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LITTLE LAKE JACKSON STORMWATER RUNOFF ANALYSES

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ABSTRACT

Little Lake Jackson is located in Highlands County in the southern portion of the City of Sebring. Recurring algal blooms and accompanying poor water clarity in Little Lake Jackson prompted a diagnostic feasibility study of the lake, which was funded jointly by the Peace River Basin Board of the Southwest Florida Water Management District, Highlands County, **and** the City of Sebring. **As** part of this study, an analyses of surface water runoff was completed. Most surface water runoff enters Little Lake Jackson through the primary inflow drainage canal located in Sub-basin 1. The most intensive sampling was performed at the mouth of this inflow. At this site concentrations of orthophosphorus, total phosphorus, and ammonium were significantly greater within storm event samples than within base flow samples (α=0.003,0.007, and 0.02, respectively, Wilcoxon-Mann-Whitney rank-sum test). Significant correlations (Spearman correlation) were observed between discharge (log transformed) and the following nutrient concentrations (log transformed): discharge and orthophosphorus rho=0.855, p=0.001, n=14; discharge and total phosphorus rho=0.893, p=0.001,n=14, discharge and ammonium rho=0.828, p=0.001,n=14. Concentrations of orthophosphorus, total phosphorus, ammonium, and total nitrogen measured within the primary inflow were unusually high during one of the largest storm events (occurred on 10-08-96). Concentrations during this particular storm event appear to be primarily associated with fertilizer application within the Sebring Municipal Golf Course. Approximately five tons of fertilizer were applied to the City golf course, one day prior to the storm event.

INTRODUCTION

Little Lake Jackson is located in Highlands County in the southern portion of the City of Sebring (Figure 1). The lake which comprises only 156 acres, is small in comparison to its drainage basin or watershed which comprises approximately 1048 acres.

Water Quality

Little Lake Jackson is a moderately eutrophic lake. The mean concentrations for total nitrogen, total phosphorus, and chlorophyll a measured during the study period were **1.29** mg/L, 0.029 **mg/L**, and 30.5 ug/L, respectively. The mean FTSI value was 54.6, Both the mean and median N:P ratio

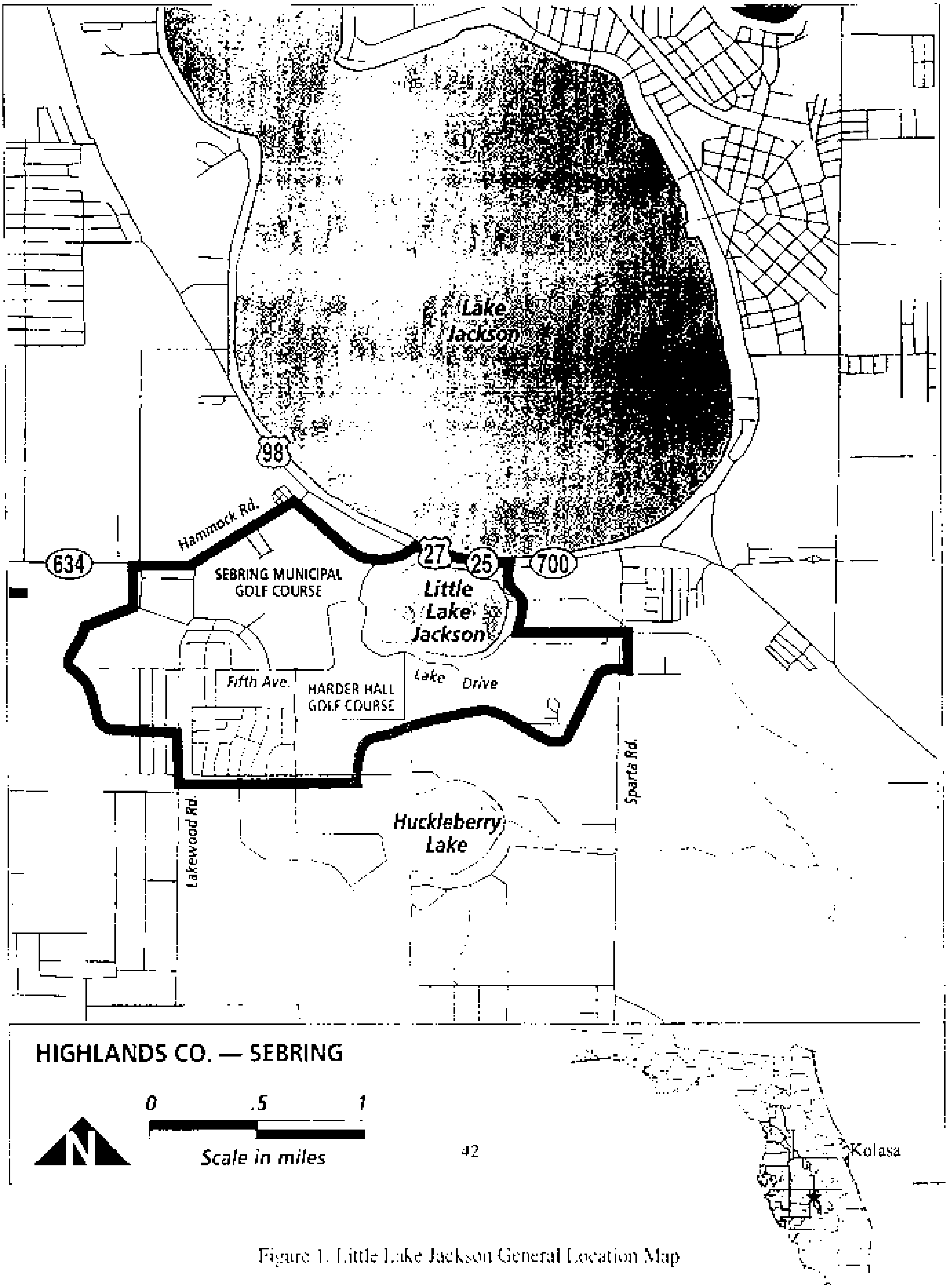


Figure 1. Little Lake Jackson General Location Map

indicated that the lake was phosphorus limited (126 and 50, respectively). Although Little Lake Jackson has average water quality when compared to many other lakes throughout Florida (FDEP database, Freidemann and Hand 1989), Little Lake Jackson has poorer water quality than most lakes in Highlands County.

Recurring algal blooms and accompanying poor water clarity in Little Lake Jackson have raised concerns from lake front homeowners and Sebring citizens for the past decade. Questions emerged regarding the possible degradation of water quality of the lake. Although recent water quality data were available, the long term historical condition of the lake was not known since little historical data were available. With intentions of finding solutions to the recurring problems within the lake and evaluating possible shifts in water quality, a diagnostic feasibility study was nominated by the Highlands County Board of County Commissioners and the City Council of Sebring as a cooperative funding project to the Peace River Basin Board of the Southwest Florida Water Management District. The study began in October 1995 and ended in October 1997. The study included **an** assessment of the lake, as well as its watershed. This paper presents the findings of the runoff assessment, which was one of the components of the watershed assessment.

Historical Changes

A comparison of 1952, 1974, and 1993 Soil Conservation Service (SCS)(available from the National Archives) aerial photographs for this region, revealed that the Little Lake Jackson watershed has changed dramatically over the last 50 years. The watershed which was mostly open land during the 1950's, has been almost completely developed as residential and recreational land uses (golf courses). Most of the drainage ditches and residential canals were constructed within the watershed during the 1960's and early 1970's. House construction progressed most rapidly during the late 1960's, 1970's, and 1980's. Numerous ponds were constructed during the construction of two golf courses during the early 1980's. Several unaltered depression wetlands, possibly cut-throat seeps, which are evident within 1950's aerial photographs are no longer evident within the aerial photos of the 1980's.

Current Land Use

The Little Lake Jackson drainage basin comprises approximately 1084 acres. Most of the watershed has been developed as residential or recreational land uses, which respectively comprise approximately 63% and **2**1% of the entire surrounding watershed. Although the watershed has been extensively altered, an overall park-like setting has been created within this community as the result of its numerous recreational facilities, which include three golf courses and a community ball park. Many of the residential yards within the western portion of the watershed remain forested with large longleaf pine trees and other native plants remnant of the original plant communities of this region. In addition, a significant portion of the watershed has remained undeveloped. Approximately 10.5 % of the watershed is collectively comprised of pine flatwoods, shrub and brushland, upland coniferous, and open urban land.

Land Use Types

Three separate drainage sub-basins were defined within this watershed during the study (Figure 2). Sub-basin 1 and 2 have similar land uses. Both are dominated by residential and recreational land uses (Table 1)(59.5 % residential and 25.2 % recreational within Sub-basin 1, and **69.7** % residential and **29.3** % recreational within Sub-basin 2). Land use within Sub-basin 3 was somewhat different. Although residential development comprised 61.5% of Sub-basin 3, recreational land-use was absent from this sub-basin. In addition, several land uses were specific to Sub-basin 3. These include cropland and pasture, citrus crops, transportation land, and coniferous uplands. Additionally, this sub-basin contains the largest area of commercial property.

Soil Types

Soil types within the Little Lake Jackson watershed primarily include the Satellite-Basinger-Urban Land Complex and the Basinger, St. Johns, and Placid Complex, which respectively comprise 50 % and 29% of the soils within the watershed. These two dominant soil types are described as ranging from somewhat poorly drained to very poorly drained (SCS 1989). According to the **SCS** (1989) the Basinger, St. Johns, Placid complex is found in lower areas of the ridge containing seeps, locally known as cutthroat seeps. **As** a result of their wetness, limitations occur for development within regions containing these soils. These include limitations for urban construction, and moderate to severe limitations for cultivated crops, citrus crops, and pasture crops. Installation of a proper drainage system is recommended to increase agriculture **and** urban development potential. In addition, septic field mounding is recommended for septic installation within these areas, since severe wetness inhibits absorption and filtering capabilities.

Surface Water Drainage within Sub-Basins

The primary surface water inflow to Little Lake Jackson is located in Sub-basin 1, the largest sub-basin (497 acres), where a system of drainage ditches and canals converge and enter the western side of the lake through one main inflow canal (Figure 2). Unlike Sub-basin 1, there are no deep drainage canals or ditches located within Sub-basin 2 and Sub-basin 3. Runoff within Sub-basin 2 and sub-basin 3 primarily occurs as sheet flow which is conveyed through shallow swales. Continuous flow was observed through the main inflow canal within Sub-basin 1, as the result of the shallow water table within this watershed. Continuous flow was also observed within one of the upstream ditches which was excavated at a greater depth (approximately 12 feet total depth) than other ditches in this region,

Since most surface water drainage occurs within Sub-basin 1, stormwater sampling analyses were primarily limited to this basin. This study reports the findings of the stormwater analyses performed within Sub-basin 1.

METHODS AND MATERIALS

Location

Although two other locations were sampled within the upstream reaches of the primary inflow ditch located within Sub-basin 1, the results discussed within this report will be limited to the station closest to lake (Station 1 - primary inflow station, Figure **2).** This station was located at the drop-pipe structure just west of Golf View Road, approximately 300 feet upstream of the lake. This structure retains water at **an** elevation higher than that of the lake, prior to discharge. During the study (1995-1997) the lake elevation ranged from **0.55** feet to 3.81 feet below the structure. Pollutant concentrations measured at this appear to represent final pollutant concentrations entering the lake through this drainage system. Nutrient concentrations measured at this station will be used for determining nutrient loads entering the lake through the primary inflow (see Sub-basin 1 - Nutrient Load Analyses).

Rainfall

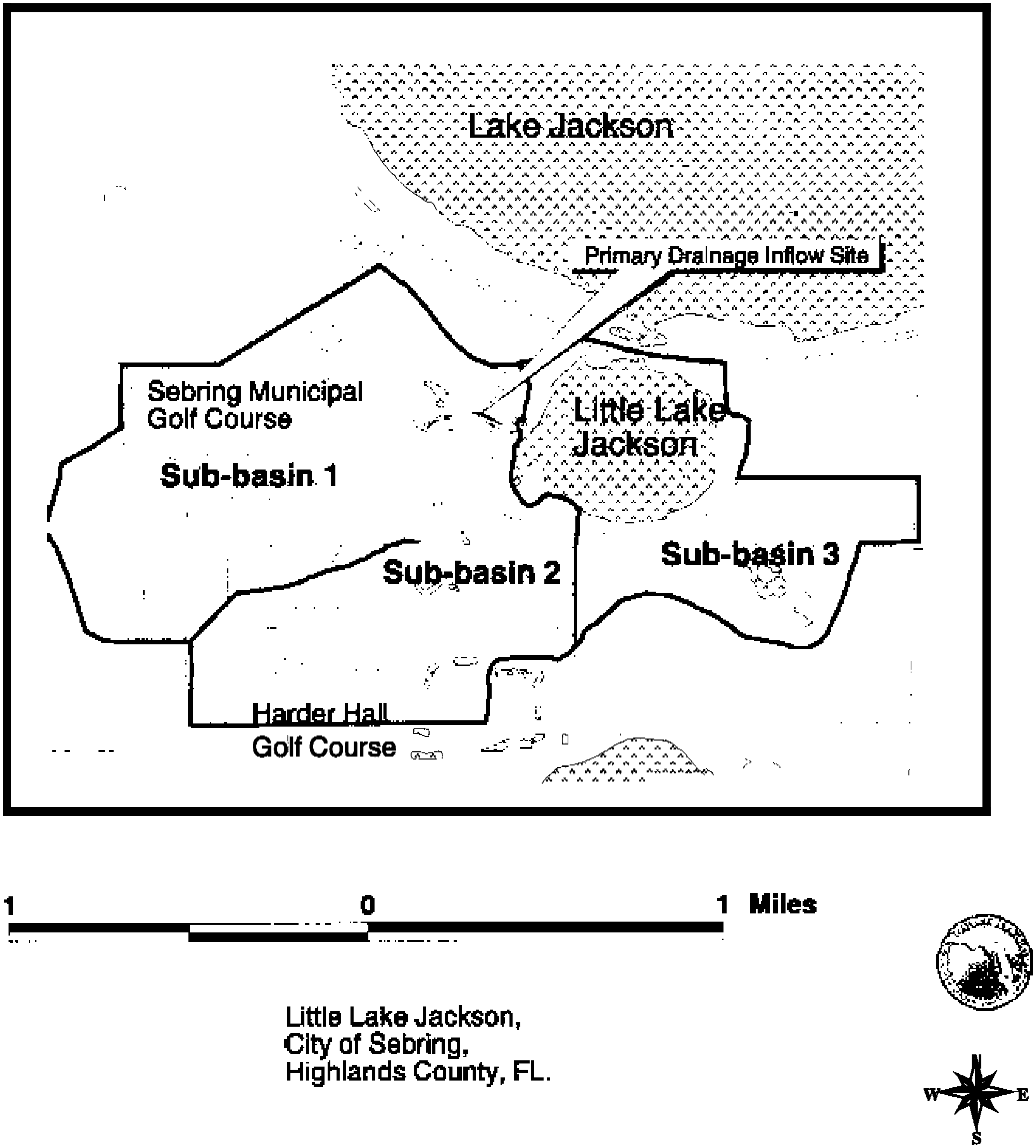
Daily rainfall totals have been collected since 1992 within the watershed by a local volunteer. The resident has generously donated his/her time as part of the volunteer data collection network of the District's Resource Data Department. In addition, during the study period, **an** electronic rainfall recorder was installed within Sub-basin 1, so that rainfall totals could be obtained at 15 minute intervals.

Primary Inflow Hydrograph

A stream hydrograph can be used to characterize fluctuations of stream water level in response to runoff, which in turn is needed to establish a stormwater sampling procedure. **A** hydrograph was prepared for the primary inflow from water level readings collected from **an** automatic electronic elevation recorder (float and pulley), which was installed next to the drop pipe structure at the primary inflow station (station 1). The recorder was set to take automatic readings every thirty minutes. The deepest point on the invert of the drop pipe structure was used as the bottom depth reference point or the "zero" setting for the electronic recorder.

The stream stage hydrograph displayed storm peaks of long duration. For example, the upward slope or rise of the hydrograph caused by a single one inch rain event, occurred over approximately a **6** hour period. The downward slope of the hydrograph for this storm event lasted approximately 3 days. **As** a result of these peaks of long duration, grab sampling appeared to be feasible for this study. In contrast, grab sampling within flashy drainage systems is typically impractical, since sampling time windows are much shorter. Separate grab samples were routinely collected for base flow, which represent low flow or dry conditions. Base flow samples were verified by the examination of the inflow hydrograph. Samples were considered to represent base flow if they were collected during **an** extended period of stabilized stream levels. Four base flow samples were taken prior to the installation of the electronic elevation recorder. Since a hydrograph was unavailable

Figure 2. Little Lake Jackson Drainage Sub-basins, Primary Drainage Inflow, and Inflow Sampling Site



Little Lake Jackson,
City of Sebring,
Highlands County, FL.

during this period these samples were verified by examining the daily rainfall record. Samples were considered to represent base flow if no rainfall was observed during the day of the sample collection, and the rainfall total was less than 0.20" for a total period of three days prior to the sample. Samples which could not be verified as base flow were eliminated from the data set. **A** total of nine qualifying base flow samples were collected,

A total of ten storm event samples were sampled, During three of these events, multiple samples were collected, so that different periods of the storm peak would be represented. Multiples samples are preferred since they provide a range of pollutant concentrations throughout a storm event. **A** single sample was collected during each of the remaining seven storm events. **All** rainfall data and all raw water quality data are available from the District if needed.

RESULTS

A comparison of base flow nutrient concentrations and storm event concentrations is provided in Table 1. Little variation was observed between median base flow concentrations and median storm event concentrations for both organic nitrogen and total nitrogen (Table 1). Median and mean concentrations of ammonium, nitrite + nitrate, orthophosphorus, and total phosphorus were higher within storm event samples. Side-by-side boxplots of base flow concentrations and storm event concentrations are shown for each nutrient parameter in Figures 3A-3F.

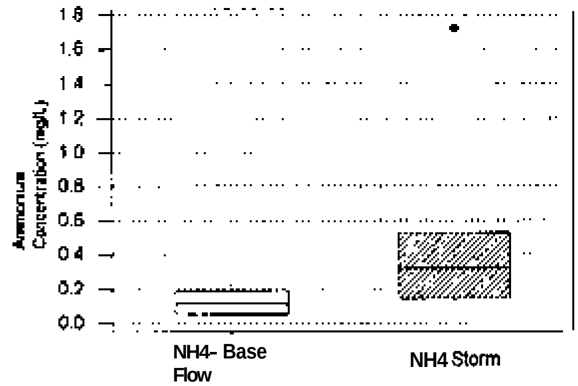
Table 1. Summary of nutrient concentrations (mg/L) measured with base flow samples and within stormwater samples within the primary inflow of Little Lake Jackson, Sub-basin 1 (1995-1997).

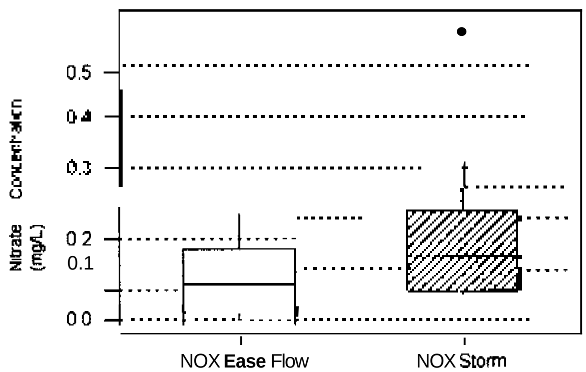
	NH_4	NO_3	ORG-N	TN	ORTH-P	**TP**
Base Flow						
N	**9**	9	**8**	8	9	9
Mean	0.137	0.087	1.40	1.63	0.152	0.172
Median	0.115	0.078	1.37	1.50	0.155	**0.172**
Min	0.029	0.004	0.685	0.88	0.102	0,123
Max	**0.375**	0.249	2.659	3.03	0.194	0.232
Storm Events						
N	10	10	9	9	10	10
Mean	0.439	0.168	1.36	2.01	0.244	0.280
Median	0.315	0.120	1.31	1.81	0.210	0.250
Min	0.124	0.045	0.752	1.41	0.118	0,160
Max	1.72	0.569	2.15	**3.22**	0.650	0.701

Differences between base flow samples and storm event samples were greatest for ammonium, total nitrogen, orthophosphoms, and total phosphorus (Figures 3A,3D,3E, and 3F), while less variation was observed for organic nitrogen and nitrate + nitrite (Figures 3B and 3C). The Wilcoxon-Mann-Whitney rank-sum test (one-sided) was used to test whether storm event nutrient concentrations were significantly higher than base flow samples. Results showed that concentrations of ammonium, orthophosphorus, and total phosphorus during storm events were significantly greater ($a = 0.003$, 0.007, and 0.02, respectively) than concentrations measured within base flow samples, These differences were not found for nitrate, organic nitrogen, and total nitrogen (nitrate $\alpha = 0.135$, organic nitrogen $\alpha = 0.332$, total nitrogen $\alpha = 0.04$).

Nutrient concentrations of the primary inflow were compared to ambient concentrations of other flowing systems within the general local region, the Jackson-Josephine Drainage Canal and Little Charley Bowlegs Creek (Table 2). Orthophosphorus and total phosphorus concentrations measured within base flow and during most storm events (median storm) were similar to phosphorus concentrations measured within other systems (Table 2). Similarity between these sites suggests that phosphorus concentrations in these flowing systems may be associated with the surrounding soil types. As previously discussed (See Soil Types), black sands associated with cutthroat seeps and bayhead wetlands are common within the Little Lake Jackson watershed, Muck soils associated with bayhead wetlands are common along the Jackson-Josephine Drainage Canal and along the Little Charley Bowlegs Creek. Nutrients stored within muck soils may continually leach into surrounding groundwater, which in turn, may seep into surface water drainage ways. Phosphorus contributions from these types of soils appears to be a significant source of phosphorus within these systems. In addition, all of these systems are located within regions which frequently contain perched water tables. Dissolution of nutrients from these soils may increase when these soils become highly saturated.

A. Comparison of boxplots of ammonium concentrations measured during base flow events and ammonium measured within storm events





C Comparison of boxplots of organic nitrogen concentrations measured during base flow events and organic nitrogen measured within storm events

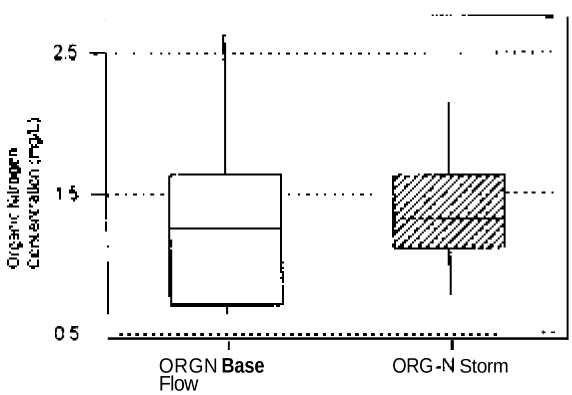


Figure 3. Comparison of **nutrient concentrations measured during base** flow **events to concentrations measured during storm events. Boxplots of ammonium (NH,) concentrations (3 A.), nitrate concentrations (3 B.), and organic nitrogen concentrations (3 C.) measured within base** flow **versus concentrations measured within storm events.**

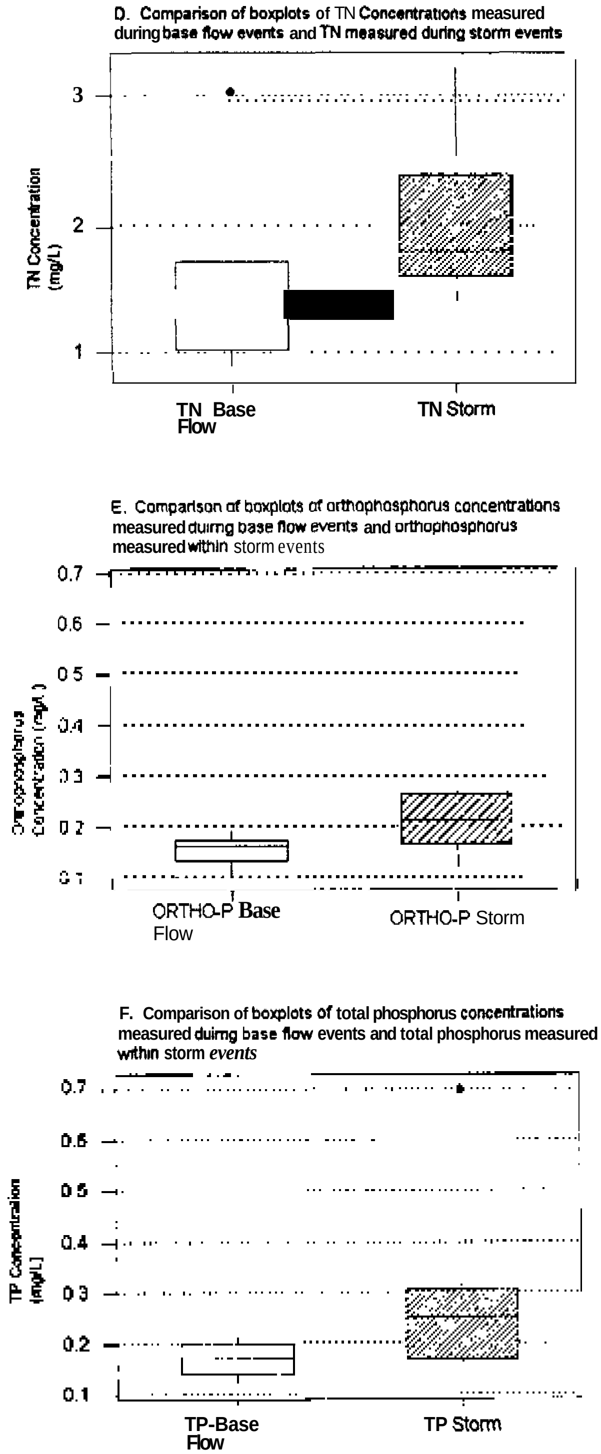


Figure 3.- Continued. Boxplots of total nitrogen concentrations (3 D.), orthophosphorus concentrations (3 E.), **and** total phosphorus concentrations (3 F.) measured within **base** flow **versus** concentrations **measured** within storm events.

Table 2. Comparison of median nutrient concentrations of the primary inflow drainage canal of Little Lake Jackson (Sub-basin 1) to concentrations measured within nearby flowing systems. Concentrations are expressed as mg/L.

	N	ORTH-P	TP	NH_4	TN
LITTLE LAKE JACKSON PRIMARY INFLOW					
Median Base Flow	9	0.155	0.172	0.115	1.5
Median Storm Event (1995-1997)	10	0.210	0.250	0.315	1.8
Maximum Storm Event Conc. (Mean for 10-08-96 event)	2	0.650	0.701	1.725	3.2
REGIONAL DATA					
Little Charley Bowlegs Creek Highlands Hammock State Park (1995)	2	0.174	0.206	0.112	1.5
Jackson-Josephine Canal Sparta Rd. Bridge (1995-1996)	4	0.160	0.264	0.342	2.6
Jackson-Josephine Canal Structure 2 (1995-1996)	2	0.099	0.106	0.422	1.9

Although phosphorus measured within base flow and during most storm events appears normal for the region, concentrations measured during one of the heaviest storm events (event on 10-08-96) were unusually high (Table 2 - average orthophosphorus 0.650 mg/L, average total phosphorus 0.701 mg/L). Elevated phosphorus concentrations carried within storm runoff, may be related to a number of factors, including both natural sources and anthropogenic sources. Higher concentrations of phosphorus are expected during heavy storm events due to factor such as increased erosion, however, other storm events of similar magnitude which were also sampled, yielded lower concentrations of phosphorus. Anthropogenic sources appear to be associated with these concentrations. The major anthropogenic sources within Sub-basin 1 are fertilizer and septic tank leachate. According to the Manager of the City Golf Course approximately five tons of fertilizer were applied to the course one day prior to the storm event in which these Concentrations were measured (event on 10-08-96). The timing of the fertilizer application suggests that it may have been the primary factor associated with the measured concentrations of this event.

Given the nature of the soils within Sub-basin 1, concentrations of ammonium measured within base flow samples of the primary inflow appear normal for the region. **As** displayed in Table 2, a median concentration of 0.115 mg/L for base flow concentrations was similar to the median concentration measured within the Little Charley Bowlegs Creek (0.112 mg/L) (Table 2). A median concentration of 0.315 mg/L for storm events may be somewhat typical of this region as well. The median ammonium concentration measured within sites within the Jackson-Josephine Canal ranged between 0.342 - 0.422 mg/L. Although these concentrations are somewhat high, soils within this region undoubtedly influence water quality within the Jackson-Josephine Canal. The canal was excavated through an area dominated by muck soils. Organic compounds which leach from muck soils and enter ground water or surface waters release ammonium and other forms of nitrogen as they decompose. Anaerobic conditions or conditions which promote decomposition were measured during most sampling events within this canal. These conditions included low dissolved oxygen concentrations, and elevated concentrations of iron and ammonium.

Unusually high ammonium concentrations (greater than 0.5 mg/L) were measured within three storm events within the primary inflow. Concentrations as high as 2.1 mg/L were measured during one of the heaviest storm events (3 inch rainfall event on 10-08-96)(Table 2). The maximum ammonium concentration of the U.S. EPA (1986) chronic-exposure criteria for natural surface waters within normal ranges of pH and temperature is 2.1 mg/L. Concentrations of this magnitude suggest that anthropogenic sources were definite contributors of ammonium loading during this event. Like phosphorus, anthropogenic sources of ammonium within Sub-basin 1 primarily include fertilizer and septic effluent, both of which probably contribute to ammonium loading within this sub-basin. Although ammonium may be released naturally from soil organic matter through such processes as decay and dissolution, these natural soil decay processes usually occur gradually (SWFWMD 1997). As previously discussed, a large quantity of fertilizer was applied within the City Golf Course one day prior to the event in which these concentrations were measured (event on 10-08-96). The timing of the fertilizer application suggests that it was a primary factor associated with the measured concentrations of this event.

Discharge Curve and Discharge Hydrograph

The water levels displayed by a hydrograph are ultimately used to determine a stream discharge curve, which in turn, is used to calculate nutrient loads. Determining a stage discharge curve for the primary inflow ditch within Sub-basin 1 was challenging due to obstructions within this conveyance system. Thick vegetation (paragrass) located downstream of the drop pipe structure blocked stream flow. Culverts within this region were clogged with sediment making standard discharge calculations difficult. The drop pipe structure located to the west of Golf View Road has settled over the years and has shifted to an approximate 80° angle with the water surface. The two sets of slotted boards within the structure have shifted as well, causing the structure to change from a rectangular shaped weir to a structure with two separate triangle shaped outlets. Obstructions downstream often caused tail-water conditions at the structure. Accurate discharge rates could not be obtained by applying a standard weir discharge equation to this structure.

A stage discharge curve was created for the primary inflow by measuring stream velocity and stream area throughout a range of flow at the drop-pipe structure. Stream velocity was measured with a Marsh McBirney ® water current meter (Model 201D). Discharge rates (cubic feet per second) were calculated by multiplying stream area by stream velocity. Since downstream vegetation was inhibiting normal flow and creating tail-water conditions at this structure, nuisance vegetation had to be removed prior to measurement of velocity recordings. Fortunately, personnel from the Highlands County Aquatic Weed Control volunteered to spray the nuisance vegetation with aquatic herbicides. Free-fall conditions were generally achieved at the structure once the invasive vegetation was removed.

The discharge rating curve was calculated by plotting discharge rates against stream depth at the invert structure and then finding a predictive equation which appeared to have the best fit for these plots, Hourly electronic water elevation recordings were then applied to the predictive equations so that hourly discharge rates could be calculated. Hourly discharge rates were then used to calculate daily discharge rate averages. The maximum average daily discharge rate in stormwater samples were collected was approximately **7** cfs (event of 10-08-96). Average daily base flow discharge dropped as low as 0.1 cfs.

Relationships between Nutrient Concentrations and Discharge

Significant correlations (Spearman correlation) were observed between discharge (log transformed) and the following nutrient concentrations (log transformed) measured within both base flow events and storm events: discharge and orthophosphorus rho=0.855, $p=0.001$; discharge and total phosphorus rho=0.893, $p=0.001$, discharge and ammonium rho=0.828, $p=0.001$. Plots of discharge and concentrations of orthophosphorus, total phosphorus, and ammonium are shown in Figures 4A., 4B., and 4C., respectively.

Nutrient Load Calculations

Hourly discharge rates were used to calculate total hourly runoff volumes. Average daily runoff volumes were then calculated and used to determine daily nutrient loads by multiplying the daily discharge volume by the appropriate nutrient concentrations. Two different nutrient concentrations were applied to the discharge curve. The median base flow nutrient concentration was applied to days which were characterized as base flow discharge. The median storm event nutrient concentration was used to calculate nutrient loading for all days which were characterized as storm or post storm discharge. **A** total yearly load was calculated from summing these daily loads. A **summary** of yearly nutrient loads (April 1996 - April 1997) is provided in Table 3a.

Separate nutrient loads were also calculated for the storm event in which the peak nutrient concentrations were measured (Oct **8,** 1996, **3**" rain event). In addition, based on this additional loading, a new total annual load was calculated (Table 3b). Most nutrient concentrations measured during this particular storm were shown **as** outliers within boxplots of storm event nutrient data (Figure 3A, 3B, 3E, and **3F).** Separate nutrient loads were calculated for this particular event by using the concentrations and flows specific to this event (Table 3b). The loads for ammonium, nitrite + nitrate, orthophosphorus, and total phosphorus comprised large portions of the total yearly load (Table 3b). The ammonium load was the largest, comprising 45 percent of the annual load (Table 3b). When this event was included within the calculations of the total yearly load, a 51 percent increase in yearly load was observed for ammonium. The total yearly load for orthophosphorus increased by approximately 17 percent, while both the total yearly load for nitrate +nitrite **and** total phosphorus increased by approximately 15 percent. **A** percentage of the total yearly load was calculated for this separate storm event (Table 3b).

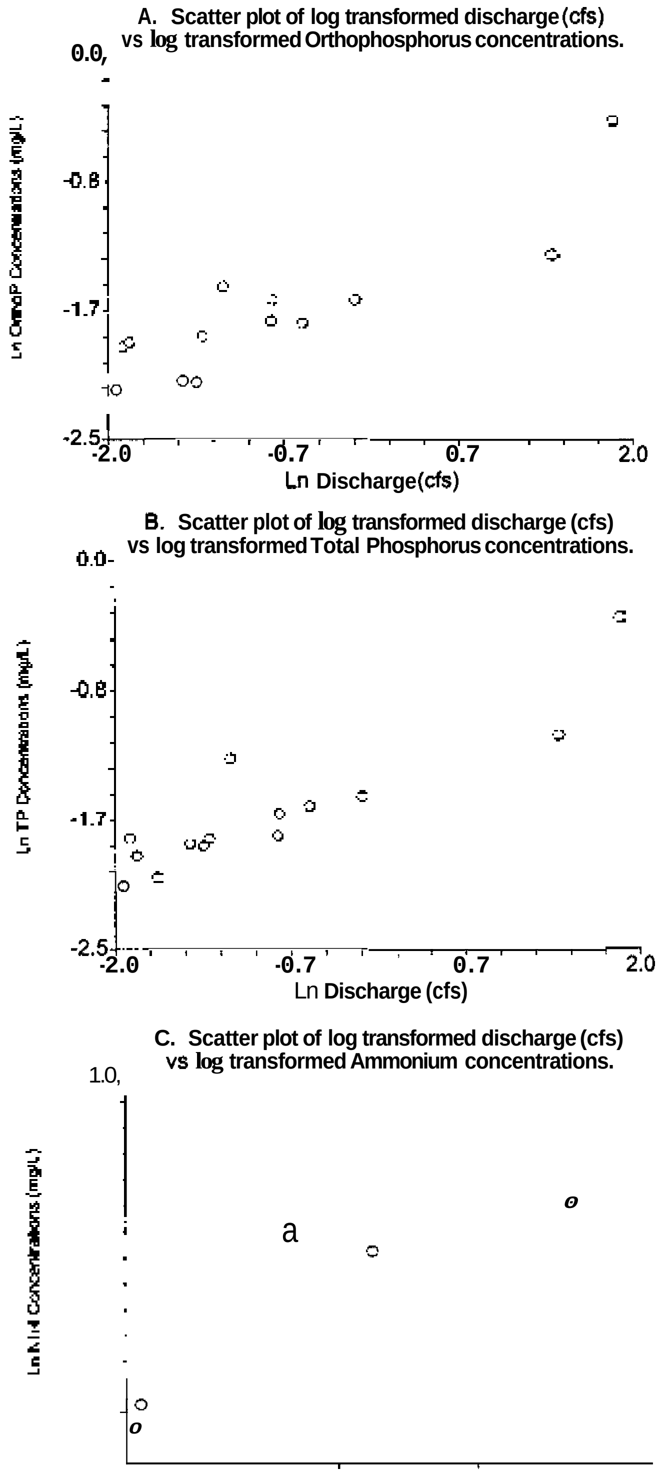


Figure 4. Scatter plots of log (ln) transformed discharge and log transformed nutrient concentrations (A. Orthophosphorus, B. Total phosphorus, C. Ammonium). Nutrient data are from both base-flow and storm event samples.

Table 3a. Nutrient loads calculated for the primary inflowto Little Lake Jackson, Sub-basin 1, based on the median base flow concentration and the median storm event concentrations. Separate loads and percentages are shown for base flow and storm events. Total loads are reported as kg/year, lbs/year, kg/acre/year, and lbs/acre/year.

	NH_4	NO_3	ORG-N	TN	ORTH-P	TP
Base Flow (kg)	7.2	7.3	151	160	14.3	16.2
Percentage	21.7	43.4	60.2	53.8	44.9	44.4
Storm Events **(kg)**	25.9	9.6	99.9	137.3	17.6	20.3
Percentage	78.3	56.6	39.8	46.2	55.1	***55.6***
Total kg/year	33.1	16.9	251.0	297.2	31.9	36.5
lbs/year	**73.0**	37.3	553.3	655.2	70.4	80.4

Table 3b. Nutrient loads calculated for peak storm event on Oct. 8, 1996 (containing maximum nutrient concentrations) for the primary inflow to Little Lake Jackson, Sub-basin 1. The overall loads for all base flow events and all storm events were recalculated to include the peak storm event.

	NH_4	NO_3	ORG-N	TN	ORTH-P	TP
Storm Event Containing Peak Conc.	23.3	4.2	23.6	42.7	8.3	9.0
of NH_4, TN, ORTH-P, and TP	44.9	21.5	9.2	13.6	22.2	21.4
Base Flow (kg)	14.5	9.9	173.8	190.3	19.6	21.8
Percentage	27.9	50.8	67.9	60.6	52.6	51.9
Storm Events (kg)	37.4	9.5	82.2	123.8	17.6	20.2
Percentage	72.0	49.2	32.1	39.4	47.4	48.1
Total kg/year	51.9	19.4	256.0	314.1	37.2	42.0
lbs/year	115	42.8	564.3	692.6	82.1	92.3
kg/acre/year	0.10	0.04	0.52	0.63	0.07	0.08
lbs/acre/year	0.22	0.09	1.2	1.4	0.17	0.18

As previously discussed, the peak nutrient concentrations measured during the storm event on Oct. **8,** 1996 (3" rain event), appear to be primarily associated with fertilizer application within the Sebring Municipal Golf Course. Approximately, five tons of fertilizer (15-5-15) was applied over the 100 acre golf course one day prior to the large rain event (Oct 8, 1996, 3" rain event). Although the golf course incorporates weather forecasts into their fertilizer application procedure, this large rain event was not forecasted. The timing of their fertilizer application suggests that golf course fertilizer was a significant contributor of nutrients during this particular storm event. Approximately 1500 lbs of total nitrogen, 750 lbs of ammonium, and 187 lbs of nitrate was distributed over the golf course. The total nitrogen load estimated from the discharge hydrograph (Table 4b) for this event for the primary surface water inflow was approximately 94.1 lbs. The ammonium load estimated from the discharge hydrograph was approximately 51.4 lbs. The nitrate load estimates from the discharge hydrograph was approximately 10 lbs. for this particular storm event.

Approximately 500 lbs of phosphorus was applied over the City Golf Course during the application. The estimated total phosphorus load and orthophosphorus load delivered to the lake through the primary inflow were approximately 20 lbs. (estimation from stage discharge curve).

DISCUSSION

Estimated Nutrient Loads to Land Surface Based on Land Use Information

Although fertilizer application within the City Golf Course was suggested as a major nutrient contributor during one the heaviest storm events, land use data suggested that residential fertilizer may be the largest nutrient contributor. Estimates were prepared for nutrient loads applied to the land surface from potential nutrient sources within Sub-basin 1 (Table **4).** These sources included septic effluent, residential fertilizer, golf course fertilizer, and rainfall. These were prepared by applying general annual loading rates acquired from literature for each specific nutrient sources and then applying those to the appropriate land use data for Sub-basin 1. Some of the literature from which general loading rates are obtained are noted in Table 5. Residential fertilizer application appears to have the greatest potential for applying the largest nitrogen loads. At least one half of the nitrogen applied to the land surface within fertilizer is probably delivered as ammonium nitrogen, which is typically the dominant form of nitrogen within most common fertilizers. Like nitrogen, the primary source of phosphorus appears to be fertilizer, with fertilizer application within residential land use as the greatest potential contributor (Table 4).

Although calculations of generalized nutrient loads suggest that residential fertilizer is the largest contributor of nitrogen and phosphorus, water quality **and** discharge data collected from within the primary inflow suggests that fertilizer application within the golf courses poses a greater threat for bulk nutrient loads carried within surface water runoff. Unlike the residential areas, fertilizer application within the golf course is performed as a bulk application over a large area during a narrow time frame. **As** suggested from data collected within this study, the risk of large nutrient loads is of course greatest when applications are applied prior to large rain events.

Table 4. Estimated annual nutrient loads to land surface for Sub-basin 1 within Little Lake Jackson watershed, Highlands County, Florida. Loads shown are for direct land surface application rates.

	TN (tons/yr)	NH_4 (tons/yr)	NO_3 (tons/yr)	TP (tons/yr)
Septic Effluent [1]	4.7-6.7	0-6.7	0-4.7	1.6
Residential Fertilizer [2]	14.3-24.4	7-12	1.8-3.0	3.2-5.2
Golf Course Fertilizer [3]	8.2	4.1	1.0	2.7
Rainfall [4]	1.7	0.2	0.7	0.1
TOTAL	29-41	11-23	3.5-9.4	13.5-17.5

1 - (Canter and Knox 1985, Cogger and Calie 1984, Henigar and Ray 1990, **Sikora** *et al.* 1976, SWFWMD 1990, SWFWMD 1990)
2 - (Florida Cooperative Extension Service **1990)**
3 - (Personal communication with staff **of the** Sebring Municipal **Golf** Course)
4 - (SWFWMD Laboratory - unpublished data)

Although anecdotal evidence (personal communication with the Golf Course Manager) suggested that golf course fertilizer appeared to be a large nutrient contributor during the one the heaviest storm events (10-08-96) anecdotal evidence is not definite. In addition, since other storm events of similar magnitude were sampled, it appears that high nutrient loads that occurred on 10-08-**96** should be treated as an isolated event. Determining the association of golf course fertilizer with this separate event does not imply that golf course fertilizer is the dominant source of nutrients within all other storm events, or within base flow.

During the course of the study an idea was developed for a stormwater sampling protocol which may be helpful for distinguishing between inorganic nitrogen sources within runoff samples collected within this watershed, or possibly for other watersheds. The sampling protocol would basically involve first performing field testing runoff samples for concentrations of nitrate and ammonium. Either **an** electronic probe could be used (Hydrolab or YSI®) or a field test kit such as a Hach® kit specific for ammonium and nitrate. If unusually high concentrations of nitrate or ammonium were detected, then additional samples would be collected for analyses of stable nitrogen isotopes ($\delta^{15}N_{AIR}$). Stable nitrogen isotope tests are helpful for distinguishing between inorganic sources such as fertilizer, and organic sources of nitrogen such as septic effluent or animal wastes. If the tests indicate that inorganic sources such as fertilizer are involved then fertilizer application schedules should be closely evaluated. These tests when combined with reviewing copies of the golf course fertilizer schedules would provide a strong indication of whether or not golf course fertilizer was a major contributor. Reviewing the fertilizer schedule is essential since residential fertilizer is also applied within this sub-basin. The absence of fertilizer application within the golf course may indicate residential fertilizer as the primary nutrient contributor. Distinguishing between these major nutrient contributors would be helpful so that target BMP's could be developed for this watershed.

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