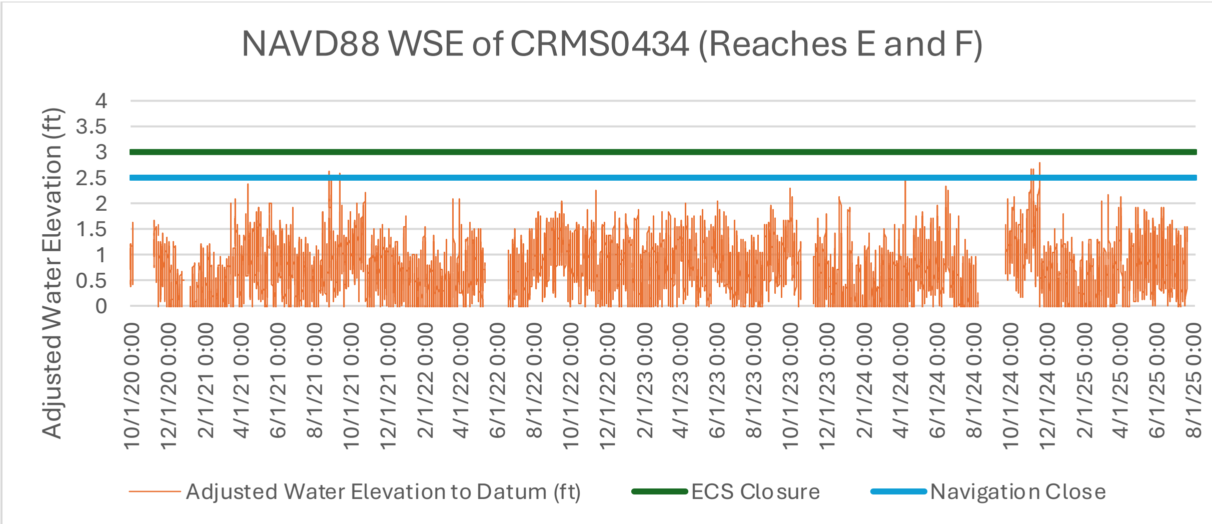

Figure 14: Graph of WSE at CRMS 0434, adjusted to NAVD88, plotted against proposed closure thresholds at Reaches E and F

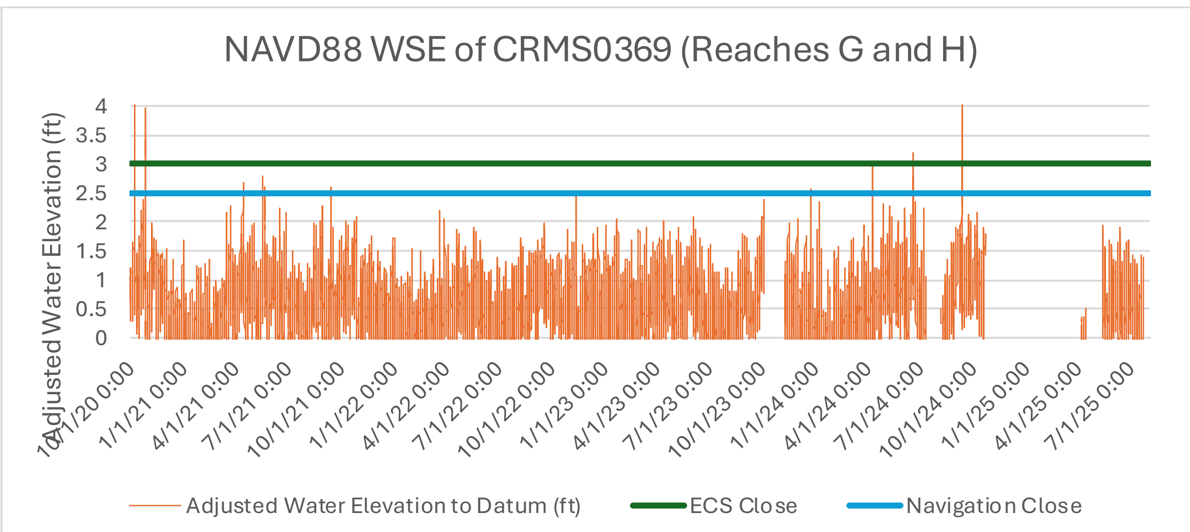

Figure 15: Graph of WSE at CRMS 0369, adjusted to NAVD88, plotted against proposed closure thresholds at Reaches G and H

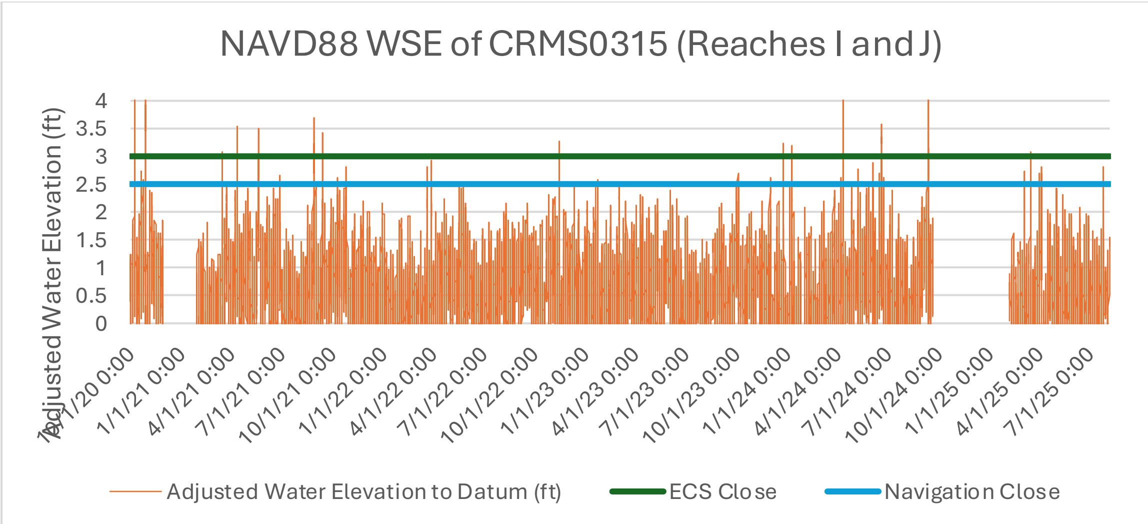

Figure 16: Graph of WSE at CRMS 0315, adjusted to NAVD88, plotted against proposed closure thresholds at Reaches I and J

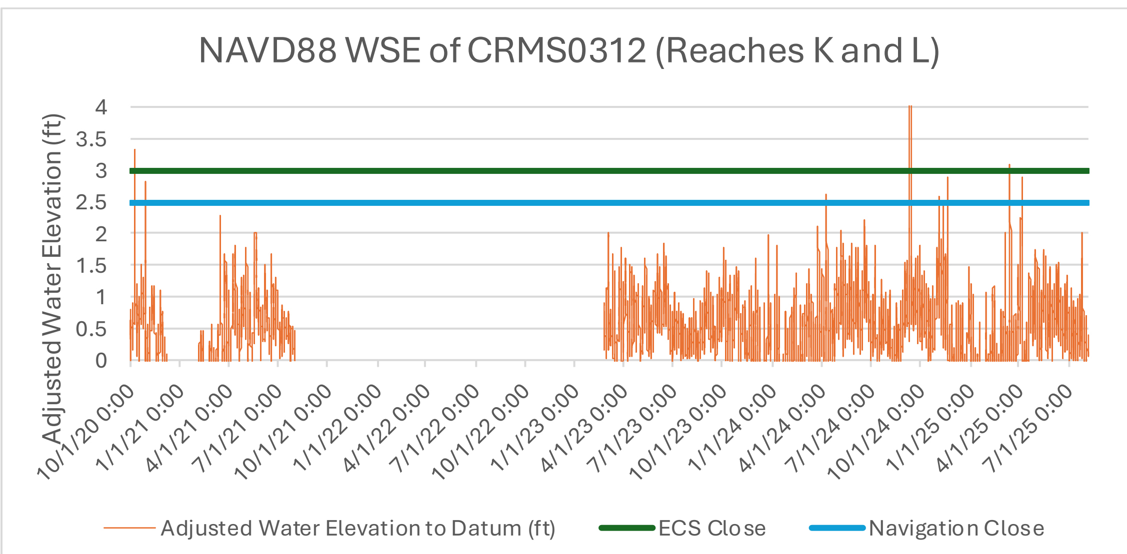

Figure 17: Graph of WSE at CRMS 0312, adjusted to NAVD88, plotted against proposed closure thresholds at Reaches K and L

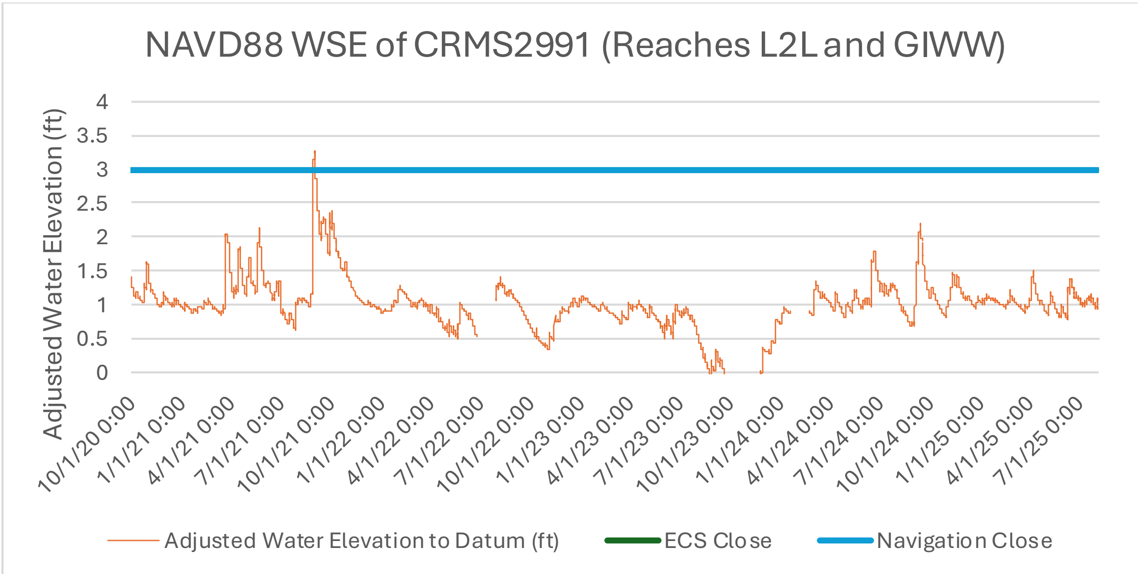

Figure 18: Graph of WSE at CRMS 2991, adjusted to NAVD88, plotted against proposed closure thresholds at Reaches L2L and GIWW

8 References

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