APPENDIX B

Ecosystem Model

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APPENDIX B-1

Resaca Reference Model Description

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RESACA REFERENCE CONDITION MODEL

Model Certification Plan

Brownsville Resaca Ecosystem Restoration Study

Background

Purpose of Model

The Resaca Reference Condition Model (RRCM) was designed to quantify the habitat quality of potential resaca restoration sites by comparing the existing habitat against reference conditions of high quality resacas and their associated riparian habitats.

Model Description and Depiction

The RRCM used high quality reference condition sites as a habitat quality target. Three modules are included in the RRCM, one for each vegetation community that may be encountered in the study area: Texas Ebony Resaca Forest, Subtropical Texas Palmetto Woodland, and Texas Ebony-Snake Eyes Shrubland.

The RRCM was composed of five suitability index (SI) categories: invasive species, aquatic habitat, bank habitat, riparian habitat, and water regime/depth. The metrics and indices incorporated into each category are described in the following section. The indices for invasive species, aquatic habitat, bank habitat and water regime/depth were the same across the three modules. The riparian habitat component was dependent on the vegetation community target for restoration. The reference conditions were based on data from 10 sampling locations: four at Resaca de la Palma State Park, three at The Nature Conservancy's Southmost Preserve, and two at Camp Lula Sams.

Contribution to Planning Effort

The RRCM was used to establish existing conditions and to forecast future with and without project conditions. The data outputs were incorporated in a Cost Effective/Incremental Cost Analysis tool within the IWR Planning Suite 2.0.6.1.

Description of Input Data

The RRCM was composed of four suitability index (SI) categories: invasive species, bank habitat, vegetative habitat, and water regime/depth. The invasive species index was comprised of a single metric, the percent of the vegetative community of a site that is comprised of invasive species. The bank habitat suitability index was comprised of two metrics, the percent vegetative canopy cover of the shoreline and the slope of the terrestrial/aquatic interface of the resaca.

The vegetative habitat index was comprised four metrics: riparian species composition, riparian species richness, percent riparian canopy cover, and percent aquatic canopy cover. The riparian species composition metric was a community specific metric based on one of the three vegetation communities identified above. A species function curve was constructed for each of the three vegetation communities and the species composition metric was a measure of the closeness of fit to these curves (see model documentation). The species richness metric was the total number of plant species identified on the site. The remaining two metrics were a measure of the percent canopy cover of the riparian and aquatic vegetation.

The final index was comprised of two metrics: the water regime of the resaca and the mean depth of the resaca. The water regime was a categorical metric describing the resaca as permanently connected, semi permanently flooded yet disconnected, or a dry resaca.

Description of Output Data

The data output of the RRCM was an index between 0.0 and 1.0 that reflects the degree that a site reflects high quality resaca sites as represented by the 10 sampling sites reference resacas.

Capabilities and limitations of the model

The RRCM was to be used only in Cameron County, Texas, for resacas that would have historically supported the three vegetation associations identified in the model documentation (Texas Ebony Resaca Forest, Subtropical Texas Palmetto Woodland, and Texas Ebony/Snake-eyes Shrubland). Resacas associated with more saline soils closer to the coast or differently vegetated resacas were not evaluated due to their rarity in the study area. Because accurate plant species identification was critical for the quantification of habitat quality, botanical expertise of the flora of the resacas was essential for the collection of field data inputs.

Due to the uniqueness of the resaca habitats and the incredible density of the lower, mid, and upper canopy vegetation layers, the model is applicable to riparian corridors as narrow as 25-30 feet. The field data collection team included at least one person with the expertise to identify resaca ecosystems plant species.

Model development process

Key ecosystem metrics were identified utilizing a resaca conceptual model developed in cooperation with biologists from the U.S. Fish and Wildlife Service (USFWS) Santa Ana Wildlife Refuge, USFWS Alamo Ecological Field Office, Palo Alto Battlefield National Historical Park, Texas Parks and Wildlife (TPWD) Wildlife Division, TPWD Parks Division, TPWD Inland Fisheries Division, The Nature Conservancy's Southmost Preserve, University of Texas Rio Grande Valley, Brownsville Public Utilities Board, and USACE Regional Planning and Environmental Center. The riparian species composition index curves (Appendix B-2) were developed in consultation with botanists with the USFWS, TPWD, and the Nature Conservancy. The functionality of the resulting model was tested in the Resaca Boulevard Resaca Section 206 Continuing Authority Program study.

Model development team

The team consisted of Jason Singhurst, the Texas Parks & Wildlife Department, Chris Hathcock, the U.S. Fish and Wildlife Service, Rolando Garza, the U.S. National Park Service, Max Pons, The Nature Conservancy, and Danny Allen, the USACE.

Technical Quality

Theory

The RRCM was based on an understanding that the more closely a potential site reflects the structural and species diversity of relatively high quality resacas, the more closely it will function as a high quality resaca, assuming other environmental prerequisites are met, such as a suitable water budget.

Resaca Reference Condition Model

Description of system being represented by the model

Resacas are defined as paleochannels of the Rio Grande delta that have long been cut off from the Rio Grande. These aquatic and riparian habitats are becoming increasingly rare as approximately 99 percent of resaca habitats have been lost to agriculture and urban development. Historically, the resacas were maintained by the periodic flooding of the Rio Grande. The floodwaters would reconnect the resacas within the floodplain and the resacas would retain the isolated floodwater well into the dry season serving as a refuge for fish and wildlife species dependent on the diverse aquatic and riparian habitats. Over time, the floodplain connectivity of the resacas and the river has been lost due to the construction of dams along the Rio Grande, irrigation canals diverting water from the river, and flood control projects within the basin. The ecosystem restoration study would restore the ecological function of the system by artificially reconnecting the resacas with the river and the floodplain.

Analytical requirements

The RRCM is a spreadsheet model developed in Excel.

Assumptions

The primary assumption of the RRCM is that the model development team has identified the highest quality remnant resaca sites in the study area and that these sites are reflective of the natural resaca ecosystem. The motives used in the model were reflective and representative of high quality resacas in the Lower Rio Grande Valley. It was assumed that the inherent variability of the vegetation and structural components of the resacas would be effectively captured and reflected in the RRCM metrics.

Conformance with Corps policies and procedures

The RRCM is compliant with Engineering Circular 1105-2-412: Assuring Quality of Planning Models, dated 31 March 2011.

Formula identification and computational accuracy

The formulas incorporated in the RRCM were developed by the multiagency model development team.

Invasive Species

The invasive species component of the RRCM was simply an index between 0.0 and 1.0 and was measured as the percent of the vegetative community comprised of non-native and non-native invasive species. The index was calculated as follows:

$$I_{SI} = 1 - \left(\frac{I_i}{100}\right)$$

Where I_{SI} = Invasive Species Suitability Index and

I_i = The percent of the vegetative community of site *i* comprised of invasive species.

The resulting invasive species index would approach zero as the percent of cover of invasive species approaches 100 percent, thereby penalizing a site with a higher proportion of invasive and non-native species.

Bank Habitat

The Bank Habitat Suitability Index is comprised of two components, the percent canopy cover of vegetation along the shoreline and the slope of the bank measured across the terrestrial/shoreline/aquatic continuum. The percent canopy cover of shoreline vegetation across the 10 reference sites averaged approximately 75 percent. Therefore, the canopy cover index for the shoreline is assumed to be 1.0 for canopies greater than or equal to 75 percent. For canopy covers between 0 and 75 percent, a linear relationship between 0 and 75 was assumed:

$$BC_i < 75, BC_{SI} = \frac{BC_i}{75};\ BC_i \geq 75, BC_{SI} = 1.0$$

Where BC_{SI} = Bank Canopy Cover Index and

BC_i = Percent bank canopy cover for site *i.*

The bank slopes of the reference resacas were flat and ranged from 1:15 to 1:30. For slopes less than 1:15, the bank slope index was 1.0. For slopes greater than 1:15, a linear relationship was assumed with vertical or bulkheaded banks resulting in a 0.0 bank slope index and a 1:15 slope resulting in a 1.0 index:

$$BS_i > 1{:}15, BS_{SI} = 0.0667 \times BS_i;\ BS_i \leq 1{:}15, BS_{SI} = 1.0$$

Where BS_{SI} = Bank Slope Suitability Index and

BS_i = Bank slope at site *i.*

The Bank Habitat Suitability Index (B_{SI}) was the mean of the bank canopy cover index and the bank slope index and calculated as follows:

$$B_{SI} = \frac{BC_{SI} + BS_{SI}}{2}$$

Vegetation Metric

Riparian Habitat

The Riparian Habitat Suitability Index was comprised of three components: species composition, species richness, and percent canopy cover. The species composition index was dependent on the target vegetation association that is being proposed for a specific restoration site. This metric was calculated separately for the Texas Ebony Resaca Forest, Subtropical Texas Palmetto Woodland, and the Texas Ebony/Snake-eyes Shrubland vegetation associations.

For each vegetation association, the respective reference site was evaluated to develop a plant list of native species inhabiting each association. Sampling sites were located within a patch of relatively homogenous habitat to minimize the effect of edge habitats. The RRCM development team determined the range of a species' abundance within a 0.1-acre sampling plot for each site. The abundance ranges (Figures B-2 [I-3])) were used as the reference standard for species composition for each vegetation association.

For potential restoration sites, species abundance falling within the range identified on the reference condition sites would result in a species abundance index of 1.0. The abundance of a specific species outside of the reference condition range was calculated as a linear function around the bounds of the range. Specific ranges and Abundance Suitability Index curves for each species is located in the "TERF Species SI", "STPW Species SI", and "TESES Species SI" tabs of the model spreadsheet for the Texas Ebony Resaca Forest, Subtropical Texas Palmetto Woodland, and Texas Ebony/Snake-

eyes Shrubland respectively. The Species Composition Suitability Index was then calculated as the mean of all the species abundance metrics for the site:

$$SC_{SI} = {\sum_{i=1}^{n} f(SC_i)}/{n}$$

Where SC_{SI} = Species Composition Suitability Index of a site,

$F(SC_i)$ = The species composition index as calculated by the species abundance curve function for species *i,* and

n = the number of species identified at the sampling location.

The species richness component of the riparian habitat suitability index was the number of plant species identified at the potential restoration site. For the reference sites, the mean species richness for the three vegetation associations was 24 (Texas Ebony Resaca Forest), 18 (Subtropical Texas Palmetto Woodland), and 20, (Texas Ebony/Snake-eyes Shrubland). The species richness suitability index was calculated as follows:

$$RR_i < RR_{RC}, RR_{SI} = \frac{RR_i}{RR_{RC}};\ RR_i \geq RR_{RC}, RR_{SI} = 1.0$$

Where RR_{SI} = Riparian Species Richness Suitability Index of the sampling location,

RR_i = Species richness of the sampling location, and

RR_{RC} = Species richness for the corresponding reference vegetative association.

The final component of the Riparian Suitability Index was the percent canopy cover of riparian vegetation. The mean percent canopy cover of riparian species for the 10 reference condition resacas was 80-percent; therefore, the riparian canopy index attains a value of 1.0 from 80-percent to 100-percent canopy cover. For canopy covers between 0 and 80 percent, a linear relationship between 0 and 80 was assumed and calculated as follows:

$$RC_i < 80, R_{SI} = \frac{RC_i}{80};\ RC_i \geq 80, RC_{SI} = 1.0$$

Where, RC_{SI} = Riparian Canopy Cover Suitability Index and

R_i = The percent canopy cover of riparian vegetation at site *i.*

Aquatic Habitat

The aquatic habitat component of the RRCM was based on the percent canopy cover of emergent and aquatic vegetation within the resaca. The mean percent canopy cover of emergent and aquatic species for the 10 reference condition resacas was 60-percent; therefore, the aquatic habitat index attains a value of 1.0 from 60-percent to 100-percent canopy cover. For canopy covers between 0 and 60 percent, a linear relationship between 0 and 60 was assumed and calculated as follows:

$$A_i < 60, A_{SI} = \frac{A_i}{60};\ A_i \geq 60, A_{SI} = 1.0$$

Where, A_{SI} = Aquatic Habitat Suitability Index and

A_i = The percent canopy cover of emergent and aquatic vegetation at site *i.*

The vegetation metric (V_{SI}) was then calculated as the average of the aquatic and three riparian indices:

$$V_{SI} = \frac{SC_{SI} \times RR_{SI} \times RC_{SI} \times A_{SI}}{4}$$

Water Regime and Mean Maximum Resaca Depth

The final RRCM were a water regime metric and a water depth metric. The water regime metric (W_{SI}) was a discrete index where a resaca with a permanent water supply and active connectivity to the resaca system would result in an index of 1.0. Resacas with a semi-permanent, yet disconnected water regime results in an SI of 0.5, while resacas that have been sedimented in or remain dry through much of the year are assigned a value of 0.0.

The mean maximum resaca depth SI was a linear index function where the index maximizes at mean maximum depths greater than five feet. This metric was based on historic resacas and measures the water quality and habitat benefits due to deeper waters such as water temperature, dissolved oxygen, and habitat variability

RRCM Index Calculation

The final Resaca Reference Condition Index was calculated as the product of the invasive species, aquatic, bank, and riparian habitat suitability indices:

$$RRCI = B_{SI} \times I_{SI} \times V_{SI} \times W_{SI} \times D_{SI}$$

System Quality

Description and rationale for selection of supporting software tool/programming language and hardware platform.

The RRCM was an Excel spreadsheet based model. The software was utilized due to the ubiquitous application of Excel within the USACE and natural resource agency field. The spreadsheet and RRCM can be run on any PC based system.

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Appendix B-2

Resaca Reference Condition Model Application

Resaca Reference Condition Model Application

The Resaca Reference Condition Model (RRCM) utilized reference condition metrics collected at high quality resaca sites within Resaca de la Palma State Park, The Nature Conservancy's Southmost Preserve, and Camp Lula Sams near the City of Brownsville, Texas. Three rare vegetation associations: Texas Ebony Resaca Forest (n=4), Subtropical Texas Palmetto Woodland (n=3), and Texas Ebony/Snake-eyes Shrubland (n=1). The Texas Ebony Resaca Forest is ranked as a critically imperiled with extinction on a global and state scale (G1S1). The Subtropical Texas Palmetto Woodland and Texas Ebony/Snake-eyes Shrubland are ranked as imperiled with extinction on a global and state scale (G2S2). The three rare vegetation associations are dependent on the floodplains and resaca habitats associated with the lower Rio Grande and provide habitat for a unique community of fish and wildlife resources. The RRCM model was comprised of three components to quantify the habitat quality of each vegetation association.

RRCM Vegetation Component

The vegetation composition metric was comprised of three indices quantifying species composition, diversity, and canopy cover of the vegetation. The vegetation component was the mean of the three indices.

Species Composition Index

The species composition index utilized both the historical description of each vegetation association as defined by Diamond (1993) and the native species composition identified on the reference resaca sites (Figure B-2-1 and Figure B-2-2). Although, Diamond does not include estimates on the percent composition for each species, data collected at the reference sites included estimated ranges for each species observed (Attachments 1-3). Suitability indices were created for the percent composition of each native species by using the reference site's estimates as the boundaries of the composition range. A value contained within the composition range was assigned a SI of 1.0 and values outside of the range were assigned SIs assuming a 5-10 percent linear relationship buffer with values between 0.0 and 1.0. The sum of each species SI was then averaged by the total number of species identified for the respective vegetation association.

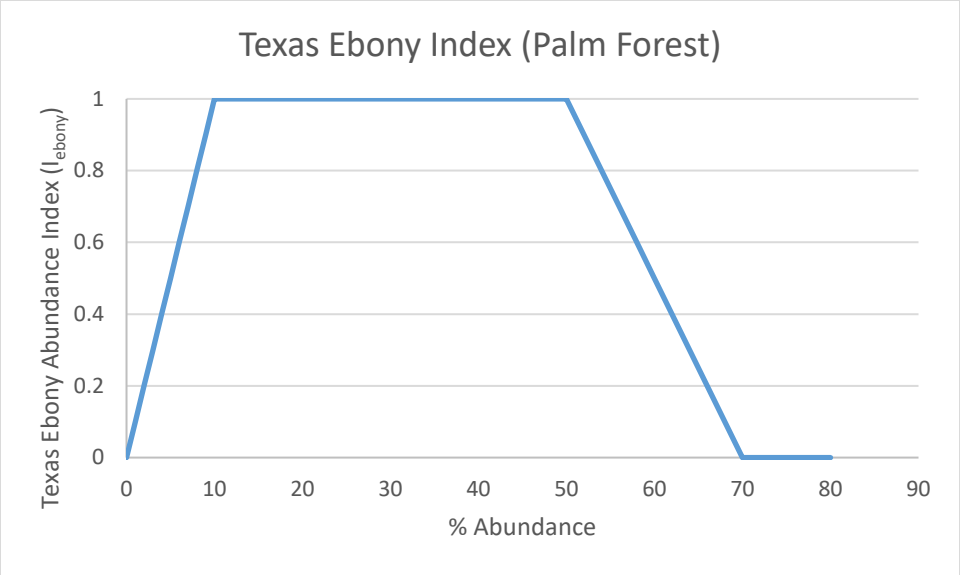

Figure B-2-1: Chart depicting the Texas Ebony Abundance Index

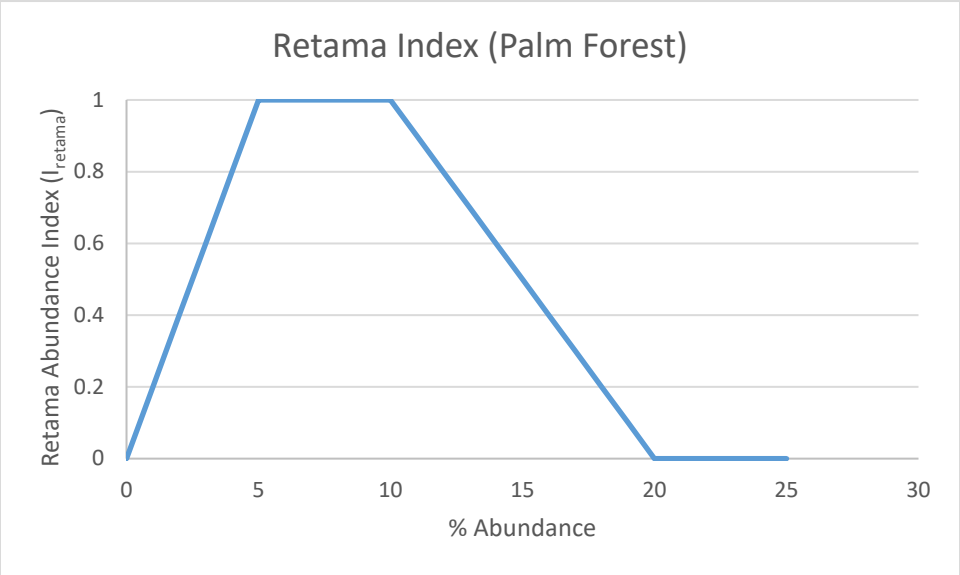

Figure B-2-2: Chart depicting the Retama Abundance Index

Equation 1:

$$C_x = \frac{\sum f\,(I_s)}{n_v}$$

Where Cv = Species Composition Index for site x, f(Is) = the SI of species s as a function of the reference site conditions, and nv = the total number of species identified by Diamond (1993) and/or observed on the reference sites for vegetation type v.

Species Diversity Index

The species diversity index captures the unique diversity of each vegetation association. Species richness was calculated for each reference site and the reference site with the highest species richness for each vegetation association was used as the richness benchmark: Texas Ebony Resaca Forest S_b=49, Subtropical Texas Palmetto Woodland S_b=35, Texas Ebony/Snake-eyes Shrubland S_b=28. The Species Diversity SI was then calculated as the species richness of the site divided by the richness benchmark for respective vegetation association.

Equation 2

$$D_x = \frac{S_x}{S_b}$$

Where Dx = Species Diversity Index for site x, Sx = Species richness for site x, and Sb= Richness benchmark for the appropriate vegetation association.

Canopy Cover Index

The canopy cover index incorporates a measure of vegetative structure for both the riparian and aquatic habitats of the three vegetation associations of interest. The percent canopy cover of the riparian overstory and shrub species within the reference sites was substantial averaging approximately 85 percent canopy closure. The percent canopy cover of nearshore emergent and aquatic vegetation of the reference sites averages approximately 60 percent. These two metrics were used as the baseline to compare against existing and future project conditions.

Equation 3

$$V_x = \frac{R_x}{0.85} \times \frac{E_x}{0.6}$$

Where Vx = Canopy Cover Index for site x, Rx = Percent riparian canopy cover for site x, Ex = Percent emergent/aquatic canopy cover for site x.

Resaca Bank Component

The resaca bank component of the RRCM was comprised of a geomorphic index capturing the slope of the shoreline along the riparian/aquatic gradient and the percent canopy cover of shrub and overstory vegetation extending over the resaca edge (Figure B-2-3). The bank slopes of the reference resacas ranged from 1:10 to 1:30; therefore, an index of 1.0 was assigned to sites with bank slopes less than 1:10 and decreased linearly to 0.0 at a 1:1 slope ().

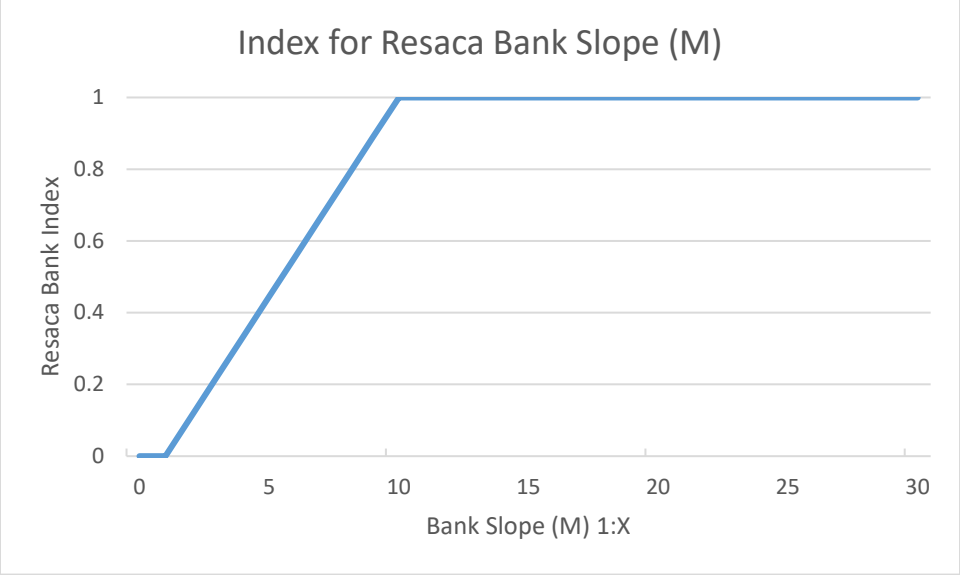

Figure B-2-3: Chart depicting the Resaca Bank Slope

The second index of the resaca bank component incorporates the percent canopy cover of the bank overstory, herbaceous, and emergent vegetation along the shoreline. The percent bank canopy cover of the reference resacas averaged 75 percent; therefore the bank canopy cover index was calculated as the quotient of the bank canopy cover and the average reference bank canopy coverage (0.75).

Equation 4

$$B_x \frac{M \times \frac{K_x}{0.75}}{2} =$$

Invasive Species Component

The invasive species component of the RRCM is simply an index between 0.0 and 1.0 and is measured as the percent of the vegetative community comprised of non-native and non-native invasive species. The index is calculated as follows:

$$I_{SI} = 1 - \left(\frac{Ii}{100}\right)$$

Where I_{SI}=Invasive Species Suitability Index and

I_i= The percent of the vegetative community of site *I* comprised of invasive species.

The resulting invasive species index approaches zero as the percent cover of invasive species approaches 100 percent, thereby penalizing a site with a higher proportion of non-native, invasive species.

References

Diamond, D.D. 1993. Classification of the plant communities of Texas (series level). Unpublished document. Texas Natural Heritage Program, Austin, TX. 25 pp.