THE LAKE SEMINOLE WATERSHED MANAGEMENT PLAN: EVALUATION OF QUANTITY AND QUALITY OBJECTIVES

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ABSTRACT

Once estuarine tidal flats, Lake Seminole was created in the 1940's by impoundment of an upper portion of Long Bayou. Lake Seminole has been used extensively throughout its existence for recreational purposes including skiing, boating, and fishing, as well as passive recreation. Recreational use, however, has declined in recent years as fishing, water clarity, and water appearance have all declined.

As a part of an overall management plan being developed for the lake and watershed by Pinellas County and the Southwest Florida Water Management District, a digital watershed and water body management model was developed using EPA's SWMM and WASP software. SWMM was used to address both water quantity and quality issues within the Lake Seminole Watershed. Water quality within Lake Seminole was then modeled using the water body model WASP. Due to the intrinsic differences between water quantity and water quality model simulations, and the different objectives of each model, two separate SWMM models were developed. A water quantity SWMM model addressed flooding and a water quality SWMM model provided pollutant loads to WASP.

Calibration was performed on the SWMM and WASP models using rainfall, runoff, and quality data collected in the field. The water quantity calibration was completed first in order to quantify the hydrologic and hydraulic characteristics of the watershed, which was followed by the water quality analyses. Although separate, the two models are similar in that the water quality SW'MM model essentially provides the hydrological loads for each water quality simulation. This interrelationship is discussed, and how it related to the development of the Lake Seminole Watershed Master Plan.

INTRODUCTION

The Lake Seminole Watershed encompasses approximately 1416 hectares (3,500 ac) of land within unincorporated Pinellas County and the incorporated cites of Largo and Seminole, and is almost entirely developed with urban land uses. The watershed was historically much larger than its current extent, however the limits of the watershed were altered in the early 1970s following construction of the Lake Seminole Bypass Canal for flood relief. The canal diverts the runoff from

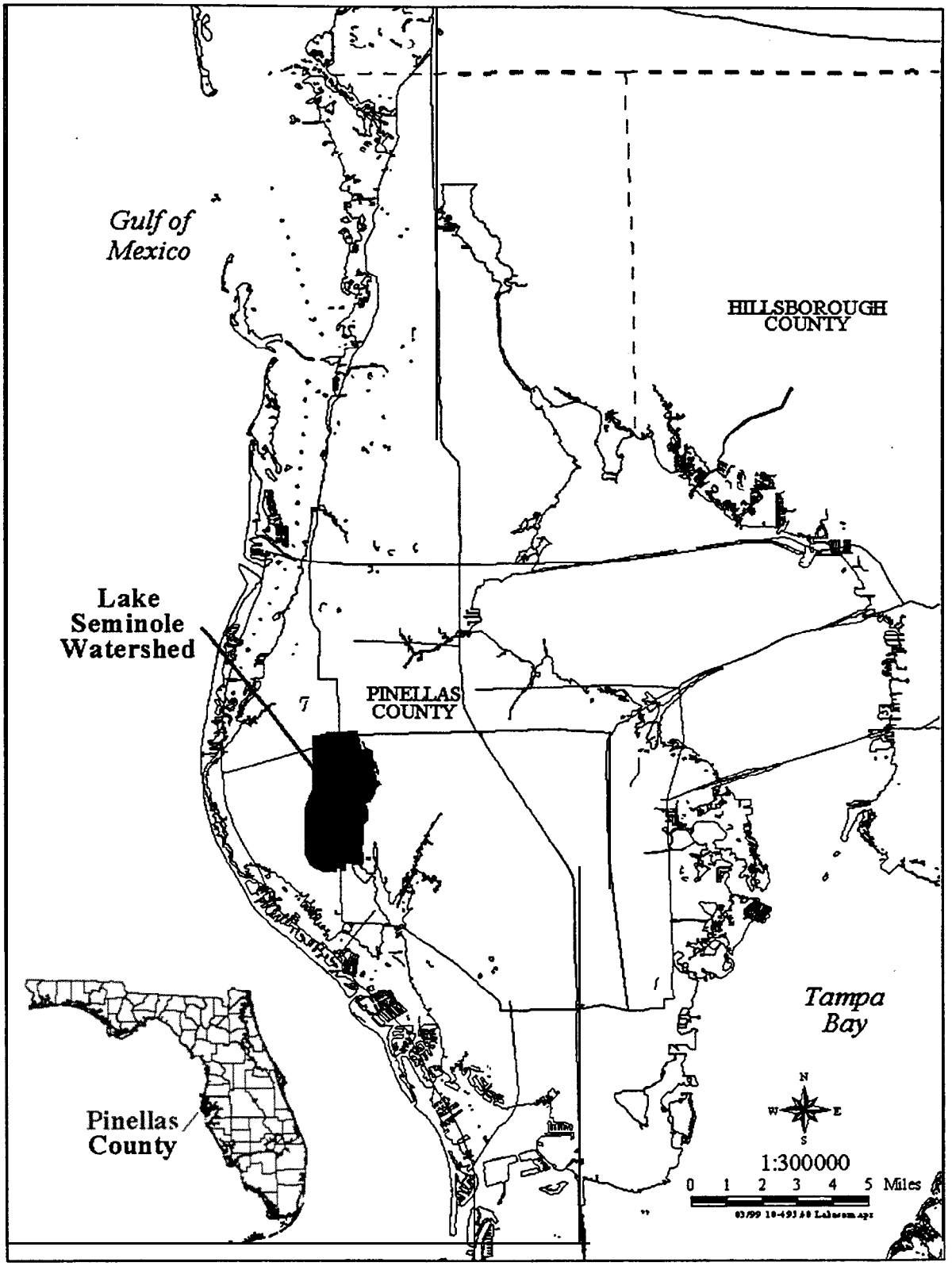

Figure 1 Lake Seminole watershed location map.

a large portion of the historical drainage area north and east of the lake, and discharges directly into Long Bayou through a separate structure along Park Boulevard east of Lake Seminole County Park.

Lake Seminole has a relatively small watershed area in relationship to total lake volume. This suggests that less storm water runoff is delivered to the lake per unit volume than for some other local lakes. Less lake water is replaced by runoff during a storm event, therefore, and the residence time for water within the lake is longer than if a larger drainage area contributed runoff. Long residence times may increase the potential for algae blooms and other symptoms of eutrophication (nutrient over enrichment). However, a smaller contributing drainage area also means that pollutant loading from nonpoint sources is likely lower than for large watersheds. Lower loadings can reduce the potential for eutrophication, and prove beneficial to the lake.

Unfortunately, the Lake Seminole Watershed appears to possess conditions that may foster eutrophication. The small drainage area allows a relatively small amount of runoff to enter the lake, thus increasing residence time. However, the highly urbanized drainage area produces runoff with relatively high concentrations of nutrients, metals, and other pollutants, thus enhancing the potential for water quality problems.

Pinellas County authorized PBS&J in late 1996 to assist in the preparation of the Lake Seminole Watershed Management Plan (LSWMP). The LSWMP is to be a comprehensive guide to managing the lake, and will include provisions for habitat protection and enhancement, water quality and flood protection and improvement, recreational opportunities, and aesthetic enhancement. As apart of this plan, the Lake Seminole Watershed Management Model (LSMM) was developed. This model was comprised of two separate but related components outlined below.

- Water quantity simulations were made using EPA's SWMM version 4.3 software. Hydrologic and hydraulic simulations for both the watershed and the lake itself were performed using the RUNOFF and EXTRAN computational blocks of SWMM.
  Water quality simulations provided non-point source pollutant loading estimates to the lake using the RUNOFF computational block of SWMM. These non-point source loads were then routed to Lake Seminole via the TRANSPORT computational block of SWMM. Water quality within Lake Seminole was then simulated using the DYNHAD and EUTERO subroutines of WASP version 4.0 software. The TRANSPORT block of SWMM and WASP water body model are currently under development. and are not discussed in this submittal.

Both the water quantity and water quality SWMM RUNOFF blocks were calibrated with respect to measured rainfall, stage. flow. and pollutant concentration data obtained from five sampling locations within the Lake Seminole Watershed during late 1997. Rainfall, stage, and flow data were used to develop stage-discharge relationships at the sampling sites, and to construct runoff hydrographs for each recorded storm event. Modifications were made to the input parameters of the water quantity portions of the LSMM to bring predicted stage and flow values at each sample location into closer agreement with recorded values for three calibration storm events recorded in late 1997. These calibrated hydrologic input data were then also used as input for water quality simulations. Laboratory analysis of flow-weighted water quality samples were used to develop Event Mean Concentrations (EMC's) for the following parameters: Total Nitrogen, Total Phosphorous, Total Suspended Solids, and BOD. Modifications were made to the input parameters

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of the water quality portions of the LSMM to bring predicted pollutant loading values at each sample location into closer agreement with laboratory results of water quality samples collected during three calibration storm events recorded in late 1997.

Results of surface water quantity simulations of the LSMM were used to predict flow rates and stages within the watershed during design storm simulations. The goal of the water quantity simulations conducted using the LSMM was to identify existing and potential future flood prone areas within the Lake Seminole Watershed. Water quantity simulations for the 100-year 24-hour, 25-year 24-hour, and 25-year 6-hour storm events under existing and future land use conditions were developed to predict flooding potential in the Lake Seminole Watershed under existing and projected ultimate build-out land use scenario.

Results of surface water quality simulations of the LSMM were used to predict non-point source loadings to Lake Seminole during three separate year-long continuous simulations. Water quantity simulations for an "average", "wet", and "dry" rainfall year under existing and future land use conditions were developed to predict pollutant loadings to Lake Seminole from the surrounding watershed under existing and projected ultimate build-out land use scenario.

Based on these modeling results, alternatives can be developed to manage existing water pollution problems, and potential flood problems. Ultimately the LSMM will be used to predict the effects of various lake management actions on water quality, living resources, and flood control.

MATERIALS AND METHODS

Many models are readily available for simulating surface water flow and flood water elevations. Pinellas County, however, requested that SWMM be used to conduct the floodplain analysis and watershed water quality simulations. Surface water runoff flows and pollutant loads were generated and routed through several subroutines of the SWMM model. Rainfall and watershed characteristic data were input into the RUNOFF block of SWMM, which computed runoff hydrographs for each subbasin. These hydrographs were written to an interface file, which allowed data transfer to other SWMM computational blocks, including EXTRAN and TRANSPORT. EXTRAN was used in water quantity simulations to estimate design storm flows and levels, and TRANSPORT was used in the water quality simulations to deliver pollutant loads to the WASP water body model. TRANSPORT and WASP model components are still under development, and not included in the discussion below.

RUNOFF Block Input Parameters

Watershed boundaries, basins, and subbasins were delineated using SWFWMD topographic aerials, aerials from the Pinellas County Property Appraiser's office, SWFWMD and Pinellas County Geographic Information System (GIS) data files, the Pinellas County Master Drainage Plan (Pinellas County, 198 1), field data and reconnaissance, and other data as noted. A total of 2 14 subbasins were identified. Subbasins represent the smallest spatial unit delineated considering land use, drainage infrastructure, and topography. These subbasins were aggregated into twelve (12) basins, which were delineated by encompassing all subbasins contributing flow to the same major drainage

system with a single outfall to the lake. In areas where there was no major drainage system with a common outfall, basins were constructed of adjoining subbasins that discharged directly into Lake Seminole in the same vicinity (Figure 2).

Existing land use within the Lake Seminole Watershed consists primarily of developed urban land. A large percentage of the watershed is residential, with little undeveloped land. However, small areas of agricultural, public, recreational, industrial, and other land uses are scattered throughout the watershed. In addition, several conservation and preservation areas are located around or in close proximity to the lake. Because the watershed is nearly built out, the variety of land uses within the watershed is consistent for both existing and future conditions. Land use coverage within the watershed for existing conditions was obtained through the Pinellas County Geographic Information System (GIS) data base from the Property Appraiser's office. These data were aggregated into one of the eighteen land use categories used to develop model input parameters. In addition, water and road coverage by subbasin were tabulated from the GIS data, although no formal category was assigned to these coverages by Pinellas County. Land use coverage within the watershed for future conditions was obtained through the Pinellas County Geographic Information System (GIS) data base from the Planning Department.

Soil types within the limits of the watershed were determined using the USDA Soil Conservation Service (SCS) Soil Survey of Pinellas County (USDA, 1972). Each of the four soil hydrological groups (HSG) "A", "B", "C", and "D" are represented in the various soil types. HSG "A" typically generates the least runoff per unit rainfall and is often associated with soils having a high sand content and low water table. HSG "D" soils generate the most runoff per unit rainfall and are often associated with soils with higher organic content and a high water table. The limits of each soil hydrologic group as reflected by soil type was determined by subbasin.

RUNOFF can also generate pollutant loads based on watershed characteristics, and this procedure was used during the water quality simulations. The "Rating Curve Method" was used for water quality simulations, which uses a single Event Mean Concentration (EMC) for pollutants. This results in pollutant concentrations which do not vary with flow. Initial EMC values were based on literature values by land use type. Final values were determined from the results of the calibration of the water quality portions of the LSMM.

EXTRAN Block Input Parameters

The water quantity portion of the LSMM included EXTRAN blocks for eight of the 12 basins, and the lake itself to route nmoff. Each separate routine read an interface file generated by the RUNOFF block for each storm event simulation. Each interface file contained the simulated runoff data for each subbasin and design storm by load point. EXTRAN was used to route the runoff through the simulated drainage network. Lake Seminole itself was also modeled using EXTRAN in order to determine floodplain boundaries around the lake. The four basins (4, 10, 11, and 12) that were not modeled using EXTRAN either lacked a well-defined conveyance system, had a direct discharge to Lake Seminole, or were too small to be appropriate for proper EXTRAN routing. Surface water runoff from these basins was simulated within the RUNOFF block and discharged directly to Lake Seminole. Only the major conveyance features within each of the basins selected

for routing were modeled using the EXTRAN block. Extreme upper reaches within the basins may contain smaller closed conduit, open channel, and pond systems which were not coded into the EXTRAN block input. As stated above, the major drainage systems were followed upstream into the basins until pipe sizes of less than 24" in diameter, or equivalent were encountered.

Floodplain geometry, storage element and preliminary drainage network information was taken from SWFWMD contour maps, FDOT design plans, and previous studies performed within the watershed. Additional field survey data of major channel reaches, pond outfall structures, and other drainage structures and invert elevations within the drainage network were collected by PBS&J from August through October of 1997. These data provided the basis for the detailed drainage system characterization of the Lake Seminole Watershed. Survey data were collected from the Lake Seminole outfall of each basin upstream to the cutoff point. The cutoff point was defined by the County as the upstream limit of pipes having a 24-inch or greater diameter and was upstream extent of the EXTRAN Block domain.

EPA SWMM Model Constraints

EPA distributes the public domain version of SWMM version 4.30, which has a limit on the maximum number of nodes, reaches, storage junctions, weirs, and several other parameters which may be modeled in a single simulation. This dictated that separate models be compiled for each of the basins, and the lake itself. Since the Lake Seminole model was not dynamically linked to the basin models, an iterative approach was utilized to determine the 100-year & 25-year/24-hour flood stages within the lake. RUNOFF and EXTRAN block output files generated by preliminary runs were reviewed, and flows generated by each of the basin models were determined for each design storm simulation. A spreadsheet was then used to combine all twelve (12) separate hydrographs from the output file for each basin into a single combined time series of flows for the 100 & 25-year/24-hour design storm simulations. Discharge into the lake resulting from rainfall excess over all basins was obtained from the EXTRAN output files for those listed above, or RUNOFF block output files for the non-routed basins. These individual hydrographs were summed, and entered in EXTRAN as a user-input hydrograph. This hydrograph was then combined by EXTRAN with the hydrograph contained on the RUNOFF block interface file calculated by each of the design storm simulations for the lake. A user-input hydrograph option then allowed this single time series of flows to be coded directly into the EXTRAN data input file (K3 cards) for the 100-year and 25-year 24-hour design storm runs for Lake Seminole. EXTRAN automatically combined these user-input hydrographs with the hydrograph contained on the interface file calculated by each of the design storm RUNOFF block simulations for the lake.

RESULTS

Calibration for the SWMM surface water quantity and quality models was accomplished using rainfall volumes and distributions measured during three storm events at five separate storm water monitoring stations established within basins 1, 2, 3, 6, and 7 of the Lake Seminole Watershed

during 1997. Model results were then compared to the measured runoff responses. RUNOFF block input parameters including basin width, DCIA, impervious "n" and pervious "n", were then adjusted to bring measured and modeled runoff peak stages and flow rates into closer agreement. Once the water quantity portions of the LSMM were calibrated, pollutant loading input parameters were adjusted to more closely align the simulated loadings to match laboratory results from storm water samples.

At each of the 5 monitoring stations, rainfall, runoff stage, and velocity data were collected through manual measurements and/or automated storm water sampling equipment. All monitoring stations were established in locations which would sample a significant portion of each basin, while remaining up-stream of any tailwater influences. In addition, storm water samples were collected at each monitoring station for use in water quality calibration simulations.

Three storm events recorded in late 1997 were selected for model calibration and verification purposes. Selection criteria required the following storm characteristics: 1) an isolated event, 2) a typical rainfall distribution, and 3) a typical hydrograph shape and runoff response. Rainfall hyetographs were developed from digital data recorded during each storm. Incremental values of rainfall were used to generate the storm record, and were input into the SWMM runoff blocks for each of the five basins containing the monitoring stations. A September 27, 1997 storm totaled approximately 3.8 1 cm (1.5 in) of rainfall over a two-hour period. Although this was a relatively large storm, which was relatively evenly distributed over the watershed and met the above three criteria. An October 17, 1997 storm totaled approximately 1.27 cm (0.5 in) of rainfall over a two-hour period. Although this was not a large storm, it was relatively evenly distributed over the watershed and met the above three criteria. A November 29, 1997 storm event totaled approximately .89 cm (0.35 in) of rainfall over a two-hour period. Although this was another relatively small storm, which displayed some variation in total rainfall distribution over the watershed, it met the remaining above criteria.

Simulated stage and flow data at the conduits and junctions corresponding to monitoring station locations in the SWMM model were then computed. Subbasin parameters in the SWMM RUNOFF Block were adjusted in an iterative process to achieve the best fit between the recorded and simulated stage and flow data. Because the majority of the parameters that were initially used in the RUNOFF Block were based on default or standard values, the parameters used in the modeling do not always reflect the conditions within each subbasin. Adjustments made during calibration were relatively minimal, with the result of the model closely approximating the measured data. Calibration runs utilized both the EXTRAN and RUNOFF Blocks of SWMM.

Modeled estimates of peak stage and flow for the five sampled basins were compared to measured values for the three storms. Deviations from maximum measured depths at the five calibration stations averaged approximately -5%, approximately -8% for peak flow, and approximately 4% for total flow. Modeled estimates of pollutant loads were then compared to laboratory results of storm water samples collected during the three storms. Following several iterations, the average deviations from measured EMC values for Total Phosphorous, Total Nitrogen, and Total Suspended Solids were also reduced as much as possible. Using these calibrated RUNOFF blocks, design storm event simulations were then performed with the water quantity portion of the LSMM to determine the extent of floodplains within the watershed, and year-long

continuous simulations were performed with the water quality portion of the LSMM to determine annual pollutant loadings to Lake Seminole.

DISCUSSION AND CONCLUSIONS

Following the successful calibration of the revised LSMM, design storm simulations were run for existing and future land use conditions for the 25-year 24-hour, and 100-year 24-hour design storms. Peak flood elevations predicted by EXTRAN were then used to identify areas of existing or potential flooding problems within the Lake Seminole Watershed. Potential flooding problem areas were also identified by running the calibrated model for future conditions. For both existing and future conditions, flooding was primarily restricted to minor street flooding, pond and lake overtopping and junction surcharging. No major flood problems were identified and simulated 25-year and 100-year floodplains were virtually unchanged for the existing and future land use conditions.

Non-point source pollutant loading estimates from the watershed were ranked by constituent and basin to determine the most significant loads to Lake Seminole during the three separate year-long water quality continuous simulations. Land use within the watershed is predominantly urbanized, with a relatively homogeneous mix of land uses. Not surprisingly, therefore, the largest TP, TN, TSS and BOD loads came from the basins with the largest areas, and were ranked in the same order. This may indicate that the best locations for BMP's and/or storm water retrofit projects are at locations near the main drainage network which covey runoff from the largest upstream areas possible. An analysis of such locations will be performed upon completion of the water quality model, which includes the WASP water body model.

Summarized below are several of the many lessons encountered so far during the completion of this study using the above described approaches:

Since SWMM 3.0 was to be used as it is available directly from the EPA for this project, maximum model array sizes for model parameters such as number of basins, noted and junctions prevented the entire watershed and lake to be modeled as one. Individual basins were therefore run separately, and only adjacent basins with intermingled flood flows were modeled together. In order to obtain tailwater elevations for each of the modeled drainage networks dumping into Lake Seminole, as well as a floodplain elevation of the lake itself, all flows from the basin watershed models were summed in a spreadsheet. This hydrograph was then entered into an EXTRAN model of the lake as a user-input hydrograph as described above. Since this process required two separate runs with an intermediate spreadsheet summation step during each step, substantial effort was required to generate a complete a water quantity simulation for a given storm event. Limiting model detail or using a modified version of the SWMM code could have prevented this effort required during the water quantity simulations.

Land use input parameters developed for the RUNOFF block water quantity simulations were based on Pinellas County classifications, and totaled 18. Separate basin input parameters were

assigned to each land use category, and ultimately used to calibrate the water quantity simulations by bringing predicted calibration hydrographs into agreement with hydrographs recorded during the three calibration storm events. Although more land uses provided a greater number of possible model input parameter variations, any gains achieved in obtaining in a more accurate and precise calibration ended up costing a price in terms of effort keeping track of 18 land uses during manipulation of the input data set and QC, and this should be considered.

- Three calibration storms were recorded, during which both water quantity and quality data were collected for calibration of both of these aspects of the LSMM. Field work involved in collecting data for these calibration events was focused on recording both water quantity and quality data during the same events. Since water quality parameters included grab samples which must be collected during the rising limb of the hydrograph, many events were not monitored where these water quality samples were not collected at the front end. In retrospect, more focus could have been placed on obtaining good stage-discharge relationships at each of the monitoring stations as a first priority, prior to attempting to obtain good water quality samples.

ACKNOWLEDGMENTS

Policy 3.1.4 of the Conservation Element within the Pinellas County Comprehensive Plan calls for the systematic development of watershed and water body-specific management plans for all major drainage basins in the County. Pursuant to that policy, in June of 1992 a preliminary diagnostic feasibility study was prepared for the County and the Southwest Florida Water Management District (SWFWMD, 1992).

Since 1992, Pinellas County has sponsored the Lake Seminole Advisory Committee (LSAC), which meets periodically to provide input from local governments, citizens, and businesses owners for management of the lake. As part of the County's on-going work to develop comprehensive management plans for all significant basins within their jurisdiction, the County authorized Coastal Environmental, Inc. (now PBS&J, Inc.) in late 1996 to assist in the preparation of the Lake Seminole Watershed Management Plan (LSWMP). The LSWMP is to be a comprehensive guide to managing the lake, and will include provisions for habitat protection and enhancement, water quality and flood protection and improvement. recreational opportunities, and aesthetic enhancement.

The authors would like to like to thank David Talhouk, and the entire Pinellas County Engineering Staff, as well as the SWFWMD for the opportunity to participate in development of the LSWMP.

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