APPENDIX E
ENVIRONMENTAL BENEFITS ANALYSIS PROCEDURES

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Note to the Reader:

The study reported here was conducted in accordance with U.S. Army Environmental Operating Principles and the Chief of Engineers' "Four Themes", derived from U.S. Army Corps of Engineers (USACE) actions for change to the corporate culture. The purpose of the Environmental Operating Principles and Actions for Change is to better serve the Nation's water resources infrastructure.

USACE's Environmental Operating Principles are as follows:

- Strive to achieve Environmental Sustainability. An environment maintained in a healthy, diverse, and sustainable condition is necessary to support life.
- Recognize the interdependence of life and the physical environment, and consider environmental consequences of USACE programs and activities in all appropriate circumstances.
- Seek balance and synergy among human development activities and natural systems by designing economic and environmental solutions that support and reinforce one another.
- Continue to accept corporate responsibility and accountability under the law for activities and decisions under our control that impact human health and welfare and the continued viability of natural systems.
- Seek ways and means to assess and mitigate cumulative impacts to the environment; bring systems approaches to the full life cycle of the processes and work.
- Build and share an integrated scientific, economic and social knowledge base that supports a greater understanding of the environment and impacts of the work.
- Respect the views of individuals and groups interested in USACE activities; listen to them actively and learn from their perspective in the search to find win-win solutions to the Nation's problems that also protect and enhance the environment.

The Chief's "Four Themes" to be employed in all studies are:

1. Employ a comprehensive systems approach in all projects, including adaptive planning and engineering, with a focus on sustainability.
2. Practice risk-informed decision making. Employ risk-based concepts in planning, design, construction and major maintenance.
3. Communicate risk to the public effectively. Establish public involvement risk reduction strategies.
4. Incorporate professional and technical expertise in staff. Invest in research and development.

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Introduction

Representatives from five agencies–South Florida Water Management District (SFWMD), Everglades National Park (ENP), U.S. Fish and Wildlife Service (FWS), Florida Department of Environmental Protection (FDEP), and U.S. Army Corps of Engineers (USACE)–participated in the Modified Water Deliveries (MWD) Tamiami Trail Modification (TTM) Benefits Workshop held 23-24 October 2007 in Jacksonville, Florida. The team included engineers, hydrologists, and biologists. The TTM project area includes the 10.7-mile length of Tamiami Trail (U.S. Highway 41) between S-333 (near L-67 Extension) and S-334 (near L-30 and L-31N) and the downstream Northeast Shark River Slough (NESRS) of ENP.

The goal of the environmental benefits analysis was to identify the hydrologic and ecological conditions that would occur under the alternatives outlined in this Limited Reevaluation Report (LRR), develop consistent and quantifiable performance measures, and agree on targets for these measures. These conditions would be evaluated and compared to identify potential quantitative benefits for each alternative.

The team used a variety of sources of information during its analysis. These included historical photos and surveys produced before Tamiami Trail was constructed in the 1920s, data on flows through Tamiami Trail bridges and culverts in the 1940s, and current topographic information. The main source of information was a spreadsheet model used to estimate total annual flows into ENP and depths at gage NESRS-2. The team also reviewed and made extrapolations based on RMA-2 modeling of bridge lengths in Tamiami Trail. The team referred to analyses contained in the 2003 General Reevaluation Report (GRR) for TTM, the associated 2003 FWS Coordination Act Report (CAR), the May 2005 Draft Tamiami Trail Alternative Optimization Report prepared by the ENP, and the 2005 Revised General Reevaluation Report (RGRR) for TTM. Please refer to these earlier reports for additional information.

The interagency team used the benefits analysis in the 2005 TTM RGRR as a baseline for selecting performance measures and focused on ways to make adjustments and produce predictions that allowed relative comparisons among the new alternatives. In addition, the team was able to use hydrologic model data (Appendix D) to develop hydro-ecological performance measures. The hydrologic model was not available for evaluation of alternatives in the 2005 TTM RGRR.

The team went through the following sequence of steps: screen performance measures from the 2005 RGRR that could not be used, add additional performance measures, assign numerical scoring to the qualitative raw values, estimate rate of change, and estimate the acreage in NESRS where the changes may occur.

A subteam worked with the scores, rates of change, and area to: normalize the scores, multiply by area to produce habitat units, factor in the rate of change, calculate the habitat unit benefit for each alternative as the difference between the with-alternative condition and future without project condition, and calculate the average annual benefit for a 50-year period of analysis.

Screen Performance Measures

The team considered the 13 performance measures displayed in the 2005 RGRR, removing the following from further consideration in this LRR due to the reasons listed below.

A. Proportion of area with low flow velocity (<0.1 f/s) discharges within one mile of the Tamiami Trail–no new RMA modeling was available.
B. Distribution of flows, east to west–this is largely affected by lengths of opening(s) in Tamiami Trail; no new RMA modeling was available.
C. Shift to open water, spikerush marsh and slough communities in NESRS–replaced with water depth performance measures that better link to white water lily slough vegetation performance.
D. Risk of ridge and tree island peat burning in NESRS–replaced by the water depth performance measures.
E. Invasion of exotic woody plant species-replaced by the water depth performance measures.
F. Total abundance of fishes in ENP marshes–the team assembled for this 2007 study was not able to use this performance measure. The performance measure is based on hydroperiods and time since last drydown. Because the spreadsheet model did not show differences in these parameters between alternatives, it was not useful for this evaluation.
G. Conditions for wading bird foraging and nesting–this performance measure was tied closely to the abundance of fish and thus was also removed.

Two performance measures were revised:

A. Reverse filling in of sloughs
B. Flows from L-29 Canal into deep sloughs of NESRS

Four new performance measures were developed:

A. One-in-ten year maximum discharge
B. Number of days water depth greater than two feet during wet season peak
C. Number of days water depth greater than three feet during wet season peak
D. Average water depth during wet season peak

The ten performance measures used in this analysis address important characteristics of ENP: hydrology, ridge and slough processes, vegetation, and wildlife mortality during movement. These ten performance measures reflect differences among alternative bridge lengths and openings, as well as stage in L-29 however, at least one performance measure is dependent on removing the L-29 levee and canal or on different upstream operations. In addition, all performance measures represent the capability to provide benefits of the structural alternatives. An operational plan was not developed for this project. Full realization of benefits is dependent upon an operational plan that utilizes the structural capacity of the alternatives.

Assumptions of Spreadsheet Model

See Appendix D–Hydrology and Hydraulics.

Description of the Performance Measures

This section presents a brief description of each of the ten performance measures–what they represent, how they were developed, the input information, units of measure, targets and the methods of calculation or estimation of values. The performance measures were placed into four groups for convenience. Values for all of the ten performance measures are contained in ***Table E-2*** which follows the text descriptions.

1. **Restore water deliveries to ENP** (hydrology)
   - A. Average annual flow volumes
   - B. One-in-ten year maximum discharge

2. **Restore Ridge and Slough Processes** (hydrology, connection to ecosystem of interest, sharp velocity ratios)
   - A. Number of sloughs crossed by bridges
   - B. Difference between average velocity in marsh and average velocity at road
   - C. Flows into NESRS provided via bridge

3. **Restore Vegetative Communities** (targets to restore deep marshes and slough hydropatterns)
   - A. Number of days water depth at NESRS-1 and NESRS-2 greater than two feet during wet season peak (slough depth duration)
   - B. Number of days water depth at NESRS-1 and NESRS-2 greater than three feet during wet season peak (deep slough conditions occurrence and duration)
   - C. Average water depth during wet season peak (average slough conditions)

4. **Restore Fish and Wildlife Resources**
   A. Reduction in wildlife mortality (bridge length/road length ratio, given bridges are inaccessible to animals and may provide safe passage to some animals through the Trail).
   B. Potential connectivity of Water Conservation Area (WCA-3B) Marsh and NESRS as percent of total project length

Performance Measure 1.A Average Annual Flow Volumes

This performance measure presents the annual volume of water passed through the culverts and proposed bridges in the Tamiami Trail alternatives. Flows entering the L-29 Canal are controlled by precipitation and operation of upstream structures. For the TTM LRR, all alternatives were evaluated using the spreadsheet model described earlier in this document.

The underlying assumption is that ecological benefits in NESRS are directly related to additional water volume delivered across the 10.7 mile road segment. This is just another way of stating that current deliveries to the NESRS area located to the east of the L-67 levees are inadequate. For this performance measure, the target is 471,587 acre-feet average (the flow allowed by complete bridging of the road segment and maintaining a 9.7 foot stage in L-29).

Performance Measure 1.B. One-in-Ten Year Maximum Discharge

The National Research Council Report Progress Toward Restoring the Everglades: The First Biennial Review 2006 Committee on Independent Scientific Review of Everglades Restoration Progress (CISRERP) states that one of the key defining ecosystem processes that shaped and maintained the Everglades landscape was "sufficient water quantity", particularly the high volume flow events that many scientists (e.g. The Role of Flow in the Everglades Ridge and Slough Landscape, Science Coordination Team, South Florida Ecosystem Restoration Working Group, Approved by the SCT: January 14, 2003) believe shape and maintain the "corrugated" patterning of the ridge and slough landscape. The "One-in-Ten Year Maximum Flow" performance measure provides a mechanism to evaluate how well each of the LRR alternatives would shape and maintain this landscape patterning. The target for this performance measure is 3,468 cubic feet per second (cfs), the one-in-ten year flow delivered by the 10.7 mile bridge at 9.7 foot stage constraint in the L-29 Canal.

Performance Measure 2.A Number of Sloughs Crossed by Bridges

This performance measure is related to the alignment of the bridge with existing degraded sloughs south of Tamiami Trail as revealed by the U.S. Geological Survey (USGS) High Accuracy Elevation Data (HAED). Situating a bridge directly upstream of a degraded slough would maximize the potential for storm flow velocities to maintain sloughs by removing excess organic sediment that has accumulated in the sloughs since Tamiami Trail was constructed. The length of the bridge has relevance only to the extent that it can encompass more sloughs within its flow cross-section. The performance measure is evaluated by counting the number of major sloughs that each bridge alternative crosses. The target for this performance measure is 21, the total number of sloughs crossed by Tamiami Trail.

Table E-1: Number of Sloughs Crossed by Each Bridge

Alternatives	Bridge(s)	Number of Sloughs Performance Measure
4.2.4	10.7 mile	21
5.1 4.2.3 3.2.3 2.2.3	2 mile + 1 mile	4
5.4, 5.3, 5.2, 4.2.2b, 4.2.2a, 3.2.2b, 3.2.2a, 2.2.2b, 2.2.2a, 1.4b, 1.4a	1 mile bridge	2
4.2.1, 4.1, 3.2.1, 3.1, 2.2.1, 2.1, 1.3, 1.2, 1.1	No bridge	0

Performance Measure 2.B Difference Between Average Velocity in Marsh and Average Velocity at Road

This performance measure describes how closely the water velocities near the road match the marsh velocity at a distance approximately 6,000 feet downstream of the road. The ideal situation is for the ENP lands to have marsh like velocities from the bridge south. The higher velocities shown in culvert-only alternatives are likely to be destructive to the ridge and slough environment immediately south of the Tamiami Trail because they can cause both scour and deposition of sediment fans.

The velocity at the center of the bridge for each alternative was compared against each alternative for a distance of approximately 6,000 feet downstream from the road. This analysis looked at the one- and 100-year return frequency discharges. The data for this performance measure (estimated velocities at the road for each alternative) are derived from RMA-2 model runs (referenced in the 2005 RGRR TTM report and reviewed for this TTM LRR performance measure).

The average velocity in the marsh that is used in the calculations for all alternatives is 0.024 feet per second.

Ratio: (average velocity in marsh) / (average velocity at road in center of bridge opening)

High velocities near the road result in low values for the performance measure. For example, a ratio of 0.5 would represent a velocity at the road that is two times the velocity in the marsh, and a ratio of 0.1 would represent a velocity at the road that is ten times the velocity in the marsh. These are then reported as percentages. Velocities near the road that are close to the velocities in the marsh have a high value approaching 100 percent which is the target for this performance measure.

Performance Measure 2.C Flows into Northeast Shark River Slough Provided via Bridge

While the existing culverts provide a hydraulic connection to the deeper sloughs existing within NESRS, the capacity is not commensurate with amount of flow expected in these deeper sloughs during both high and low flow conditions. Preferential flow through these deeper sloughs is even more pronounced during drier times.

The eastern portion of Shark Slough (from the L-67 extension to the L-31N Levee) varies in elevation from about 5.6 feet National Geodetic Vertical Datum (NGVD) to 7.2 feet NGVD. Without the obstruction of Tamiami Trail the preferential flow path from this varying elevation would be in the deeper sloughs. The distribution of flow within NESRS would become more uniformly distributed (from west to east) as depth increases and the relative depth differences reduce.

<u>Average and High Flow Conditions</u>

The stages in NESRS range from about 4 feet NGVD (about two foot below ground surface) to 9 feet NGVD with a median stage of about 7.5 feet NGVD. Ground elevations vary along the trail (***Figure E-1)***. The median stage of 7.5 feet NGVD results in an average water depth of about 1.1 feet with a maximum depth of about 1.9 feet and a minimum depth of about 0.3 feet.

The increased connection provided by the bridge aligned with deeper portions of northeast Shark Slough facilitates increased flow where it should occur preferentially. When the water level is less than 0.5 foot above the ridges, most of the flow occurs in the deeper sloughs. It is important for water to be rapidly delivered to these deeper sloughs, commensurate with this capacity, during wet periods, to produce higher velocities desirable for the redevelopment and maintenance of open water vegetation in these sloughs. This assessment assumes that sheet flow is based on the following equations

Manning Equation; $Q = (u/n)\ A\ Rh^{(2/3)}\ (hf / L)^{(1/2)}$
A depth dependent Manning n ($n = \sim d^{\ 0.77}$)

Where:
A = Cross Section Flow Area = W * d
W = Flow Width
d = Flow Depth
P = Wetted Perimeter
R = Hydraulic Radium = A/P = (W * d) / W ~ d

Dry Conditions

The importance of these connections during drier periods is increased by the fact that both the existing condition and the expected range of the "with project" conditions (Tamiami Trail Bridge in conjunction with revised operations) are drier than the desired conditions as represented by the Natural System Model (NSM)[1]. The increased connection that a bridge provides over culverts in terms of capacity and connectivity (sheet flow with low velocity versus flow through culverts) is expected, for the same water availability, to have the following effects:

- Better distribution of the water; high water levels with more natural recession rates and less abnormal dry out as the limited water available can reach these sloughs.
- May reduce unnatural predation around the culverts due to their limited area.

Evaluation Procedure

The benefits of different bridge lengths and locations were assessed considering each bridge location. A representative "marsh capacity" was estimated on 200 foot wide intervals using the USGS helicopter ground elevations and Manning's "n" based flow equation used in the South Florida Water Management Model (SFWMM). The location of each bridge is then used to calculate the marsh capacity directly connected by a bridge opening. This marsh capacity for the bridge is then divided by the marsh capacity of the approximately 11 mile wide

[1] The Natural System Model depicts the hydrologic response of the pre-drained system to rainfall and other hydrologic conditions of the period from 1965 through 1995. It does not depict the conditions of the pre-drained Everglades system, although there is a misconception that it does; such data does not exist (1999 *Final Integrated Feasibility Report and Programmatic Environmental Impact Statement*, a product of the *Central and Southern Florida Project Comprehensive Review Study*, also known as the *Restudy*).

NESRS from the L-67 Extension to the L-31N Levee (NAD83 horizontal coordinates from 763,500 to 821,250) and expressed as percentage.

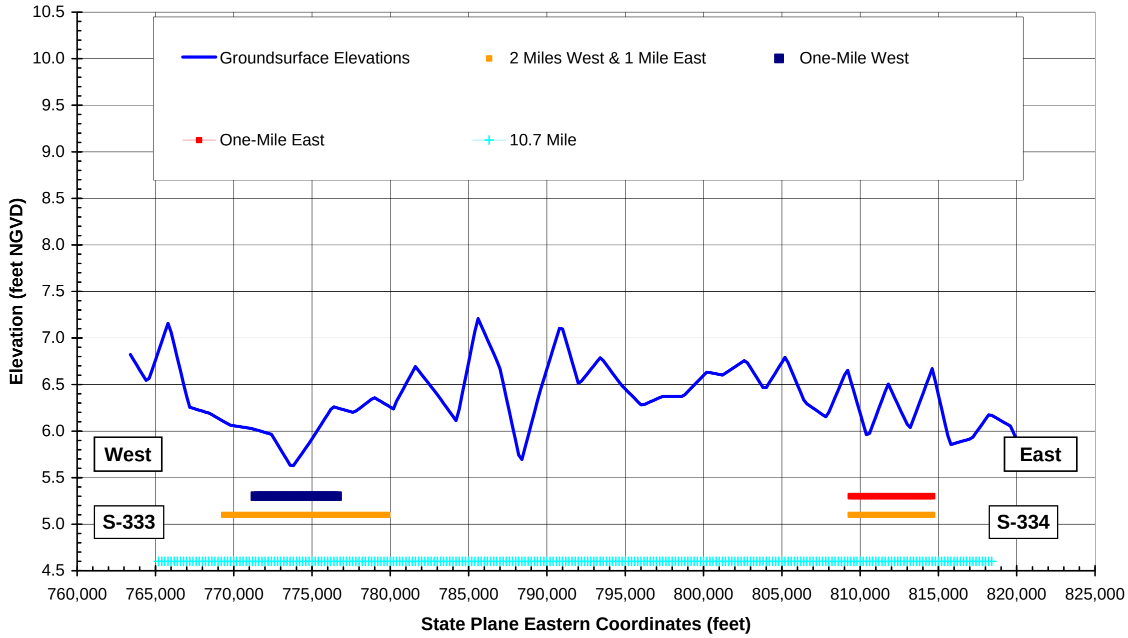

FIGURE 1
Ground Surface Elevations 700 feet south of Tamiami Trail and Proposed Conveyance Openings in Tamiami Trail

Figure E-1: Elevations Along Tamiami Trail and NESRS in the Study Area

Performance Measure 3.A Number of Days Water Depth is Greater Than Two Feet During Wet Season Peak

NESRS historically was part of the ridge and slough ("corrugated") Everglades landscape. Sloughs are conspicuous and major landscape features in the southern Everglades and are the main pathway of water flow through the natural Everglades. The slough community is present in areas with the longest hydroperiods and the deepest water that rarely dries out. It also has a distinct plant community which is a mixture of floating, submerged species, and sometimes emergent species. A dominant and characteristic species of pre-drainage native sloughs is the white water lily (*Nymphaea odorata*). Over the past 40 years of hydrologic isolation from the ecosystem to the north, NESRS has largely converted to a drier community of mixed sawgrass (***Figure E-2***). This performance measure evaluates the potential for alternatives to restore the historic landscape, and hydrologic suitability for white water lily as an indicator.

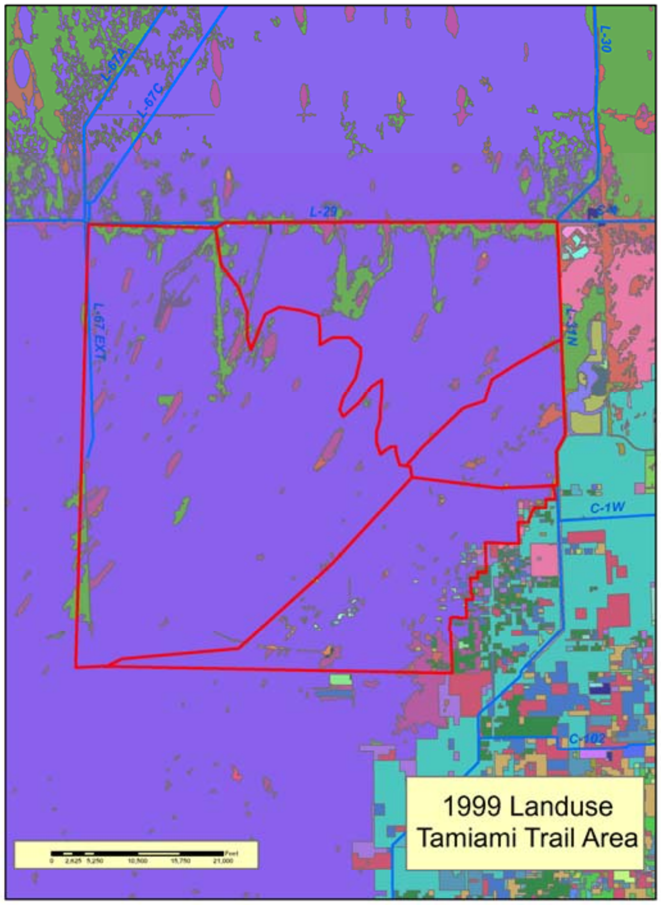

Figure E-2: Current Land Use Classification Showing Sawgrass Domination

The uniform purple shading indicates sawgrass; the pink ovals are the tree islands.

Today, white water lily is more abundant in deeper slough habitats and areas less subject to drydown events. Paleoecological studies indicate that pre-drainage ENP slough communities were once dominated by white water lily and banana lily prior to the widespread artificial draining of slough communities.

Many scientific studies and field observations indicate conditions where white water lily does better than other plants and is more abundant than other species. Depth and hydroperiod are all important. A number of studies suggest that white water lily does well where wet season average depths are between 60 centimeters (cm) (over two feet), and 100 cm (over three feet). White water lily has more root biomass at water depths of 60 cm and 90 cm than at 30 cm. White water lily is also most abundant where the hydroperiod in most years approaches 360 days and there are few years with dry down periods.

Performance Measure 3.A presents the number of days that water depth is greater than two feet (~60 cm) at NESRS-2 and NESRS-1 for the dates 1 August through 31 October (the wet season peak) for all years in the period of record. The greater the number of days at or above this depth, the better the conditions for white water lily and all slough vegetation. Performance of the alternatives for this performance measure is illustrated on ***Figure E-6*** in the last section.

Performance Measure 3.B Number of Days Water Depth is Greater Than Three Feet during Wet Season Peak

Performance Measure 3.B presents the number of days that water depth is greater than three feet (approximately 90 cm) at NESRS-2 and NESRS-1 for the dates 1 August through 31 October (the wet season peak) for all years in the period of record. The greater the number of days at or above this depth, the better the conditions for white water lily and all slough vegetation. Performance of the alternatives for this performance measure is shown on ***Figure E-7*** in the last section.

This performance measure supplements Performance Measure 3.A (days with depth greater than two feet) in describing the hydrologic conditions that favor slough vegetation, particularly white water lily. While the number of days with water depth greater than two feet is important to maintaining slough vegetation, the duration (number of days) with depth greater than three feet may be even more important in excluding non-slough vegetation from the sloughs. Many alternatives achieve depths greater than two feet. Within this group, there is little variation in the degree the alternatives restore slough conditions and vegetation. Only a few alternatives achieve depths greater than three feet; these alternatives should be the most effective in restoring sloughs. This performance measure alone would not be sufficient to evaluate the alternatives because only a few alternatives redistribute enough water to achieve this optimal condition. The analysis also requires Performance Measure 3.A to demonstrate the increased duration/depth that intermediate but still substantially effective alternatives would provide.

Performance Measure 3.C Average Water Depth During Wet Season Peak

This performance measure presents the average of daily water depths at NESRS-2 and NESRS-1 for the dates 1 August through 31 October for all years in the period of record. Performance of all the alternatives is shown in ***Figure*** E-3**.**

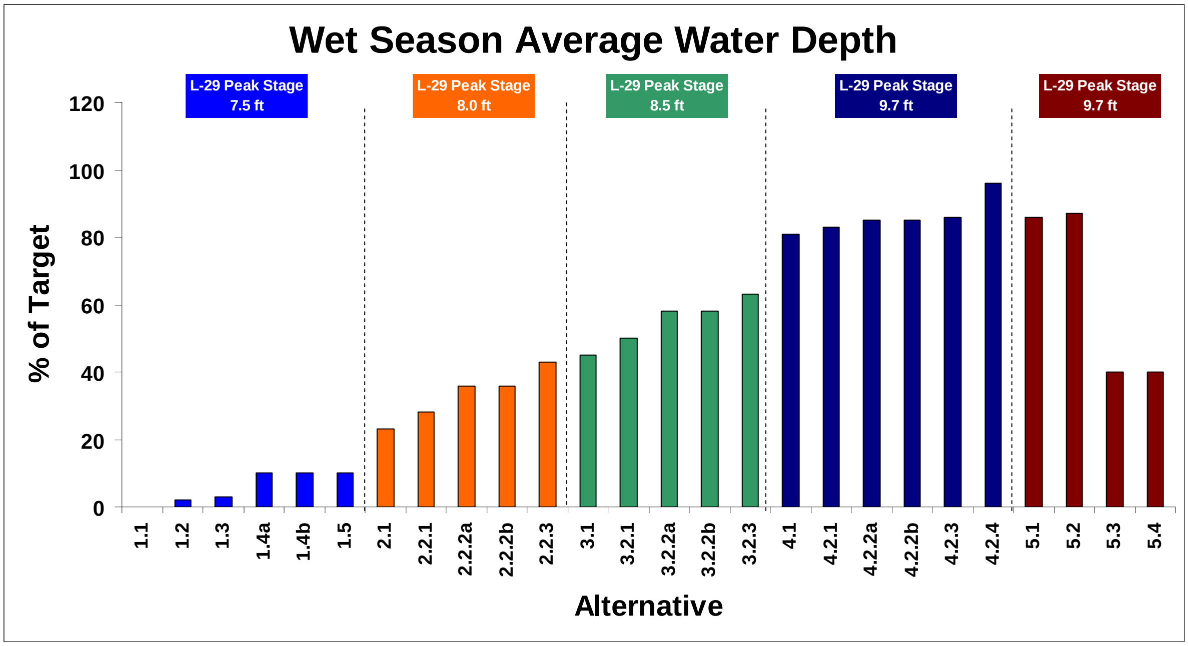

Figure E-3: Wet Season Average Water Depth

Performance Measure 4.A Reduction in Wildlife Mortality

This performance measure is based on average mortality data from FWS for Tamiami Trail. The data describe an average of 261 deaths per mile of road per year and assumes that this rate applies to the entire 10.7 mile long project area.

The deaths of small animals from collision with automobiles would continue to occur on the sections of Tamiami Trail that would be connected to the adjacent marsh and canal. The deaths would not occur on the bridged sections of Tamiami Trail because there would be no connection between the road surface and the marsh and canal habitat of the animals. The animals would not easily reach the road surface in these sections and then be at risk of being hit. However, because the L-29 canal and levee are not eliminated and because conditions may be artificially deep under the bridge, limited bridging (e.g., one mile) may simply redirect animals to cross at other sections of the unbridged Tamiami Trail.

The performance measure presents the numbers of deaths that would be avoided because of the presence of the bridge(s). It is calculated by multiplying 261 deaths per mile per year by the total length of the bridge(s) in miles. A short bridge would only result in a small reduction in mortality while a bridge that spans the entire project area would produce the maximum value of 2,737 deaths per year avoided.

Performance Measure 4.B Potential Connectivity of WCA-3B Marsh and NESRS as Percent of Total Project Length

This performance measure describes the potential connection between WCA-3B and NESRS if the L-29 Levee is removed under a future project. This performance measure is calculated by dividing the length of bridge opening in miles by 10.7 miles, the length of the longest possible bridge that could be constructed in the project area.

A 100 percent value indicates full *potential* connectivity and is the target. Note that this marsh to marsh connectivity would also require degrading the L-29 Levee that encloses the WCA-3 impoundments. Degrading L-29 is not authorized under the MWD legislation.

Table E-2: Values for Each Performance Measure

Alternatives	Bridge(s)	Connectivity Performance Measure
4.2.4	10.7 mile	100%
5.1 4.2.3 3.2.3 2.2.3	2 mile + 1 mile	28%
5.4, 5.3, 5.2, 4.2.2b, 4.2.2a, 3.2.2b, 3.2.2a, 2.2.2b, 2.2.2a, 1.4b, 1.4a, 1.5	1 mile bridge	9%
4.2.1, 4.1, 3.2.1, 3.1, 2.2.1, 2.1, 1.3, 1.2, 1.1	No bridge	0%

Performance Measure Values

The raw values for all of the performance measures described in the previous section are presented in ***Table E-3***. The values for the performances measures were expressed in many different units (i.e., percent, feet, acre-feet, and cfs).

Calculating Habitat Units and Benefits

Although the Tamiami Trail Project Delivery Team (PDT) evaluated many performance measures to ascertain how well each of the alternative plans performed on various criteria indicative of ecosystem restoration, (e.g., average annual flow volumes, number of sloughs crossed by bridges, number of days water depth is greater than two feet during wet season peak), habitat units derived from the performance measures were selected by the PDT as the metric that best integrated information regarding the quality and quantity of improved hydrologic and ecologic function within the study area. Habitat units are calculated by multiplying relative lift due to each alternative by the acreage benefitted.

Sometimes it is difficult to summarize the results when the analyses are performed separately for distinct performance indicators. This phenomenon often occurs simply because different management measures or alternative plans “do” different things, provide different types of output, and provide benefits to different biological communities. This is true for the Tamiami Trail features and alternatives, in which certain performance measures quantify output in flows and other hydrologic units, while other performance measures examine ecological responses as a percent or number of days.

In order to estimate total benefits from the various alternatives, the USACE must be able to perform cost effectiveness/incremental cost analysis (CE/ICA) on a metric that combines all performance measures output. Simply adding the performance measure output would be problematic, because the performance measures operate at vastly different scales (i.e., one performance measure only applies to a small geographic area), ecosystem responses to alternatives occur gradually through time, and the performance measures resources are represented in very different metrics (e.g., feet, acre-feet, percent, cfs). All three of these issues are addressed in the following description of the calculation of benefits.

The changes produced by most alternatives were assessed over the same acreage of NESRS, even though not all of the individual performance measures affected the same acreage and even though the alternatives themselves may affect different acreages. The main area for analysis and comparison is defined by L-67 Extension on the west, Tamiami Trail on the north, and the L-31N and the 8.5 Square Mile Area (SMA) on the east. There is no firmly defined boundary on the south; the differences between alternatives and the without project condition gradually decrease as one moves south. For this study, the southern limit is defined by the team as an east-west line connecting the end of the L-67 Extension to 8.5 SMA. The total area is 63,195 acres. Refer to ***Figure E-2***, on which the red outer line illustrates the primary benefits area for most alternatives. Nine of the ten performance measures apply to the entire 63,195 acres. The other performance measure, 4.B, only applies to the northernmost one-mile wide by 10.7-mile long strip of land nearest Tamiami Trail, which totals 6,848 acres. In addition, Alternatives 5.3 and 5.4 impact a different area of benefit. Due to the proposed levee to the south of L-29, the flows into NESRS under these two Blue Shanty alternatives would only be affected between the L-67 extension and the proposed levee. This total area is 17,379 acres. Performance measure 2.B would likewise only be applied to an acreage of 1,694 for Alternatives 5.3 and 5.4. However, it should be clear that the spreadsheet model could not adequately simulate Alternatives 5.3 and 5.4; therefore, it is possible that the benefit area for these alternatives is underestimated.

The team prepared a simple description of the changes in ecosystem conditions through time in response to the alternatives. The performance measures values and scores represent the ultimate, or end-point, of changes due to the alternatives, and the team recognized that the enhancement of the entire area would not occur immediately after construction is complete. For the alternatives, the USACE estimated that a varying rate of change per alternative would be achieved within two and a half years. The reasoning is that more extreme changes would affect vegetation more quickly than subtle changes over time. Therefore, the "one-in-ten year maximum discharge" performance measure value was also used as the value for the percent of benefit achieved in two and a half years. Most of this represents the hydrological changes such as depth, velocity, and hydroperiod. The team further estimated an additional two and a half years, for a total of five years, for the full extent of changes to occur. The herbaceous vegetation may take this long to fully respond to the hydrological changes. Fish and wildlife populations may require a few seasons to respond to the changed hydrology and vegetation. Although not fully predictable, there is a good likelihood that a wet or dry year would occur during this period, further emphasizing the importance of incorporating events such as scouring some of the sediments and vegetation that have accumulated in the sloughs during high water events or connecting deep sloughs to the L-29 Canal to maintain water during the lowest flow periods. The without project condition, also the National Environmental Policy Act (NEPA) 'no action' alternative, is proposed to remain the same throughout the period of analysis, the same as existing conditions. The period of analysis is 50 years, from 2010 to 2060.

The different metrics made it necessary to normalize the different performance measures into a 0-100% index. The normalization method used was "percent of maximum", in which the maximum output achieved in each category by any of the alternatives was assigned a "100%", and the output values for other alternatives for that same resource category were scaled as a percentage of that maximum (between 0 and 100%). The 10.7 mile bridge (Alternative 4.2.4) scored 100% for each of the performance measures and was therefore the alternative to which all other performance measures were normalized. An index value of 100%

would thus be assigned to an alternative that provides the maximum output value for the habitat unit categories, while a value of 50% would equate to the output value for an alternative that only provides half of the maximum output provided by the "largest" alternative (a hypothetical "largest" alternative in terms of delivering the maximum output of every habitat type). While other normalization techniques exist (e.g., percent of range, percent of total, unit vector), the percent of maximum is the most widely used technique and is usually the default method. Thus, a combined, normalized metric was calculated to perform CE/ICA on all outputs provided by the Tamiami Trail alternatives.

It is important to understand the implications of normalizing in this manner. Although the 10.7 mile bridge is shown as achieving 100% of potential benefits, the team is not implying in any way that this project can provide 100 percent restoration to this area. For the purposes of comparison, these habitat units are calculated as potential benefits of this project only (TTM). It is widely recognized and agreed that additional benefits would be gained in this area due to potentially increased storages and flows under the Comprehensive Everglades Restoration Plan (CERP), as projects in CERP are authorized, constructed and in operation. However, for comparison purposes, these alternatives were normalized to the 10.7 mile bridge and therefore that bridge would reflect maximum achievable benefit for this project.

As stated in LRR Section 1, all the alternatives were evaluated for their forward compatibility with CERP projects, and specifically with the "Decompartmentalization of WCA-3" Project, which would presumably be operating under the "CERP 1" flow volumes. The general assumption is that the LRR initial alternatives capable of passing higher volumes are more compatible with CERP objectives than alternatives passing lower peak and average volumes. Decompartmentalization, as described in the 1999 *Final Integrated Feasibility Report and Programmatic Environmental Impact Statement*, a product of the *Central and Southern Florida Project Comprehensive Review Study* (also known as the *Restudy*), visualized degradation of the L-29 levees and fill of the L-29 Canal. Furthermore, all alternatives that include degradation of part of the roadway and emplacement of a bridge are assumed more compatible with future CERP modifications than alternatives that include only reinforcing the road.

Table E-3 contains the raw value for each performance measure and alternative while ***Table E-4*** includes the normalized value for each performance measure and alternative.

Habitat units were calculated by multiplying habitat indices by the appropriate acreages that were impacted by the performance measures (Performance

Measure 2.B affected 6,848 acres, while the rest of the performance measures affected the full 63,195 acres, except for Alternatives 5.3 and 5.4 which affected 1,694 acres for Performance Measure 2.B and 17,379 acres for the rest of the performance measures).

To find the total habitat units for each alternative for the entire study area, it was first necessary to find the total habitat units of the upper eastern and western sections of the study area, and then the total habitat units of the lower eastern and western sections of the study area, and add these together to determine the total (HU) lift for the entire study area. This was necessary because one performance measure only affected the upper 6,848 acres (or 1,694 acres for Alternatives 5.3 and 5.4) of the study area, while the rest of the performance measures affected the entire study area and because two alternatives only affect the western section. This procedure ensured that no performance measure was double counted and the performance measures that only affected the upper section of the study area were adjusted to reflect the lesser impact.

In developing habitat indices, each of the performance measures were determined to be of equal importance, and were therefore all given a weight of 1". Since all of the habitat units occupied the same geographic area, an average of all the performance measures was warranted. Indices were calculated separately for the upper and lower sections described above. Each index was multiplied by its matching acreage to produce total habitat units. ***Table E-5*** shows the habitat indices of the upper (northern) and lower (southern) sections, the acreages for upper and lower sections, and the combined total habitat units for each alternative.

The calculation of average annual lift (benefit) takes into account that achievement of full performance is estimated to take five years because the plant and animal resources only gradually respond to the physical changes generated by the alternatives. The average annual lift for each alternative also incorporates subtracting the average annual habitat units for the no action plan from the average annual habitat units for each alternative. ***Table E-5*** displays average annual habitat unit lift for each alternative.

Table E-3 Performance Measure Values for each Alternative

					1. Water Deliveries to ENP			2. Ridge and Slough Processes			3. Vegetation			4. Wildlife
	ALTERNATIVES	% achieved in 2.5 years	% achieved in 5 years	L-29 DESIGN STAGE (FEET)	A. Average Annual Flow Volume (ac-ft)	B. Potential connectivity of WCA-3B Marsh and NESS, percent of total length	C. One in ten year maximum discharge (cfs)	A. Number of sloughs crossed by bridges	B. Ratio of average velocity in marsh and average velocity at road (%)	C. Flows into NESS provided via bridge (%)	A. Total # days at NESRS-1 and NESRS-2 with water depth >2 ft. during wet season peak	B. Total # days at NESRS-1 and NESRS-2 with water depth >3 ft. during wet season peak	C. Average water depth at NESRS-1 and NESRS-2 during wet season peak (ft.)	C. Reduction in wildlife mortality (# average annual deaths avoided)
	Benefit area (acres)				63195	63195	63195	63195	6484	63195	63195	63195	63195	63195
	Benefit area for blue shanty plans				17379	17379	17379	17379	17379	17379	17379	17379	17379	17379
1	**No roadway reinfocing (note 2)**													
1.1	no action (19 culvert sets)	33	100	7.5	176,559	0	1146	0	1.8	0	86	0	1.30	0
1.2	spreader swales (30ft x 1000ft - bottom dimensions)	34	100	7.5	184,626	0	1166	0	2.5	0	74	0	1.32	0
1.3	add culvert sets (19 - 3x5ft dia) with swales **(note 3)**	33	100	7.5	187,925	0	1146	0	3.3	0	78	0	1.33	0
1.4a	add 1-mile eastern bridge	36	100	7.5	203,451	9	1255	2	26	11	101	0	1.40	261
1.4b	add 1-mile western bridge	36	100	7.5	203,451	9	1255	2	26	20	101	0	1.40	261
1.5	reinforce western section of road to 12.75ft (crown) and add 1-mile western bridge	36	100	7.5	203,451	9	1255	2	26	20	101	0	1.40	261
2	**Roadway improvements - Crown 11.05ft (note 4)**													
2.1	reinforce road (low points only)	41	100	8.0	239,492	0	1410	0	1.8	0	335	0	1.53	0
2.2.1	reinforce low points, add culvert sets with swales	41	100	8.0	251,080	0	1410	0	1.8	0	711	0	1.58	0
2.2.2a	reinforce road, add 1-mile eastern bridge	41	100	8.0	273,565	9	1416	2	26	11	1428	3	1.66	261
2.2.2b	reinforce road, add 1-mile western bridge	41	100	8.0	273,565	9	1416	2	26	20	1428	3	1.66	261
2.2.3	reinforce low points, add 2-mile + 1-mile bridges	43	100	8.0	292,559	28	1459	4	65	42.9	1931	3	1.73	783
3	**Roadway improvements - Crown 11.55ft (note 4)**													
3.1	reinforce road	43	100	8.5	303,065	0	1474	0	1.8	0	2343	4	1.75	0
3.2.1	reinforce road, add culvert sets with swales	43	100	8.5	316,202	0	1504	0	1.8	0	2527	5	1.80	0
3.2.2a	reinforce road, add 1-mile eastern bridge	47	100	8.5	339,703	9	1642	2	26	11	2578	7	1.88	261
3.2.2b	reinforce road, add 1-mile western bridge	47	100	8.5	339,703	9	1642	2	26	20	2578	7	1.88	261
3.2.3	reinforce road, add 2-mile + 1-mile bridges	47	100	8.5	355,115	28	1640	4	65	42.9	2579	10	1.93	783
4	**Roadway improvements - Crown 12.75ft (note 4)**													
4.1	reinforce road	55	100	9.70	409,138	0	1920	0	1.8	0	2581	809	2.11	0
4.2.1	reinforce road, add culvert sets with swales	57	100	9.70	416,773	0	1980	0	1.8	0	2581	977	2.13	0
4.2.2a	reinforce road, add 1-mile eastern bridge (RGRR)	57	100	9.70	430,363	9	1984	2	26	11	2581	1093	2.15	261
4.2.2b	reinforce road, add 1-mile western bridge (RGRR)	57	100	9.70	430,363	9	1984	2	26	20	2581	1093	2.15	261
4.2.3	reinforce road, add 2-mile + 1-mile bridges (RGRR)	59	100	9.70	435,872	28	2050	4	65	42.9	2581	1093	2.16	783
4.2.4	10.7-mile bridge (RGRR)	100	100	9.70	471,587	100	3468	21	100	100	3058	1085	2.26	2793
5	**Structural alternatives and/or road realignment (note 4)**													
5.1	northern alignment of Alt 14	59	100	9.70	435,872	28	2050	4	65	42.9	2581	1093	2.16	783
5.2	northern alignment with 1-mile bridge	57	100	9.70	430,363	9	1984	2	26	20	2581	1093	2.17	261
5.3	northern alignment with 1-mile bridge and relocation of L-67 levee - Crown 13.00ft	100	100	9.70	471,542	9	3468	2	13	20	1135	321	1.70	261
5.4	current alignment with 1-mile bridge and relocation of L-67 levee - Crown 13.00ft	100	100	9.70	471,542	9	3468	2	13	20	1135	321	1.70	261
5.5	pump stations along L-29	H36	100	-										

Notes:
2 Existing road has 19 culvert sets resulting in an average culvert set spacing of ~3000 feet.
3 Reduces the average culvert set spacing to approximately 1500 feet.
4 All road improvements require 3.05 feet between road crest and L-29 design elevation.

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Table E-4 Normalized Values of Performance Measures for Each Alternative

Alt	ALTERNATIVES	% achieved in 2.5 years	% achieved in 5 years	L-29 DESIGN STAGE (FEET)	1. Water Deliveries to ENP: A. Average Annual Flow Volume (ac-ft)	1. Water Deliveries to ENP: B. Potential connectivity of WCA-3B Marsh and NESS, percent of total length	1. Water Deliveries to ENP: C. One in ten year maximum discharge (cfs)	2. Ridge and Slough Processes: A. Number of sloughs crossed by bridges	2. Ridge and Slough Processes: B. Ratio of average velocity in marsh and average velocity at road (%)	2. Ridge and Slough Processes: C. Flows into NESS provided via bridge (%)	3. Vegetation: A. # days at NESRS-2 that water depth >2 ft. during wet season peak	3. Vegetation: B. # days at NESRS-2 that water depth >3 ft. during wet season peak	3. Vegetation: C. Average water depth at NESRS-2 during wet season peak (ft.)	4. Wildlife: C. Reduction in wildlife mortality (# average annual deaths avoided)
Benefit area (acres)					63195	63195	63195	63195	6484	63195	63195	63195	63195	63195
Benefit area for blue shanty plans					17379	17379	17379	17379	17379	17379	17379	17379	17379	17379
1	**No roadway reinforcing (note 2)**													
1.1	no action (19 culvert sets)	33	100	7.5	0.37	0.00	0.33	0.00	0.02	0.00	0.03	0.00	0.58	0.00
1.2	spreader swales (30ft x 1000ft - bottom dimensions)	34	100	7.5	0.39	0.00	0.34	0.00	0.03	0.00	0.02	0.00	0.58	0.00
1.3	add culvert sets (19 - 3x5ft dia) with swales **(note 3)**	33	100	7.5	0.40	0.00	0.33	0.00	0.03	0.00	0.03	0.00	0.59	0.00
1.4a	add 1-mile eastern bridge	36	100	7.5	0.43	0.09	0.36	0.10	0.26	0.11	0.03	0.00	0.62	0.09
1.4b	add 1-mile western bridge	36	100	7.5	0.43	0.09	0.36	0.10	0.26	0.20	0.03	0.00	0.62	0.09
1.5	reinforce western section of road to 12.75ft (crown) and add 1-mile western bridge	36	100	7.5	0.43	0.09	0.36	0.10	0.26	0.20	0.03	0.00	0.62	0.09
2	**Roadway improvements - Crown 11.05ft (note 4)**													
2.1	reinforce road (low points only)	41	100	8.0	0.51	0.00	0.41	0.00	0.02	0.00	0.11	0.00	0.68	0.00
2.2.1	reinforce low points, add culvert sets with swales	41	100	8.0	0.53	0.00	0.41	0.00	0.02	0.00	0.23	0.00	0.70	0.00
2.2.2a	reinforce road, add 1-mile eastern bridge	41	100	8.0	0.58	0.09	0.41	0.10	0.26	0.11	0.47	0.00	0.73	0.09
2.2.2b	reinforce road, add 1-mile western bridge	41	100	8.0	0.58	0.09	0.41	0.10	0.26	0.20	0.47	0.00	0.73	0.09
2.2.3	reinforce low points, add 2-mile + 1-mile bridges	43	100	8.0	0.62	0.28	0.42	0.19	0.65	0.43	0.63	0.00	0.77	0.28
3	**Roadway improvements - Crown 11.55ft (note 4)**													
3.1	reinforce road	43	100	8.5	0.64	0.00	0.43	0.00	0.02	0.00	0.77	0.00	0.77	0.00
3.2.1	reinforce road, add culvert sets with swales	43	100	8.5	0.67	0.00	0.43	0.00	0.02	0.00	0.83	0.00	0.80	0.00
3.2.2a	reinforce road, add 1-mile eastern bridge	47	100	8.5	0.72	0.09	0.47	0.10	0.26	0.11	0.84	0.01	0.83	0.09
3.2.2b	reinforce road, add 1-mile western bridge	47	100	8.5	0.72	0.09	0.47	0.10	0.26	0.20	0.84	0.01	0.83	0.09
3.2.3	reinforce road, add 2-mile + 1-mile bridges	47	100	8.5	0.75	0.28	0.47	0.19	0.65	0.43	0.84	0.01	0.85	0.28
4	**Roadway improvements - Crown 12.75ft (note 4)**													
4.1	reinforce road	55	100	9.70	0.87	0.00	0.55	0.00	0.02	0.00	0.84	0.75	0.93	0.00
4.2.1	reinforce road, add culvert sets with swales	57	100	9.70	0.88	0.00	0.57	0.00	0.02	0.00	0.84	0.90	0.94	0.00
4.2.2a	reinforce road, add 1-mile eastern bridge (RGRR)	57	100	9.70	0.91	0.09	0.57	0.10	0.26	0.11	0.84	1.00	0.95	0.09
4.2.2b	reinforce road, add 1-mile western bridge (RGRR)	57	100	9.70	0.91	0.09	0.57	0.10	0.26	0.20	0.84	1.00	0.95	0.09
4.2.3	reinforce road, add 2-mile + 1-mile bridges (RGRR)	59	100	9.70	0.92	0.28	0.59	0.19	0.65	0.43	0.84	1.00	0.96	0.28
4.2.4	10.7-mile bridge (RGRR)	100	100	9.70	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	**Structural alternatives and/or road realignment (note 4)**													
5.1	northern alignment of Alt 14	59	100	9.70	0.92	0.28	0.59	0.19	0.65	0.43	0.84	1.00	0.96	0.28
5.2	northern alignment with 1-mile bridge	57	100	9.70	0.91	0.09	0.57	0.10	0.26	0.20	0.84	1.00	0.96	0.09
5.3	northern alignment with 1-mile bridge and relocation of L-67 levee - Crown 13.00ft	100	100	9.70	1.00	0.09	1.00	0.10	0.13	0.20	0.37	0.30	0.75	0.09
5.4	current alignment with 1-mile bridge and relocation of L-67 levee - Crown 13.00ft	100	100	9.70	1.00	0.09	1.00	0.10	0.13	0.20	0.37	0.30	0.75	0.09
5.5	pump stations along L-29	-	-	-										

Notes:
2 Existing road has 19 culvert sets resulting in an average culvert set spacing of ~3000 feet.
3 Reduces the average culvert set spacing to approximately 1500 feet.
4 All road improvements require 3.05 feet between road crest and L-29 design elevation.

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Table E-5 Habitat Indices, Acreages, Total Habitat Units and Habitat Unit Lift for Each Alternative

	ALTERNATIVES	HABITAT UNIT INDICES (SOUTHERN SECTION)	HABITAT UNIT INDICES (NORTHERN SECTION)	TOTAL HABITAT UNITS	% achieved in 2.5 years	% achieved in 5 years	AVERAGE ANNUAL HABITAT UNITS	AVERAGE ANNUAL HABITAT UNIT LIFT (note)
	Benefit area (acres)	56711	6484					
	Benefit area (acres) for Alternatives 5.3 and 5.4	15685	1694					
1	No roadway reinforcing							
1.1	no action (19 culvert sets)	0.15	0.13	9103	33	100	9103	N/A
1.2	spreader swales (30ft x 1000ft - bottom dimensions)	0.15	0.14	9301	34	100	9290	187
1.3	add culvert sets (19 - 3x5ft dia) with swales	0.15	0.14	9354	33	100	9341	238
1.4a	add 1-mile eastern bridge	0.20	0.21	12918	36	100	12719	3616
1.4b	add 1-mile western bridge	0.21	0.22	13543	36	100	13312	4209
1.5	reinforce western section of road to 12.75ft (crown) and add 1-mile western bridge	0.21	0.22	13543	36	100	13312	4209
2	Roadway improvements - Crown 11.05ft							
2.1	reinforce road (low points only)	0.19	0.17	11833	41	100	11697	2594
2.2.1	reinforce low points, add culvert sets with swales	0.21	0.19	13012	41	100	12818	3715
2.2.2a	reinforce road, add 1-mile eastern bridge	0.29	0.28	18108	41	100	17662	8559
2.2.2b	reinforce road, add 1-mile western bridge	0.30	0.29	18733	41	100	18257	9154
2.2.3	reinforce low points, add 2-mile + 1-mile bridges	0.40	0.43	25583	43	100	24784	15681
3	Roadway improvements - Crown 11.55ft							
3.1	reinforce road	0.29	0.26	18163	43	100	17724	8621
3.2.1	reinforce road, add culvert sets with swales	0.30	0.27	18995	43	100	18515	9412
3.2.2a	reinforce road, add 1-mile eastern bridge	0.36	0.35	22851	47	100	22212	13109
3.2.2b	reinforce road, add 1-mile western bridge	0.37	0.36	23477	47	100	22808	13705
3.2.3	reinforce road, add 2-mile + 1-mile bridges	0.46	0.48	29000	47	100	28075	18972
4	Roadway improvements - Crown 12.75ft							
4.1	reinforce road	0.44	0.40	27424	55	100	26757	17654
4.2.1	reinforce road, add culvert sets with swales	0.46	0.42	28795	57	100	27977	18874
4.2.2a	reinforce road, add 1-mile eastern bridge (RGRR)	0.52	0.49	32666	57	100	31688	22585
4.2.2b	reinforce road, add 1-mile western bridge (RGRR)	0.53	0.50	33291	57	100	32287	23184
4.2.3	reinforce road, add 2-mile + 1-mile bridges (RGRR)	0.61	0.62	38661	59	100	37464	28361
4.2.4	10.7-mile bridge (RGRR)	1.00	1.00	63195	100	100	62113	53010
5	Structural alternatives and/or road realignment							
5.1	northern alignment of Alt 14	0.61	0.62	38661	59	100	37464	28361
5.2	northern alignment with 1-mile bridge	0.53	0.50	33337	57	100	32331	23228
5.3	northern alignment with 1-mile bridge and relocation of L-67 levee - Crown 13.00ft	0.43	0.40	7475	100	100	13974	4871
5.4	current alignment with 1-mile bridge and relocation of L-67 levee - Crown 13.00ft	0.43	0.40	7475	100	100	13974	4871
	NO ACTION FOR ALT 5.3 AND 5.4	0.15	0.13	2505				

Performance Comparisons

Hydrologic Performance

<u>PM-1A Flow Improvement</u>

Figure E-4, above, compares relative low volume performance of all alternatives. Alternatives in Group 1, the culvert-only alternatives (no increase in stage constraint) provided insignificant (i.e., greater than 20 percent) increase in flow volumes across Tamiami Trail. Alternatives in Group 2 (raise stage constraint to 8 feet) provided increased benefits, and Group 2 alternatives that included bridges (2.2.2a and b, 2.2.3) improved flow by nearly 50 percent over no-action. Group 3 alternatives provided additional flow volume improvements, with Alternative 3.1 (raise stage to 8.5 only) showing flow volume benefits higher than those of the bridge alternatives at 8.0 feet; however, Alternatives 3.1 and 3.2 did not provide comparable improvements in 'ridge and slough processes', and Alternatives 3.2.2a and b were above the initial cost constraints of the MWD authorization. Alternatives in Groups 4 and 5 provided even greater flow volume increases but were too costly.

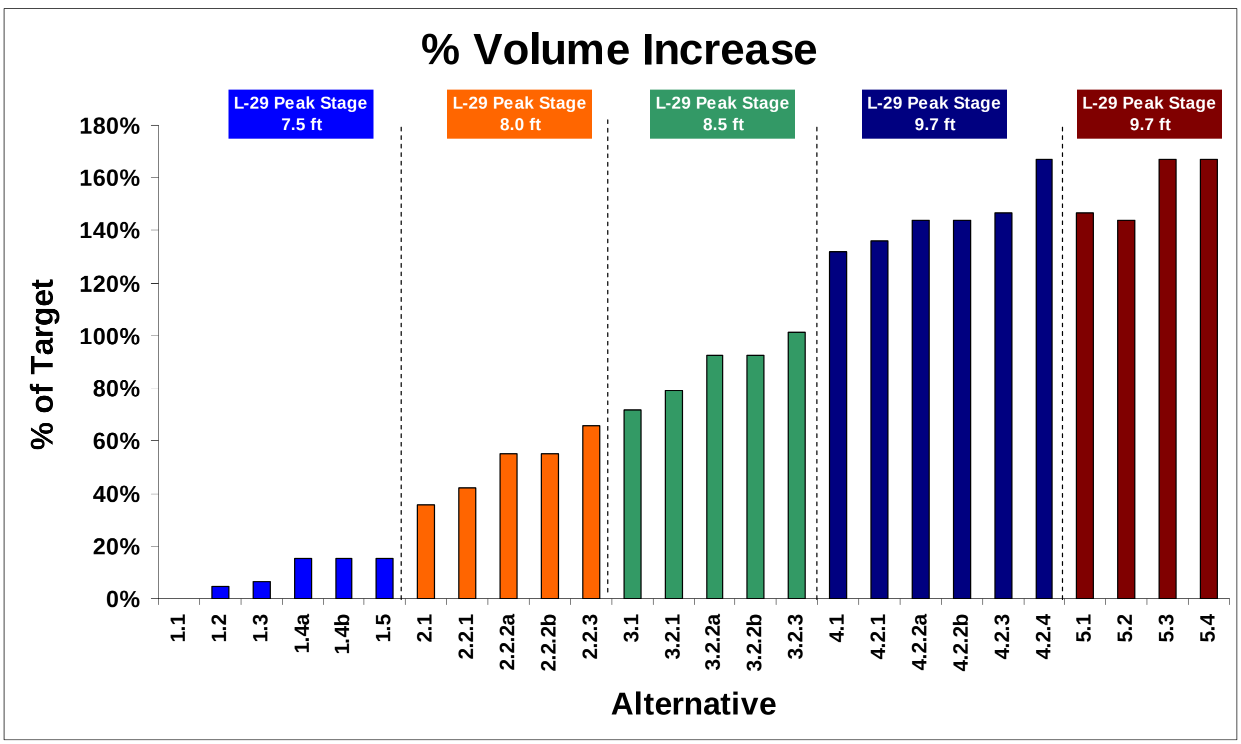

Figure E-4: Flow Volume Capacity Comparison for Each of the Alternatives

Ridge and Slough Processes

Figure E-5 shows comparative performance of the alternatives for those hydrologic performance measures that respond to velocity changes into the ENP marshes. For this performance measure, performance is tied directly to the length of the bridges, with all alternatives in the "no-bridge" category showing no significant improvement, and "bridge" alternatives showing improvement in direct relation to bridge length. For this set of performance measures, the stage constraint makes no difference (in other words, bridges can pass water at all stage constraints up to 9.7 feet). This demonstrates that bridges are an important project feature to avoid unnaturally high velocities. In contrast to the output shown for water volume improvement, including a bridge feature makes a significant difference in overall performance, as well as providing forward compatibility with CERP flows.

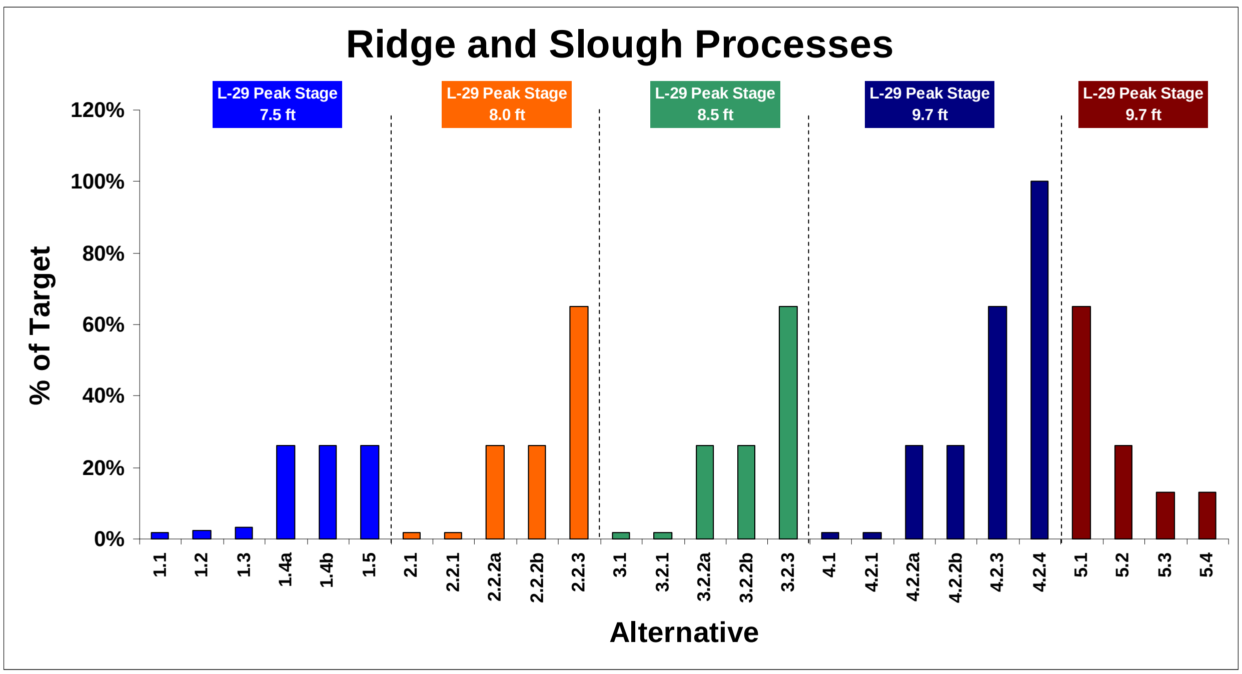

Figure E-5: Ridge and Slough Process Outputs

The one-bridge alternatives show lower output (more scour and sedimentation) than the two-bridge or full bridging alternatives.

Ecologic Performance

Figure E-6 shows performance of the alternatives for maintenance of sloughs with white water lily (duration of depths greater than two feet during the wet season). For this performance measure, the first alternatives to show an improvement of 25 percent or more (over no action) were the bridge alternatives at stage constraint equaling 8.0 feet. All alternatives in Group 3 (stage = 8.5

feet) Groups 4 and 5 (stage = 9.7 feet) met more than 80 percent of the target. Again, all of the "3" (Stage 8.5 feet) alternatives showed better performance than all Group 2 (stage 8.0 feet) alternatives (including the 2+1 bridge alternative in Group 2); however, note that Alternatives 3.1 and 3.2.1 "failed" the velocity-change performance measure in "ridge and slough processes" (***Figure E-5*** above). Alternative 3.2.2a appeared to offer the best mix of performance (volume + ridge-and-slough + vegetation suitability).

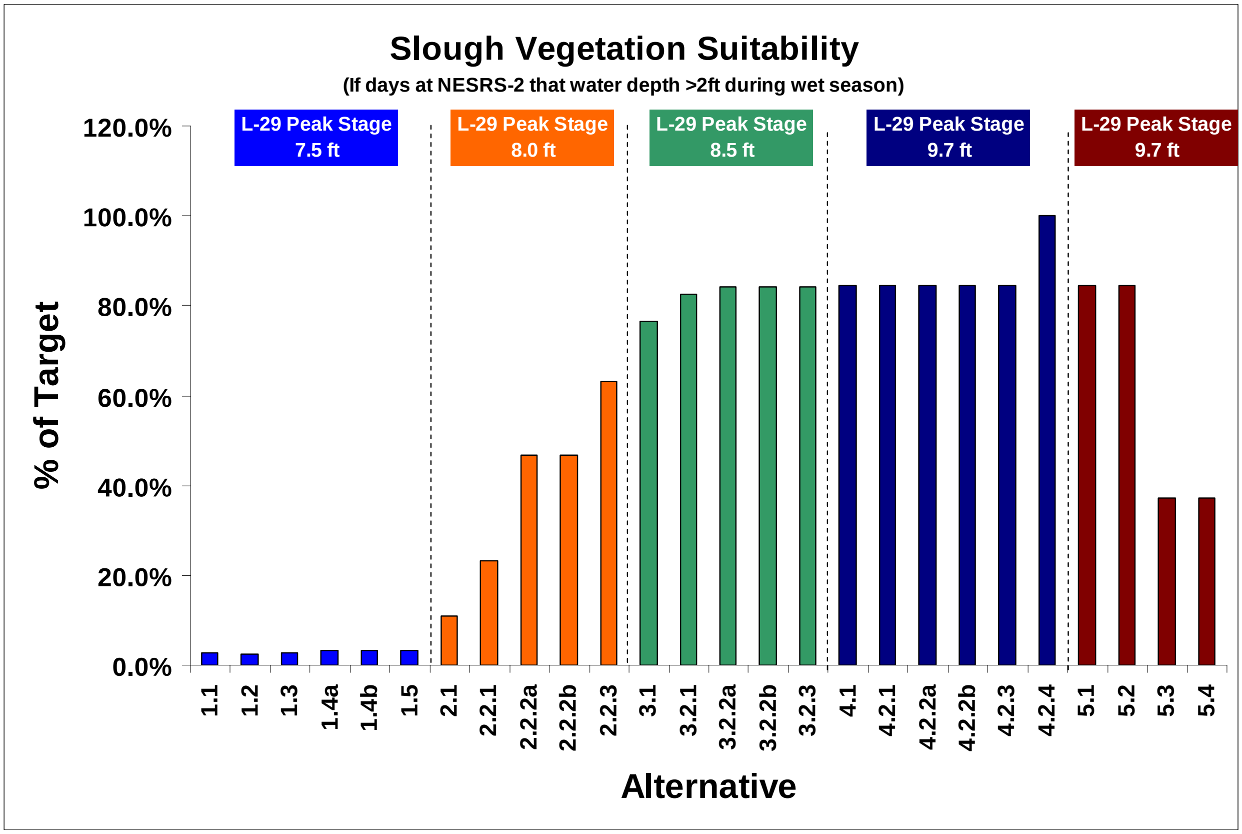

Figure E-6: Slough Vegetation Performance Measure, Days with Water Depth >2 ft During Wet Season

<u>Slough Vegetation Suitability, Wet Season Stage Greater Than Three Feet</u>

This performance measure, indicative of very long hydroperiod deep marsh, was chosen to indicate the likelihood of reaching marsh conditions that would favor conversion from mixed marsh to open slough habitat (re-conversion from marsh to slough). As ***Figure E-7*** shows below, the only alternative groups that showed significant improvement over existing conditions (no action) were alternatives in Groups 4 and 5 (stages in L-29 with a 9.7 foot or higher constraint). The cost estimates for these alternatives were all above established project limits, except for Alternative 4.1 (reinforce road only), and this alternative did not perform in the ridge-and-slough category as shown above.

From this second, deep water evaluation of slough vegetation suitability it can be concluded that none of the MWD alternatives within a feasible cost limit can deliver full restoration to Everglades sloughs.

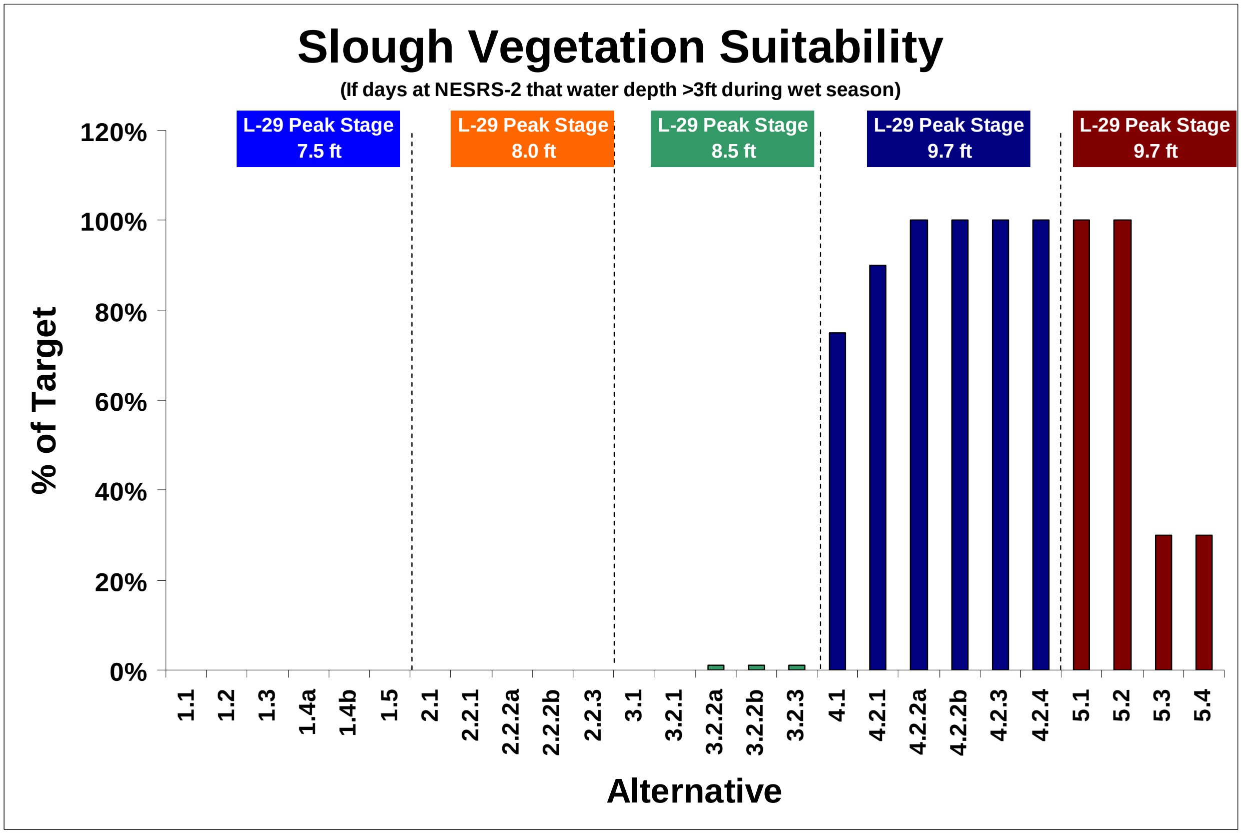

Figure E-7: Slough Vegetation Performance Measure, Days with Water Depth >3 ft During Wet Season

Overall Performance Summary: Average Annual Lift

Figure E-8 summarizes "lift" in average annual habitat units (benefit increase multiplied by acres benefitted) for all alternatives. The preferred plan or Recommended Plan would provide 8,559 average annual habitat units (AAHU). In comparison, higher performing plans , incorporating a greater bridge length or higher stage constraint, provide greater habitat benefits (up to over 53,000 AAHU for the 10.7 mile bridge, with a 9.7 foot stage constraint) but at higher costs.

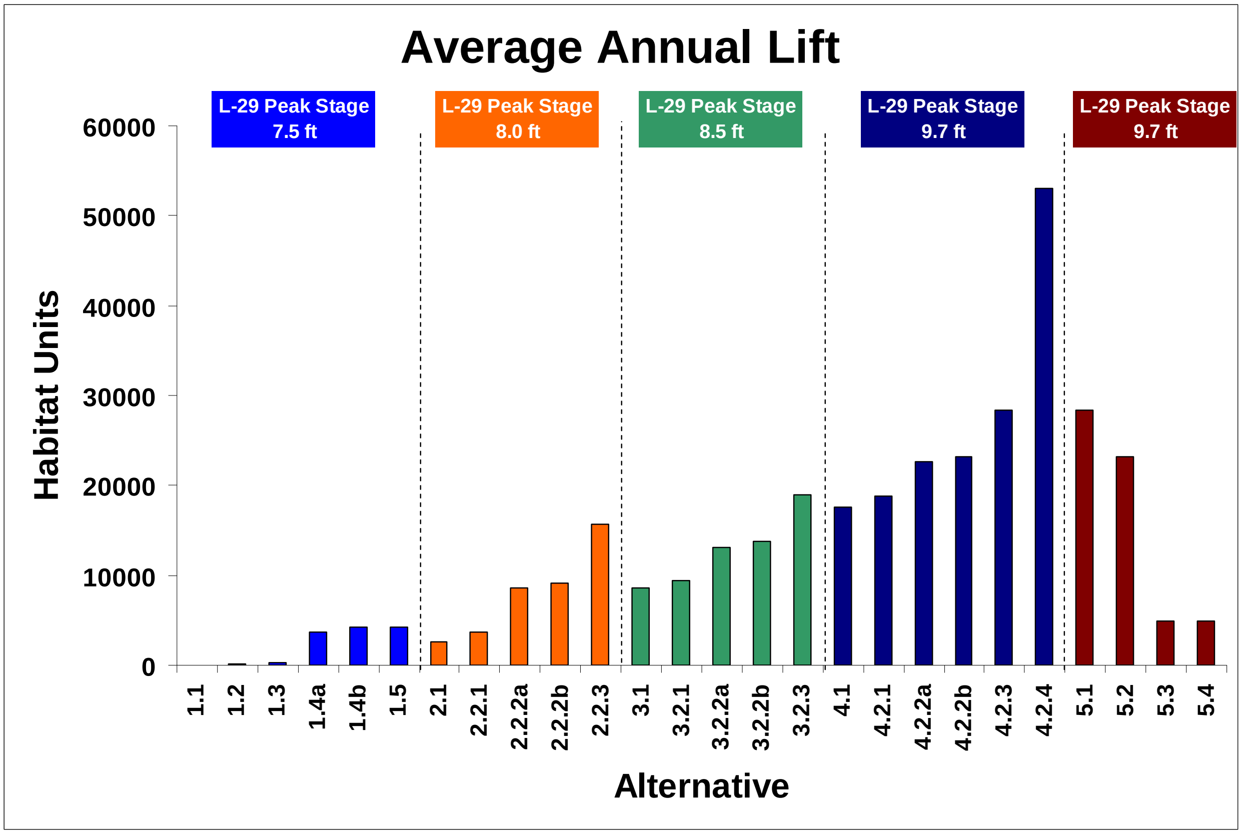

Figure E-8. Comparison of All Alternative Plans by AAHU Produced

Alternative 3.2.2a is the Recommended Plan because it gives the most ecological benefit within the cost constraint and stages anticipated now and in the immediate future. Within the Group 2 and 3 alternatives, those alternatives that incorporate a bridge segment are forward compatible with future CERP flows to a greater degree than non-bridge alternatives. Bridge segments are not stage constrained; they can pass stages up to and including 9.7 feet. Therefore, changes required in the future could include road reinforcement only. As stated above, increasing "lift" above about 14,000 AAHU is expected to be too costly for the MWD project budget.

Monitoring Plan Framework

This section provides an overview of the environmental monitoring that will be conducted to measure ecological response both upstream and downstream of the Tamiami Trail modifications. The intent of this overview is not to provide a project level monitoring plan, but rather to briefly describe other monitoring initiatives that will be relied upon to assess project performance. While this Limited Reevaluation Report (LRR) authorizes only hydrologic monitoring to assess whether actual improvement in water deliveries is occurring south of Tamiami Trail, a number of ongoing and/or proposed monitoring programs conducted under other authorities will be utilized to measure ecological response. Additionally, the proposed monitoring programs will also be targeting assessment of reduced water flows to Northwest Shark River Slough resulting from implementation of the proposed modifications. Results of the monitoring and assessment activities will be summarized every two years in the Restoration, Coordination and Verification (RECOVER) biennial System Status Report (SSR), primarily written to document the cumulative performance of CERP projects.

There are two general categories of monitoring that will be used to assess the ecological effects of the Tamiami Trail modifications; system-wide (or landscape level) monitoring and project level monitoring programs. System-wide monitoring is primarily coordinated through the RECOVER Monitoring and Assessment Plan (MAP) which includes components conducted by U.S. Army Corps of Engineers (USACE), USGS, Everglades National Park (ENP), and through the Everglades Division of the South Florida Water Management District (SFWMD). The National Science Foundation (NSF) funded Long Term Ecological Research program (LTER) conducts monitoring in the Taylor and Shark slough/river/estuary transition zones primarily through Florida International University. Together, results from these monitoring programs will allow the USACE to develop a comprehensive, information-based view of the ecological effects of projects like the Tamiami Trail LRR that are expected to have a significant impact on the ecological function and pattern of the landscape. Summary analyses presented in the SSR are based on the combined sampling funded by the various authorities listed above.

The system-wide programs that will collect information in WCA-3B and Northeastern Shark River Slough in order to detect change in ecological conditions due to the Tamiami Trail modifications include:

1) Hydrologic monitoring network–More than one hundred permanent water stage monitoring stations are distributed across the Everglades Restoration Area that deliver hourly measurements of the water surface. The Everglades Depth Estimation Network (EDEN-USGS) consolidates the hydrologic information and interpolates a water surface for the entire area each day.
2) Soil nutrient mapping–Soil cores from across the everglades restoration area are collected in order to produce an accurate map of soil nutrient conditions. This program detects water quality impacts throughout the ecosystem at decadal intervals.
3) Vegetation mapping program–Every five years the entire Everglades ecosystem is systematically photographed and each image is classified by vegetation type. This program allows for the detection of vegetation community changes that occur at the scale of acres to square miles.
4) Marl prairie/slough gradients monitoring project–Every two years a comprehensive set of transects that cross the Shark River slough/Marl prairie

ecotone are monitored in order to detect fine scale shifts in vegetation species compositions. These shifts are closely correlated with the quantity of water passing through the Shark River Slough.

5) Ridge and slough flow pattern monitoring–Biennial surveys of plant species composition are related to water depth patterns along the historically predominate direction of flow through WCA-3A and 3B. These transects should capture the return to normal ridge and slough pattern that is expected to occur when these areas begin to experience a more natural pattern of water flow as barriers to flow are removed.
6) Regional Environmental Monitoring and Assessment Program (REMAP)-Fine scale vegetation monitoring, change analysis, micronutrient levels (Phosphorus, Nitrogen, and Sulfur). This U.S. Environmental Protection Agency program fills gaps in fine scale vegetation and micronutrient monitoring that is not conducted by other projects.
7) Periphyton mat cover structure, composition and aquatic fauna regional population–Quarterly samples of these rapidly changing microbial and animal communities are broadly indicative of seasonal patterns. Continuous monitoring of highly variable communities allows us to tease apart the relative importance of hydrologic events such as drydowns in determining ecological health, and to differentiate threshold levels where the frequency of extremely intense events indicate foundational shifts in the functioning of the ecosystem.
8) Crayfish abundance in relationship to hydrologic pattern–Crayfish abundance patterns are monitored quarterly much like the periphyton and aquatic fauna program. The analysis of these patterns is similar to the periphyton and aquatic fauna program.
9) Wading bird colony location, size and timing–Continuous surveys of wading bird colonies are conducted with small aircraft throughout the ecosystem. Changes in the location, timing, and size of wading bird colonies are expected to be broadly indicative of recovery of the historical ecosystem patterns that are expected to occur as the ecosystem progresses.
10) LTER monitoring–The LTER program is focused on freshwater marsh to estuarine transition zones along the major water flow paths of the Southern Everglades ecosystem. Water volume, water stage, micronutrient levels, plant productivity patterns, and basal food web features (invertebrates and fishes) are sampled at relatively fine scales of resolution. These samples are used to develop predictive models that shape expectations for positive system response and/or deterioration of the ecosystem.

Project level monitoring may be required by three CERP projects that are focused on the WCA 3B to Tamiami Trail to NE Shark River Slough transition area; Comprehensive System Operation Plan (CSOP), Decompartmentalization (DECOMP) and ENP Seepage Management. These three projects will have regulatory requirements for monitoring endangered species and other permit specific criteria, and may produce more detailed monitoring plans based on the deliberations of the CERP Project Delivery Teams. Potential for overlap/redundancy between project-level and system-wide monitoring is recognized, and RECOVER has initiated a process to coordinate the various monitoring projects in order to facilitate change analysis, eliminate redundancy and optimize monitoring efforts.

The aggregation of information provided by these monitoring programs should yield a precise and revealing characterization of the changes that occur to a cross-section of organisms across a spatially integrated landscape as a consequence of the modifications made to Tamiami Trail. These organisms should cumulatively represent the effects of changes on the ecosystem, and should also provide the USACE the ability to detect and remedy any problematic shifts to the ecosystem that arise in a rapid and cost-effective manner.

In addition to the physical monitoring programs, predictive models for ridge and slough development/recovery based on shifts in hydropattern are being developed to frame the assessment data with the expectations of change that we have for the area of project influence. Modeling tools are essential for teasing apart the changes in vegetation pattern that we would expect to see as a part of normal fluctuations in climate versus the changes in vegetation that are caused by the project-related alterations in the landscape. The ridge and slough recovery model is primarily being developed by the Everglades division of the SFWMD. Since changes to the Tamiami Trail will profoundly alter the spatial distribution of water delivered to Florida Bay, we expect that the monitoring of the freshwater marsh to estuarine transition to demonstrate direct effects of the project. The set of predictive models will be used to specifically characterize the differences in conditions in the ecosystem that were caused by the alterations made to the Tamiami Trail and/or other CERP related projects.

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