Tamiami Trail Investigations
Interim Report
Modified Water Deliveries to Everglades National Park

1. Introduction. This interim report has been prepared to investigate and document potential high water conditions along U.S. Highway 41 (U.S. 41) also known as Tamiami Trail caused by construction and operation of the Modified Water Deliveries to Everglades National Park and the Comprehensive Everglades Restoration Project (CERP).

2. Authorizations and Background. Water regulation in the Everglades and Everglades National Park (ENP) are part of the larger Central and Southern Florida project (C&SF). Phase I of the Comprehensive Plan for the C&SF Project was authorized in 1948, as outlined in House Document No. 643, The remainder of the Comprehensive Plan was authorized by the Flood Control Act of 1954. The project purposes include flood control, prevention of salt water intrusion, water supply to ENP, municipal and agricultural water supply, groundwater recharge, and preservation of fish and wildlife. Project features include Water Conservation Area (WCA) Nos. 1, 2, and 3. WCA No. 3 is the largest and southernmost of the three WCA's with a total area of about 915 square miles. It is subdivided into WCA No. 3A (760 square miles) and 3B (156 square miles) by Levee 67A and C (L-67A and C). WCA No. 3B is completely encircled by levees and is not regulated. The majority of inflow and outflow consists of direct rainfall, seepage, and evaporation and transpiration.

2.1 In 1962, construction of Levee 29 (L-29) was completed. This was the final feature of WCA No. 3A and enabled control of all flows into Shark River Slough in the northern portion of ENP. After 1962, all flows into the ENP via Shark River Slough were discharged at the S-12 structures.

2.2 L-67 Extension (L-67 Ext.) was authorized by the Flood Control Act of 1948 (PL-858; 80th Congress). Its purposes are: to convey water releases through the S-12 structures far enough into the Park to prevent increases in water levels on adjacent private lands above those experienced under prior conditions; and to prevent flooding of U.S. Highway 41. The L-67 Ext. borrow canal was constructed from May 1966 through April 1967 to aid in the implementation of the 1966 Interim Release Schedule for ENP that was agreed upon following a severe drought from 1962 through 1965. The L-67 Ext. borrow canal was designed to provide 1,000 cfs of water to the Park during relatively wet conditions (its conveyance during the dry season is considerably less).

2.3 The Flood Control Act of 1965 authorized a plan to provide seasonal flood protection in Southwest Dade County. The plan consisted of levees, canals, water control structures, and pumping stations capable of removing 15 inches of runoff per month plus seepage into the area following a 10-year flood. The approved plan provided for the southward and eastward continuation of the L-67 extension to connect with the L-31W levee at the western edge of the Frog Pond. The plan was designed to enable desirable water levels for winter agriculture in southwest Dade County. Growing recognition of the potential negative environmental impacts of the Southwest Dade project caused the local sponsor to withdraw their support for the project. This project was officially deauthorized after Congress expanded the ENP to include most of the area that would have been protected.

2.4 In 1968, the ENP-South Dade Conveyance System was authorized by Congress. It is designed to enable conveyance of flood waters for water supply needs and deliver water to the ENP's Taylor Slough and Canal 111 (eastern panhandle). The Conveyance System was superimposed over the existing flood control system. Design flood control and operation were not altered by the construction of these works.

2.5 On December 13, 1989, Congress passed Public Law 101-229, the Everglades National Park Protection and Expansion Act. This law authorizes modification to the Central and Southern

Florida project to improve water deliveries to ENP. The purpose of the Act was to increase the level of protection of the outstanding values of Everglades National Park and to enhance and restore the ecological values, natural hydrologic conditions, and public enjoyment of such area by adding the area commonly known as Northeast Shark River Slough and the East Everglades to Everglades National Park; and assure that the Park is managed in order to maintain the natural abundance, diversity and ecological integrity of native lands and animals, as well as the behavior of native animals, as a part of their ecosystem. The Park was also expanded by 107,000 acres to include portions of Northeast Shark River Slough (NESRS). In 1992, as directed by the Act, the U.S. Army Corps of Engineers published a General Design Memorandum for Modified Water Deliveries to Everglades National Park. The Modified Water Deliveries to Everglades National Park Project consists of structural and operational changes to the Central and Southern Florida Project in south Dade County. Specifically, water will be passed through WCA No. 3B into Northeast Shark River Slough through additional structures. Project components include reconnecting WCA No. 3A to 3B by structures through L-67A and gaps in L-67C, and reconnecting WCA No. 3B to Shark River Slough with structures in L-29.

2.6 The Water Resources Development Act of 1992 (Public Law 102-580) authorized the Chief of Engineers to review the report of the Chief of Engineers on Central and Southern Florida, published as House Document 643; 80th Congress, 2nd Session, and other pertinent reports, with a view to determining whether modifications to the existing project are advisable at the present time due to significantly changed physical, biological, demographic, or economic conditions, with particular reference to modifying the project or its operation for improving the quality of the environment, improving protection of the aquifer, and improving the integrity, capability, and conservation of urban water supplies affected by the project operation.

2.7 The Water Resources Development Act of 1996 was enacted on October 12, 1996. Section 528 of the Act (Public Law 104-303) entitled "Everglades and South Florida Ecosystem Restoration" authorizes a number of ecosystem restoration projects and provided specific guidance for the Comprehensive Everglades Restoration Plan (CERP). As a result of this Act, the U.S. Army Corps of Engineers submitted a report to Congress on July 1, 1999, containing a comprehensive blueprint for Everglades restoration.

3 <u>Purpose of this Study</u>. Due to implementation of these projects, higher stages in WCA No. 3B and the L-29 borrow canal may cause problems for U.S. Highway 41 (Tamiami Trail). This study was conducted to identify any potential impacts caused by implementation of the Modified Water Deliveries to Everglades National Park (MWD) and the Comprehensive Everglades Restoration Plan (CERP) project to U.S Highway 41.

4. <u>Tamiami Trail (US 41)</u> was completed in the late 1920's. As a source of borrow for Tamiami Trail and a means of conveying water in an east/west direction, the Tamiami Canal was constructed along the north side of the roadway. The original construction plans were not available for review. However, based on a consultants work on the western portion of Tamiami Trail, they estimate that the existing roadway pavement structure consists of a limerock base (10"-12" thick), an asphalt structural course (2"-3" thick), and an asphalt friction course (5/8"-1" thick). For this analysis, it is assumed that the subgrade extended 18" below the crown of the road. There are 19 sets of culverts under Tamiami Trail in the approximately 11 mile stretch of highway between S-333 and S-334. Each culvert set consists of one to four culverts with diameters ranging from 42-inches to 60-inches. Culvert invert elevations and lengths are typically about 4 ft. and 60 ft., respectively.

5. <u>Study Plan</u>. Three hydrologic models were used to determine the stage and flow-paths in Everglades National Park for various flows. Plate 2 shows the extent of the models. The South Florida Water Management Model (SFWMM) was used to establish boundary conditions for the two-dimensional RMA-2 model. Plate 2 shows RMA-2 model related features. The RMA-2 model was used for more detailed modeling in a limited area. The north-south extent of the model extended from just south of Tamiami Trail to about 15 miles south of the southern terminus of L-

67 Ext. The east-west extent extended from just west of S-12A to about L-31N and the 8 1/2 Square Mile Residential Area. The model boundary is also shown on Plate 3. The RMA-2 model constructed for this effort was calibrated against existing gage data in the area. The HEC-RAS hydraulic modeling was done to evaluate L-29 borrow canal stages between S-333 and S-334. The north-south model boundary starts just south of Tamiami Trail and extends northward to the L-29 borrow canal. The east-west limits are S-333 and S-334 respectively. The purpose of this effort was to determine stages in the L-29 borrow canal given stages and flow conditions immediately south of Tamiami Trail. A description of these models is found below.

6. Current Conditions. Currently stages in the L-29 Borrow Canal are artificially controlled at 7.5 ft. or below based on legal constraints imposed by the Experimental Water Delivery Program. The implementation of the Modified Water Deliveries (MWD) Project including the purchase of private lands in Northeast Shark River Slough (NESRS) and the 8.5 Square Mile mitigation plan will remove these legal constraints. Therefore the pre-project condition is artificial and does not relate to the restored condition with the project in place. Prior to the construction of the Central and Southern Florida project features, flow in the everglades was uncontrolled and stages varied greatly and at times overtopped Tamiami Trail.

7. Future Flow Conditions. The full flow for the MWD as it is presently configured is approximately 4000 cfs. A frequency analysis was performed on the expected flows to be generated for the Comprehensive Everglades Restoration Plan (CERP) AltD13R. The CERP represents the future project condition. These flows represent the SFWMM estimate using AltD13R of the overland flows from WCA-3B to NESRS; specifically the sum of the southward flows across the southern faces of the following grid cells: Row 22, Columns 22-26. These values were then sorted to determine the frequency of the events.

8. Hydrologic Models. A description of the models used is provided below.

8.1 RMA-2 was developed by Resource Management Associates of Davis, California. RMA-2 is a two dimensional, depth averaged, free-surface, finite element program for solving hydrodynamic problems. RMA-2 can be used to compute water surface elevations and flow velocities at nodes; points in a finite element mesh representing a body of water such as a rivers, harbor, or estuary. RMA-2 can perform both steady-state and transient solutions. In other words, the boundary conditions (incoming flowrate, water surface elevation) can vary with time and a solution can be found at a number of time steps. This makes it possible to model dynamic flow conditions caused by fluctuating runoff or tidal cycles. RMA-2 is not applicable to supercritical flow problems. The output from RMA-2 is written to a binary solution file. The file may contain the solution for one or more time steps depending on whether a steady-state or transient analysis is performed. The solution file can be input to SMS (Surface-Water Modeling System) for graphical display of the results. SMS is a pre- and post-processor for a two-dimensional finite element model and is specifically designed to be used in conjunction with the TABS-MD suite of programs maintained by the U.S. Army Corps of Engineers Waterways Experiment Station (WES). The TABS-MD programs will calculate water surface elevations and flow velocities for shallow water flow problems.

8.2 HEC-RAS was developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center (HEC) in Davis, California. (HEC River Analysis System) is an integrated system of software, designed for interactive use in multi-tasking, multi-user network environment. The system is comprised of a graphical user interface (GUI), separate hydraulic analysis components, data storage and management capabilities, graphics and reporting facilities. The system contains three one-dimensional hydraulic analysis components for : (1) steady flow water surface profile computations; (2) unsteady flow simulation; and (3) movable boundary sediment transport computations. A key element is that all three computations use a common geometric data representation and common geometric and hydraulic computation routines. In addition to the three hydraulic analysis components, the system contains several hydraulic design features that can be invoked once the basic water surface profiles are computed. The Steady Flow Water

Surface Profiles component of the modeling system is intended for calculating water surface profiles for steady gradually varied flow. The system cam handle a full network of channels, a dendritic system, or a single river reach. The steady flow component is capable of modeling subcritical, supercritical, and mixed flow regime water surface profiles. The basic computational procedure is based on solution of one dimensional energy equation. Energy losses are evaluated by friction (Manning's equation) and contraction/expansion (coefficient multiplied by the change in velocity head). The momentum equation is utilized in situations where the water surface profile is rapidly varied.

9. Model Features. There are a numerous structures, levees, canals, and roads that influence stages and flow paths into and within ENP.

a. The HEC-RAS model was built using the ENP transects which are approximately a mile apart (Plate 2). Additional HEC-RAS cross sections were interpolated every 1000 feet between transect lines for model stability. Steady state conditions were modeled using critical depth as the starting water surface elevation at the downstream most cross section.

b. RMA-2 grid was developed from the ENP transects plus surveys of the Residential Area, Blue Shanty Canal (Survey NO. 94-122), L-67 Ext (93-348), and L-31W (94-114). The base grid of the model is 1000 ft by 2000 ft, with the grid transitioning on the north side of the model into the culverts and bridge openings as necessary (Plate 3). The 19 culvert groups were modeled as 32 ft wide gaps in US 41 within +/- 300 ft of their actual location. Bridge openings were modeled at their actual sizes of 300 ft and 425 ft. No piers were taken into account for this model. Inflow points into the model were taken at the following structures: S-333, S-334, S-355A, and S-355B. A boundary headline (BHL) was placed along the southern end of the model. The water surface elevation for the BHL was taken from the second cross section in the HEC-RAS model. The boundary condition file (BC file) contained the 9 flow events that were established from C&SF Restudy AltD13R. To simulate steady state conditions the model was run for 50 time steps per event. These time steps were required to remove the effects of water storage in the model from previous events (steady state condition).

9.1 L-67 Extension (L-67 Ext.) extends from S-333 to approximately 11 miles due south. The levee crown ranges from elevation 13 to 15 ft. There is a borrow canal on the levee's west side from which the levee was constructed. Canal invert elevations range from about -11.0 to -3.0 ft. and canal top widths range from about 30 to 60 ft. See Plate 2 for structure and canal locations. The L-67 Extension will be removed and the adjacent borrow canal backfilled prior to completion of the Modified Water Deliveries project.

9.2. There are 19 sets of culverts under Tamiami Trail in the approximately 11 mile stretch of highway between S-333 and S-334. Each culvert set consists of one to four culverts with diameters ranging from 42-inches to 60-inches. Culvert invert elevations and lengths are typically about 4 ft. and 60 ft., respectively. Table 3 contains an inventory of the culverts compiled from data furnished by the Florida Department of Transportation (FDOT) to the U.S. Army Corps of Engineers.

9.3 Centerline elevations for Tamiami Trail in this reach range from about 10.2 ft to 12.2 ft based on data provided by FDOT. The average centerline elevation is about 10.9 ft.

9.4 West of S-333 are the S-12 structures (S-12 A,B,C, &D). These structures contribute flow to the western portion of the model from WCA No. 3A.

10. Model Assumptions. The following assumptions for the HEC-RAS and RMA-2 models were made:

10.1. Topographic Data. Cross-Sections 1&2 are survey lines south of Tamiami Trail in the ENP were used in the HEC-RAS model. These transects (x,y,z) were obtained from a 1981 survey by the ENP. Cross section 3 is line 1 modified by adding 50 ft. sumps in downstream (south) of the culverts for getaway. This is based on drawings provided by FDOT for the Tamiami Trail. Cross-Section 4 is generated by HEC-RAS based on information for Cross-sections 3 and 6 and data entered in the bridge/culvert editor. The road bed is based on the centerline survey information provided by FDOT. Cross-Section 6 is based on as-builts for the L-29 Borrow Canal enlargement August 1975.

10.2 Culverts. Culvert data was furnished by FDOT. There are 19 sets of culverts under Tamiami Trail between FDOT stations 732+10.0 and 1298+5.0 (S-333 to S-334) with each group having between 1 & 4 barrels (55 total barrels). Due to the limited capacity of HEC-RAS, 5 separate Culvert Groups were formed. Each Culvert Group was based on a common diameter and near common length. The HEC-RAS input used a mean length, mean invert upstream, and mean invert downstream. (An exception to this was Culvert Group 1 which contains eleven 54-inch diameter barrels and three 60-inch barrels, mixed diameters). All 55 barrels are accounted for in this manner.

10.3 Tamiami Trail. The Tamiami Trail centerline is input in accordance with its survey data by FDOT. The HEC-RAS model treats U.S. Highway 41 as a broad crested weir with a non-uniform crest elevation (actual centerline).

10.4. Manning's Roughness Coefficient. Part VI General Studies and Reports Section 7 – Design Memorandum, Interim Report on Evaluation Of Manning's n In Vegetated Areas, April 1954 was used in the determination of a Manning's n-value. In this report three flow tests were performed in Water Conservation Area 2 during high water conditions of October and November 1953 to determine an appropriate Manning's roughness coefficient ("n"). This information was used for this study based on the similarity of vegetative cover south of Tamiami Trail and WCA No. 2. A value of 0.325 was used for the Manning's n-value for the HEC-RAS model. RMA-2 model allows for a depth averaged n-value which was computed by fitting the RMA-2 curve through the data from the flow tests. Fixed values for the n-value were assumed through the canal (0.035), culvert and bridge locations (0.025), at the sumps for these openings (0.125), and for the vegetative barrier south of the road (0.75). For a sensitivity analysis for the HEC-RAS model, water surface elevations were computed along the south side of US 41 for a range of Manning's n-value. Critical depth was used as the downstream boundary condition of the model.

10.5 Water Surfaces: The RMA-2 model described above was calibrated to known water surfaces and flow rates at gages. The RMA-2 model then was given a variety of flowrates to determine associated water levels. For the HEC-RAS model the starting water surface south of Tamiami Trail were obtained the RMA-2 model shown in Plate 3. The HEC-RAS model starts approximately 5000 ft. south of Tamiami Trail in ENP and extends northward to the L-29 Borrow Canal. The water levels determined from the RMA-2 model were then used as a starting point for the HEC-RAS model to determine the effects on Tamiami Trail. Four different models were developed for this effort. The models were as follows:

(1) HEC-RAS for existing conditions
(2) RMA-2 for existing conditions
(3) HEC-RAS with four new bridges (proposed)
(4) RMA-2 with four new bridges (proposed)

Below is a description of the specific models.

(1) HEC-RAS for existing conditions. This model started at critical depth near the 8.5 square mile area. The RAS model then backwatered up to Tamiami Trail and used the RAS culvert routines to determine the L-29 BC stage under the 9 flow events. Due to limitation in the number of culverts permitted in HEC-RAS, the culverts were grouped to handle them.

(2) RMA-2 existing conditions. This model started with the calculated water surface at the second cross-section in the HEC-RAS model described above. The RMA-2 model stopped just downstream of Tamiami Trail. These water surfaces were then used as the tailwaters and a standard culvert rating was done to determine the L-29 BC stage.

(3) HEC-RAS with four bridges. This model removed the groups of culverts and replaced them with the four proposed bridges. The HEC-RAS bridge routines were used to determine the L-29 BC stage.

(4) RMA-2 with four bridges. The RMA-2 model had four gaps added to simulate the bridge openings. Due to the very low velocities seen in the model, it is not expected that the proposed bridge piers will introduce head loss.

11. Model Results. The table below contains the results of the HEC-RAS and RMA-2 models with Tamiami Trail in its existing condition.

Existing Conditions

		L-29 Borrow Canal Stage	
Event	Flow (cfs)	HEC-RAS	RMA-2
1-yr	597	7.17	7.32
2-yr	1600	7.87	8.02
5-yr	2250	8.23	8.40
10-yr	2700	8.53	8.70
20-yr	3150	8.78	8.90
50-yr	3770	9.13	9.30
100-yr	4270	9.41	9.60
200-yr	4800	9.73	9.90
500-yr	5550	10.19	10.30

A graphical representation of the existing conditions is shown on the attached Figure 1.

11.1 Based on MWD Plan the existing culverts are unable to pass the desired flows. The backwater analysis from HEC-RAS shows the downstream constraint on the culverts being at 9.01 ft (9.05 ft RMA-2) for a flow of 5000 cfs. Based on a rating discharge for all the culverts with the tailwater at 8.90 ft the discharge would be 2805 cfs and a stage of 9.2 ft in L-29 BC. This analysis does not take into effect the thick stand of exotic vegetation growing along the south side of US 41 which ponds water along the road.

12. Alternatives. A group of alternatives were then developed which would permit larger flows to cross Tamiami Trail southward into Everglades National Park. As part of this study, four bridges strategically placed in Tamiami Trail to evaluate the effects of greater conveyance. The four proposed bridges were added to the HEC-RAS and RMA-2 models and the L-29 Borrow Canal then calculated. Models 3 and 4 described above were used for this analysis. This additional conveyance should be included as part of the alternatives.

13. Bridge Description. To allow for the larger discharges and minimize the head loss across the road four additional bridge openings were designed. These bridges were designed to pass the required discharge (a total of 5000 cfs) with a tenth of a foot head loss and assuming a Manning's roughness coefficient of 0.84 (representing the thick stand of exotic vegetation immediately downstream of the road). Two of the bridges were designed at 300 ft to pass 1000 cfs each from both S-355A and S-355B and are located immediately south of each structure. The other two bridges were designed at 425 ft to pass 1500 cfs each with a tenth of a foot head loss. The two larger bridges will be placed 1 to 3 miles east and west of S-333 and S-334, respectively. These

locations were selected based on visual observations and proximity to the outlet structures. The existing culverts were not considered in this design. The bridges used in the model are similar to those used over Taylor Slough (C-111 Project) to avoid larger "humps" along Tamiami Trail. These additional bridges will permit lower stages to be maintained in the L-29 BC, reducing the amount of base material that may be submerged from this side of the road while passing the flows.

With Bridges In Place

Event	Flow (cfs)	L-29 Borrow Canal Stage HEC-RAS	L-29 Borrow Canal Stage RMA-2
1-yr	597	7.15	7.30
2-yr	1600	7.77	7.92
5-yr	2250	8.04	8.22
10-yr	2700	8.29	8.44
20-yr	3150	8.45	8.60
50-yr	3770	8.64	8.79
100-yr	4270	8.80	8.95
200-yr	4800	8.96	9.10
500-yr	5550	9.18	9.30

A graphical representation of with project conditions is shown on the attached Figure 2 .

14. Conclusions. The HEC-RAS and RMA-2 models are in good agreement. Under existing conditions, as determined by the hydraulic models, water levels in the L-29 Borrow Canal can get as high as 10.96 ft., NGVD. Based on the centerline profile of Tamiami Trail provided by FDOT, water will be in the subgrade for flows greater than 4000 cfs. For flows greater than 5000 cfs, water begins to overtop the road at several low spots. Modifications to the existing Tamiami Trail should be investigated to permit additional conveyance to the south. The hydraulic models reveal that adding four additional bridges will save significant headloss through the Tamiami Trail and should be considered as part of the alternatives.