Special Publication SJ92-SP16

LAKE JESSUP RESTORATION
DIAGNOSTIC EVALUATION
WATER BUDGET AND NUTRIENT BUDGET

Prepared for:

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EXECUTIVE SUMMARY

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Lake Jessup is a large, shallow lake with an average stage (for years 1980 through 1990) of 1.86 feet National Geodetic Vertical Datum (NGVD) that lies near the center of Seminole County in east-central Florida. The lake is hydraulically connected to the St. Johns River by an outlet channel constricted by the S.R. 46 bridge. Lake elevation is controlled by the elevation of the St. Johns River at the confluence with Lake Jessup. When local rainfall is lower than regional rainfall (particularly to the south), water will flow from the St. Johns River into the lake.

The Lake Jessup watershed encompasses approximately 100,660 acres which includes the lake area of approximately 10,661 acres. The watershed is divided into nine major hydrologic subbasins ranging in size from 964 to 32,153 acres. Soils of the watershed tend to be well-drained and sandy.

Land cover and use classifications within the watershed are varied, including urban, residential, agricultural, and various undeveloped land cover types. The predominant land uses in the watershed are agricultural and residential. The remainder primarily supports recreational uses and undeveloped lands.

The hydraulic residence time for lake waters, estimated variously at approximately 99 days (Brezonik and Fox 1976), 82 days (U.S. EPA 1977), and 87 days (this study), does not indicate a large flushing action as compared to the nearby Lakes Harney and Monroe with retention times on the order of 10 days.

Lake Jessup has for many years been one of the most eutrophic bodies of water in Florida (U.S. EPA 1977) primarily due to the input of secondary wastewater effluent for over 20 years. While direct discharge ended in 1983 (FDER 1992), it is believed that runoff and other anthropogenic impacts continue to degrade water quality. The accumulated muck on the lake bottom remains a potential nutrient source. Presently, the lake is characterized by frequent algal blooms and frequent fish kills (Hand et al. 1990).

The purpose of this study was to use existing data to prepare a comprehensive water budget and nutrient budget for Lake Jessup to support an analysis of restoration feasibility and techniuqes for the lake. The budget calculations for water, total nitrogen, and total phosphorus were performed with a monthly time step, then the monthly budgets were totaled (flows) or averaged (storages) for the yearly budgets. The results are reported as the annual totals and averages for the period of record, January 1980 through December 1990.

Outflow from Lake Jessup to the St. Johns River is largely regulated by the river itself through its effect on lake elevation. Since lake stage follows changes in the river stage, changes in lake volume are not necessarily a function of the watershed inflows to the lake.

Changes in lake volume were a major component of the water budget and directly affected volumes of outflow to the river. Outflow to the St. Johns River was considered an estimate of the total net water budget for the lake since it represents the overflow after all losses have been taken out. Discharge to the St. Johns River averaged 177,807 acre-feet per year (241 cubic feet per second) for the 1980 to 1990 period of record.

Streamflow was the largest input to the lake at 95,117 acre-feet per year. Bank seepage volume was the next largest input at 68,060 acre-feet per year. Together, these inputs made up approximately 74.6 percent of the discharge to the St. Johns River.

Direct precipitation to the lake surface was a large input with an annual average of 42,490 acre-feet, but this was more than offset by evaporation which averaged 45,252 acre-feet per year. Other minor inputs included septic tanks, wastewater treatment plants (WWTPs), artesian inputs from upwelling Floridan aquifer water through springs and diffuse leakage through the lake bottom.

Nitrogen (N) and phosphorus (P) budgets for Lake Jessup were determined through a spreadsheet-based modeling effort using results of the water budget and estimates of total nitrogen (TN) and total phosphorus (TP) concentrations for each flow component.

TN yearly loadings to Lake Jessup averaged 805 tons. The annual total loadings generally varied according to the rainfall. The combined inflow from septic tanks and WWTPs was the largest TN source at 333 tons per year. Bank seepage averaged 163 tons TN per year. The total of bank seepage, septic tanks, and WWTPs results in a total average TN loading to Lake Jessup through the groundwater pathway of 496 tons per year. Other major TN sources included surface runoff loading (206 tons per year) and direct rainfall (92 tons per year). Minor TN loading sources included springs, upward leakage, and St. Johns River inflow to the lake.

TP loadings to Lake Jessup averaged 60 tons per year. As with TN, the total loadings responded to changes in rainfall. The highest and lowest loadings occurred in 1983 and 1990, respectively. Surface runoff was the largest TP loading source, averaging 29 tons per year. Other major TP loadings were due to bank seepage (19 tons per year) and direct precipitation (10 tons per year). Minor sources were springflow, upward leakage, and St. Johns River inflow.

TN export to the St. Johns River averaged 859 tons per year. Fluctuations in TN export reflect changes in both outflow volume (decrease from 1988 to 1989) and nutrient concentration (increase from 1989 to 1990). Denitrification loss of TN to the atmosphere remained constant at 33 tons per year. Total TN export from Lake Jessup averaged 892 tons per year.

TP outflows from Lake Jessup occur only through surface water export to the St. Johns River (75.7 tons year).

The nutrient budget calculations were based on a mixture of two data types: data from actual measurements of the Lake Jessup system and data estimated by separate modeling efforts. Data from actual sampling measurements was used whenever possible.

Deficiencies in the available data were noted for bank seepage water quality, surface runoff water quality for many tributaries, number and distribution of septic tanks, and the impact of WWTPs and septic tanks on groundwater quality.

Retention times for water and nutrients within Lake Jessup water and sediments were calculated by the ratio of average storage to average outflow.

The results were as follows:

Hydraulic Retention Time (RT)	= 86.7 days
Water Total Nitrogen RT	= 82.0 days
Water Total Phosphorus RT	= 87.6 days
Sediment Total Nitrogen RT	= 873 years
Sediment Total Phosphorus RT	= 155 years
Combined Total Nitrogen RT	= 80.7 years
Combined Total Phosphorus RT	= 27.3 years

The hydraulic retention time of 86.7 days allows nutrients in the lake to undergo biological uptake, storage in plant or animal tissue, and deposition in the sediments, which tends to retain nutrients within the lake.

Nutrient export rates for the Lake Jessup watershed averaged 20.1 kg/hectare (ha) per year for TN and 1.5 kg/ha per year for TP.

Nutrient loading rates to Lake Jessup averaged 16.93 g/m^2 per year for TN and 1.27 g/m^2 per year for TP. These values exceed the critical loading rates of 3.4 g/m^2 per year and 0.49 g/m^2 per year, respectively, developed by Shannon and Brezonik (1972) for north central Florida lakes. Loading beyond the critical rate will cause or maintain a state of eutrophication. These results indicate that nutrient inputs to Lake Jessup must be significantly reduced before any restoration methodology will be able to succeed.

The three easiest nutrient sources to control (surface runoff, septic tanks, and WWTPs) accounted for 67 percent of the TN inflow and 44 percent of the TP inflow. While it may not be possible to completely remove the nutrient input from these sources, it is possible to reduce the amount of nutrients they release to receiving waters. The use of stormwater retention/detention systems throughout the watershed would decrease the nutrient loading from runoff by the mechanisms of settling/filtration and biological uptake by plants.

WWTP percolation ponds were assumed to provide no treatment of TN in effluent, which probably led to an overestimate of WWTP input of TN. However, without some component of the treatment system specifically removing nitrogen from the effluent, WWTPs within the watershed will continue to contribute significant amounts of nitrogen to the lake through the groundwater pathway.

Reduction of septic tank effluent can only be accomplished through the systematic sewering of areas currently using septic tanks. Since this input was approximately 20 percent of the TN budget, this alternative should be investigated as part of any restoration effort.

The other nutrient inputs of direct precipitation, artesian upwelling through springs and diffuse leakage, bank seepage, and inflow from the St. Johns River account for less than one-third of the TN budget and approximately 56 percent of the TP budget. These inputs cannot be practically controlled, so efforts to restore Lake Jessup should focus on the inputs from stormwater, septic tanks, and wastewater treatment plants within the watershed.

1.0 INTRODUCTION

1.0 *INTRODUCTION*

Lake Jessup is a large, shallow lake in east-central Florida (Figure 1.0-1) that lies near the center of Seminole County and is bordered on the east and north by the St. Johns River (Figure 1.0-2). Lake Jessup is hydraulically connected to the St. Johns River by an outlet channel that is constricted at the confluence by the S.R. 46 bridge.

Lake Jessup has for many years been one of the most eutrophic bodies of water in Florida (U.S. EPA 1977) primarily due to the input of secondary wastewater effluent for over 20 years. Recently, direct discharge from wastewater treatment plants to Lake Jessup has been either routed outside the watershed or discharged to land application systems or percolation ponds (Seminole County 1991). Although direct discharge ended in 1983 (FDER 1992), it is believed that runoff and other anthropogenic impacts continue to degrade water quality. The accumulated muck on the lake bottom remains a potential nutrient source. Presently, the lake is characterized as having frequent algal blooms and fish kills (Hand et al. 1990).

1.1 PURPOSE

The purpose of this study was to use existing data to prepare a comprehensive water budget and nutrient budget for Lake Jessup to support an analysis of restoration feasibility and techniques for the lake. The budget calculations for water, total nitrogen, and total phosphorus were performed with a monthly time step, then the monthly budgets were totaled (for flows) or averaged (for volumes, or pools) for individual years as well as the entire period of record, January 1980 through December 1990.

Two main tasks were performed for this study:

- Preparation of a comprehensive water budget to determine the relative magnitudes of separate inflows for existing conditions, and

- Preparation of a nutrient budget for Lake Jessup to evaluate the relative magnitudes of the various nutrient loading sources and sinks.

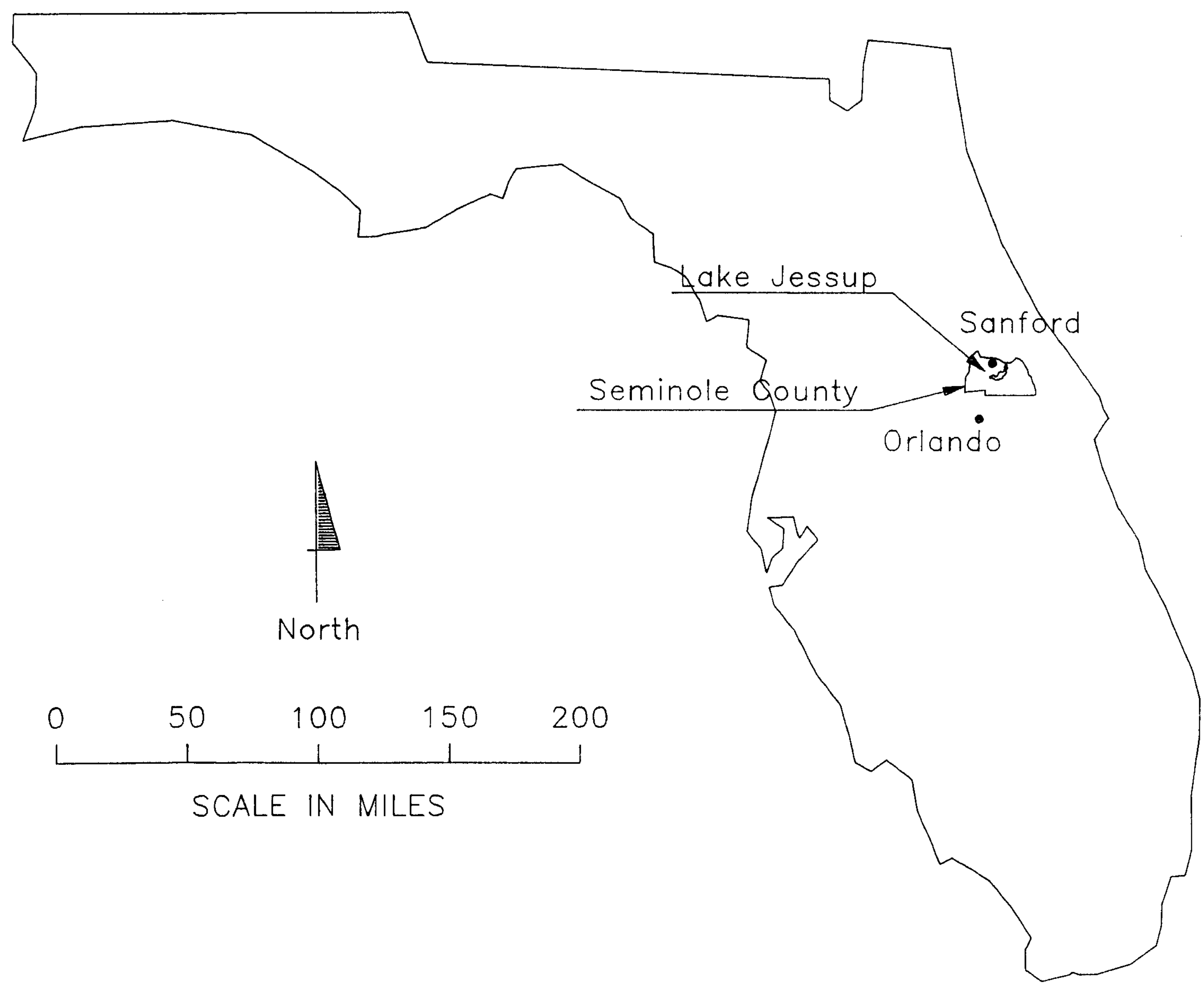

FIGURE 1.0-1. Location of Lake Jessup in East Central Florida.

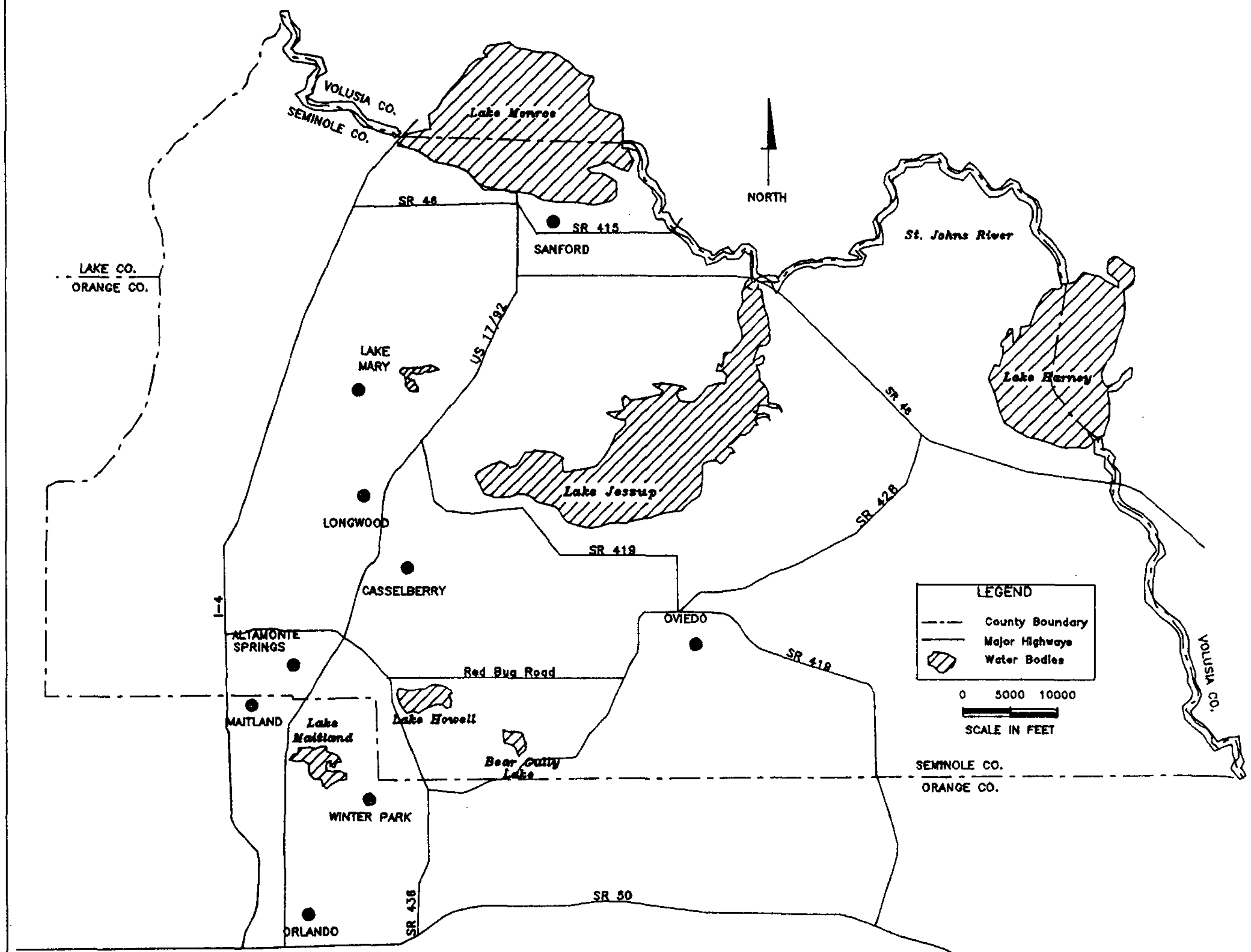

FIGURE 1.0–2. Location of Lake Jessup in Seminole County, Florida

SOURCE: WAR 1991

1.2 DESCRIPTION OF THE STUDY AREA

The Lake Jessup watershed occupies approximately 100,660 acres (≈157.3 miles^2) in central Seminole County, Florida. Lake Jessup occupies approximately 10,660 acres (≈16.7 miles^2) of this area. Soils of the watershed tend to be sandy and well-drained, with the exception of some large low-lying marshy areas adjacent to Lake Jessup.

The watershed is divided into nine major hydrologic subbasins ranging in size from 964 to 32,153 acres. The locations of the subbasins are illustrated in Figure 1.2-1. Streamflow is the largest input to the lake. Total streamflow inputs average approximately 95,117 acre-feet per year. This input is primarily from Gee Creek, Soldier Creek, Howell Creek, and the Sanford Avenue Canal. Smaller creeks include Salt Creek, Sweet Creek, and Six Mile Creek, in addition to a number of agricultural canals.

Lake Jessup is a low-lying lake with an average stage of only 1.86 feet National Geodetic Vertical Datum (NGVD) for the 1980 to 1990 period of record. Lake elevations tend to follow water surface elevations of the St. Johns River at the confluence with Lake Jessup. When local rainfall is lower than regional rainfall (particularly to the south), the river will rise and water will flow from the St. Johns River into the lake.

The mean hydraulic residence time for lake waters, estimated variously at approximately 99 days (Brezonik and Fox 1976), 82 days (U.S. EPA 1977), and 87 days (this study), does not indicate a large flushing action as compared to the nearby lakes Harney and Monroe with retention times on the order of 10 days. However, other Florida lakes have retention times on the order of several years. Lake Apopka, a nearby large, hypereutrophic lake has a retention time of approximately 3 years (Stites 1992).

Land cover and uses within the watershed include urban, residential, agricultural, and various undeveloped land cover types. Undeveloped lands comprise the largest area (48 percent). Other predominant land uses are residential (30 percent) and agricultural (11 percent). Recreational, commercial, and industrial uses account for most of the remainder.

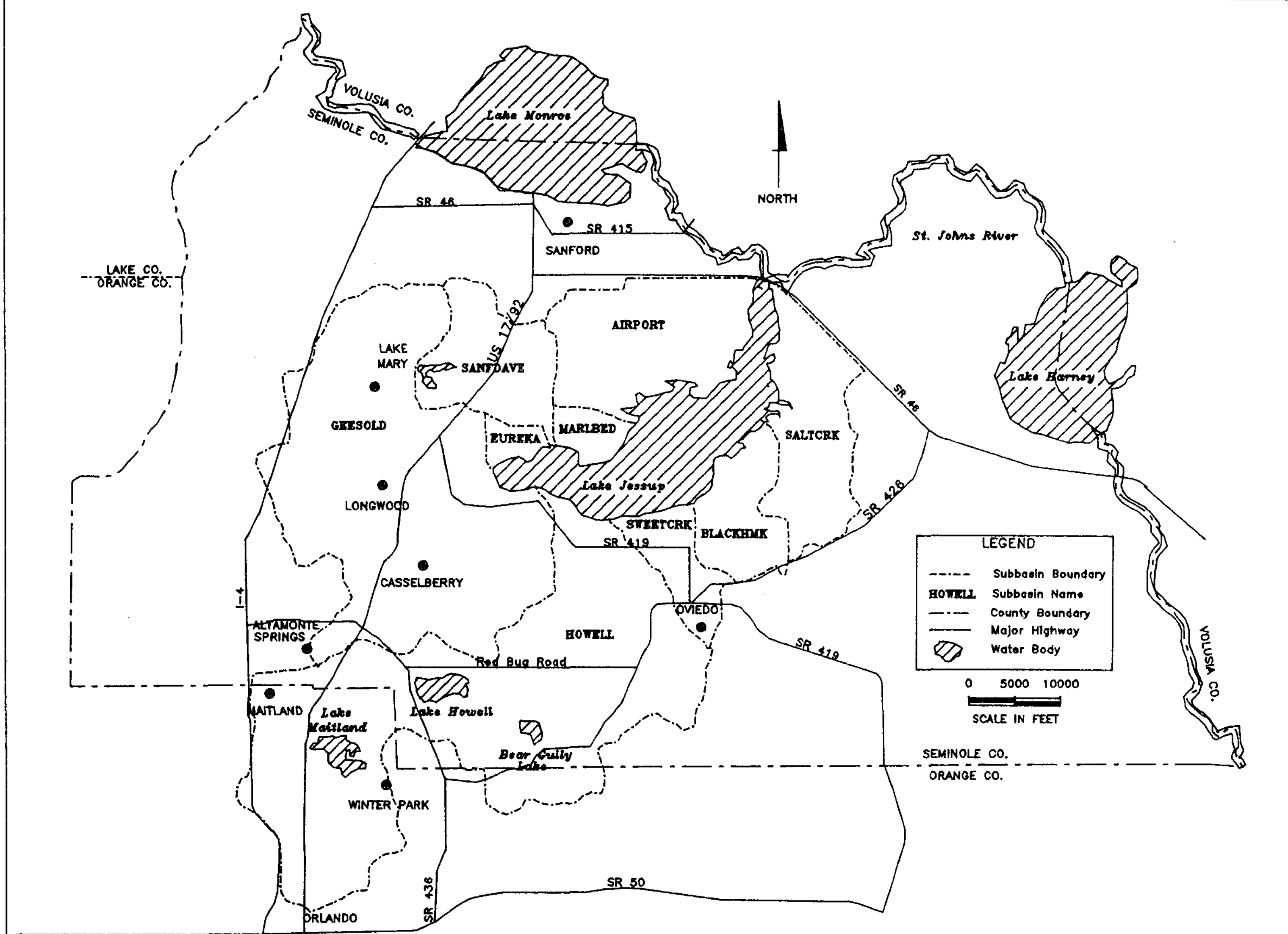

FIGURE 1.2-1. Location of Lake Jessup Watershed Subbasins.

SOURCE: WAR 1991

In the past, several cities within the Lake Jessup watershed discharged municipal wastewater to Lake Jessup. This contributed to the accumulation of a thick layer of nutrient-laden organic muck on the lake bottom. As of May, 1983, these discharges have been directed outside of the watershed or switched to percolation/evaporation ponds (FDER 1992), but lake sediments may remain a source of nutrients to the overlying waters.

2.0 DATA COMPILATION

2.0 DATA COMPILATION

Two basic types of information were required to establish the water and nutrient budgets for Lake Jessup: (1) data to establish subbasin hydrologic characteristics, and (2) data to establish estimated water quality constituent inputs, pathways, reactions, and interrelationships. The water and nutrient budget models for Lake Jessup can be used to predict the impact of changes in nutrient loadings due to anticipated changes in land use practices within the watershed and to assess the effectiveness of management recommendations for nutrient control and restoration alternatives.

2.1 HISTORICAL DATA

Available historical data characterizing the climatology, surface water hydrology and hydrogeologic characteristics, and surface and groundwater quality of the Lake Jessup watershed were investigated and assembled.

2.1.1 Previous Studies

The following reports document surface and subsurface hydrology and water quality of the study area and immediately adjacent areas:

The 1990 Florida Water Quality Assessment - 305(b) Technical Appendix prepared by the Division of Water Management at Florida Department of Environmental Regulation (FDER). The Federal Clean Water Act Section 305(b) directs each state to produce a report such as this describing water quality indices and trends for surface waters of the state and identifying threats to surface water quality. Surface water quality information in this report consists of one station presented as representative of Lake Jessup.

Analysis of Eutrophication and Water Quality Factors in the Middle St. Johns River Basin by P.L. Brezonik and J.L. Fox. This presents a summary of hydrologic and water quality data and analyses for Lakes Jessup, Monroe, and Harney for conditions existing in the late 1960s and early 1970s. Chemical, physical, and biological data for the systems are included as well as rough water and nutrient budgets. Other analyses presented include sediment nutrient exchange, benthic oxygen demand, and trophic state index models.

The Howell Branch Basin Surface Water Management Study, Phase I prepared by the St. Johns River Water Management District (SJRWMD). This study describes the hydrology of the Howell Branch Basin and furnishes technical information in the form of maps, graphs, and data tables depicting various flood discharge and elevation frequency data.

Middle St. Johns Ground Water Basin Resource Availability Inventory, Technical Publication SJ 90-11, prepared by M. McKenzie-Arenberg and G. Szell for the St. Johns River Water Management District, Palatka, Florida, provides a general inventory of the groundwater resources of the Middle St. Johns groundwater basin, including hydrogeologic features, recharge and discharge areas, groundwater quality characteristics, water uses, potential for direct water reuse, and areas suitable for future water resource development.

Hydrology of the Floridan Aquifer System in East-Central Florida prepared by C.H. Tibbals for the U.S. Geological Survey describes the groundwater flow in the Floridan aquifer system in east-central Florida, quantifies the amount of recharge and discharge to the Floridan aquifer, and gives the location of recharge and discharge areas.

South Florida Water Management Model: Documentation Report, Technical Publication 84-3, by T.K. MacVicar, T. Vanlent, and A. Castro for the Resource Planning Department, South Florida Water Management District (SFWMD) contains evapotranspiration coefficients as a function of land use type and month of year.

Gee and Soldier Creeks, Flood Plain Management Study, Seminole County, Florida, by United States Department of Agriculture, Soil Conservation Service, Gainesville, Florida, for SJRWMD. This study furnishes technical information in the form of maps, graphs, and data tables depicting various flood discharge and elevation frequency data.

Lake Jessup Basin Flood Plain Management Study, Seminole County, Florida, by United States Department of Agriculture, Soil Conservation Service, Gainesville, Florida, for the SJRWMD. This study furnishes technical information in the form of maps, graphs, and data tables depicting various flood discharge and elevation frequency data.

Water Resources of Orange County, Florida, Report of Investigations No. 50, by W.F. Lichtler, W. Anderson, and B.F. Joyner for the U.S. Geological Survey, Florida State Board of Conservation, Division of Geology. This report includes stream flow data, chemical quality of surface and ground waters and groundwater levels, evaluation of stream-basin characteristics, delineation of recharge and discharge areas, and assembly of water-use information and interpretations of water data.

Ground-water Resources of Seminole County, Florida, Report of Investigations No. 27, by J.T. Barraclough, U.S. Geological Survey, for the U.S. Geological Survey, Florida State Board of conservation, Division of Geology.

Report on Lake Jessup, Seminole County, Florida, by National Eutrophication Survey Staff, U.S. Environmental Protection Agency. This report describes the drainage basin characteristics, water quality, and nutrient loadings.

2.1.2 Climatologic Data

Daily precipitation data were compiled from the National Oceanic and Atmospheric Administration (NOAA) meteorological station at the Sanford Experimental Station, located just north of the study area. Rainfall averaged 3.99 inches per month or 47.83 inches per year (Table 2.1.2-1). Monthly rainfall (Figure 2.1.2-1) ranged from 0.10 inch to 15.10 inches and annual rainfall totals ranged from 36.59 inches to 62.85 inches. Maximum and minimum annual total rainfall occurred in 1983 and 1990, respectively. Daily pan evaporation data were compiled from the NOAA meteorological station at Lisbon, approximately 30 miles west-northwest of Lake Jessup. Evaporation averaged 4.91 inches per month or 58.88 inches per year (Table 2.1.2-1). Monthly evaporation (Figure 2.1.2-1) ranged from 1.37 inches to 8.88 inches and annual evaporation totals ranged from 54.38 inches to 63.45 inches. Maximum and minimum annual total evaporation occurred in 1990 and 1982, respectively.

January had the lowest monthly average rainfall (2.36 inches) and evaporation (1.75 inches) for the period of record (Table 2.1.2-1). July and May averaged the highest rainfall (6.76 inches) and evaporation (7.85 inches), respectively (Figure 2.1.2-2).

Table 2.1.2-1. Period of Record Monthly Means for Rainfall, Pan Evaporation, Evapotranspiration, Lake Pan Evaporation Coefficients and Lake Evaporation, January 1980 to December 1990.

Month	Sanford Rainfall (in/mo)	Lisbon Pan Evap (in/mo)	Evapotranspiration: Urban ET (in/mo)	Evapotranspiration: Natural ET (in/mo)	Urb/Nat Avg Adjusted Orlando (in/mo)	Lake-Pan Evaporation Coeff	Calc'd Lake Evap (in/mo)
Jan	2.97	1.98	1.6	1.96	1.78	0.871	1.73
Feb	2.66	2.89	1.8	2.27	2.06	0.815	2.36
Mar	4.09	5.17	2.5	2.75	2.66	0.775	4.01
Apr	3.44	6.48	2.8	3.27	3.09	0.841	5.46
May	3.31	7.85	3.2	3.91	3.59	0.910	7.15
Jun	5.28	7.17	2.9	4.10	3.53	0.858	6.15
Jul	6.76	7.21	2.9	4.24	3.63	0.929	6.70
Aug	6.50	6.65	2.9	4.36	3.69	0.891	5.93
Sep	4.61	5.46	2.5	3.96	3.26	0.850	4.65
Oct	2.85	4.09	2.3	3.68	3.05	0.836	3.42
Nov	2.99	2.15	1.8	2.48	2.15	0.834	1.79
Dec	2.36	1.75	1.6	2.02	1.81	0.915	1.60
Annual Total	47.83	58.88	28.7	39.00	34.31	0.860	50.94

Period of Record Statistics:

	Sanford Rainfall (in/mo)	Lisbon Pan Evap (in/mo)
Monthly Avg	3.99	4.91
Monthly Max	15.10	8.88
Monthly Min	0.10	1.37
Annual Avg	47.83	58.88
Annual Max	62.85	63.45
Annual Min	36.59	54.38

Notes:

Rainfall and Evaporation Data from NOAA National Climatic Data Center
Natural ET data source: SWFWMD (1975)
Urban ET data source: MacVicar et al. (1984)
Adjusted average based on Orlando ET total from Bartel and Barksdale, (1985)
Lake Pan Evaporation Coefficient Source: Lichter et al (1968)

Source: WAR 1991

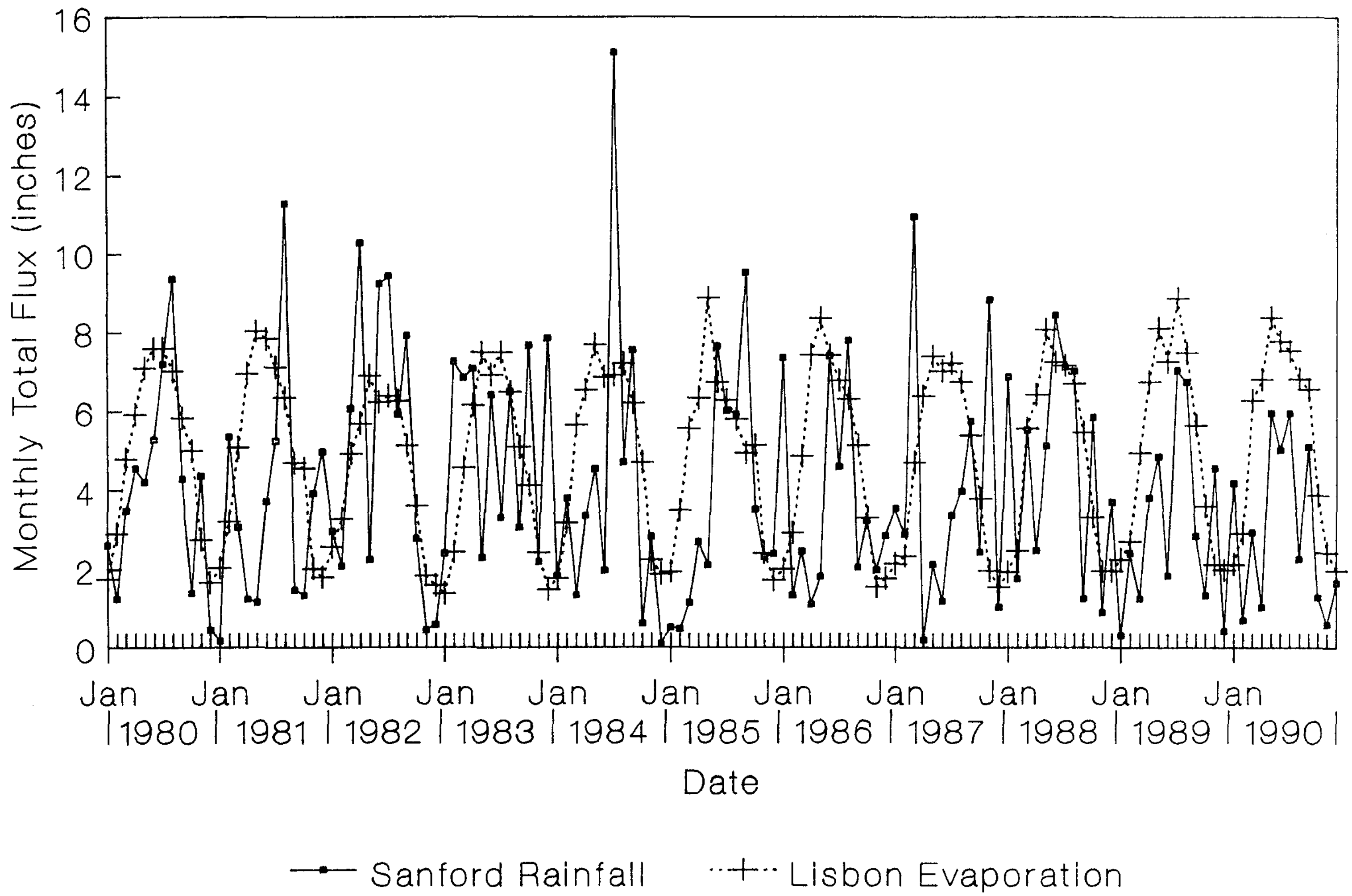

FIGURE 2.1.2-1. Monthly Totals for Sanford Rainfall and Lisbon Pan Evaporation in the vicinity of Lake Jessup, 1/80 to 12/90.

SOURCE: WAR 1991

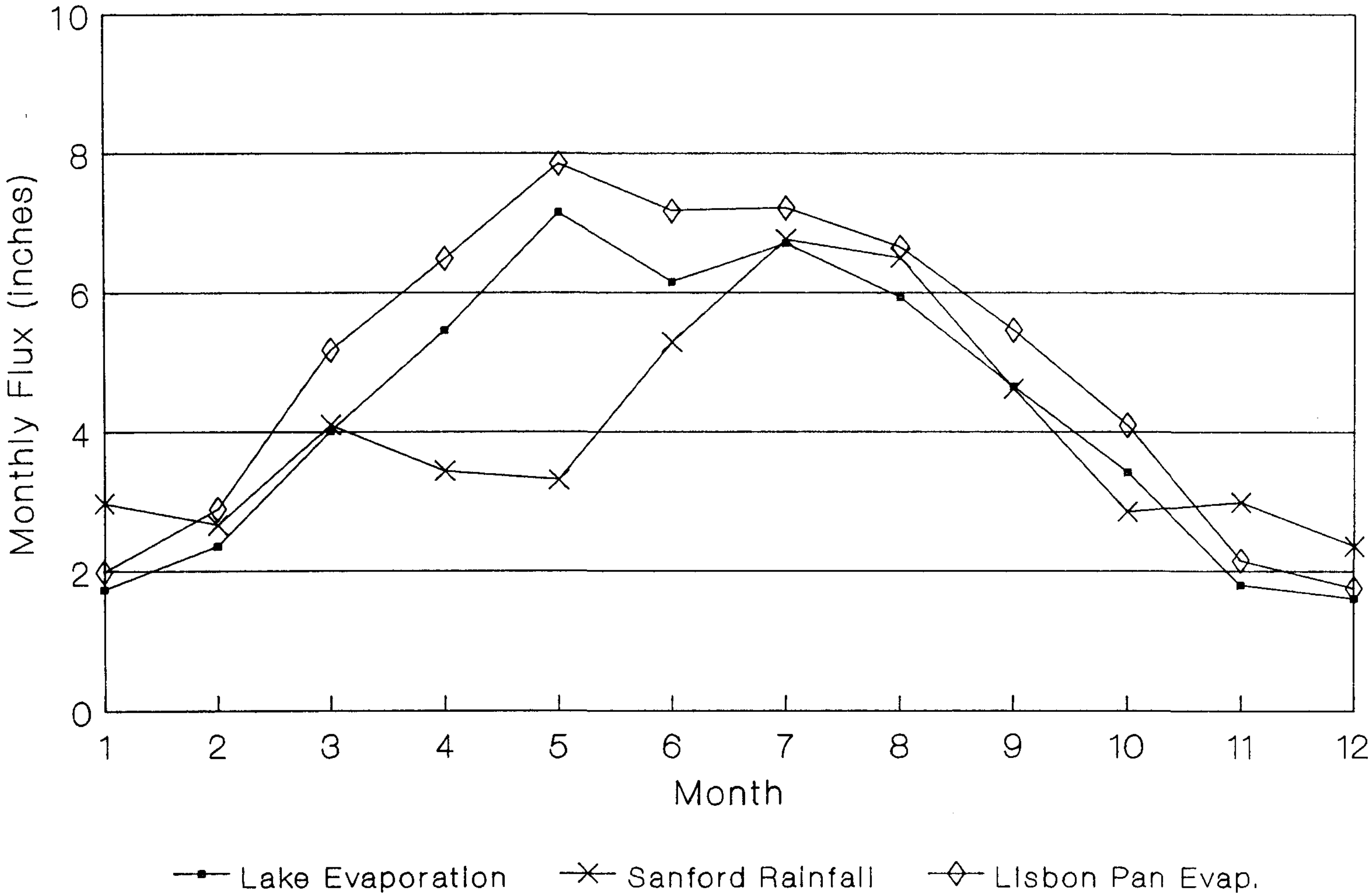

FIGURE 2.1.2-2. Average Monthly Lake Jessup Evaporation, Sanford Rainfall, and Lisbon Pan Evaporation, January 1980 to December 1990.

SOURCE: WAR 1991

Natural evapotranspiration data was obtained from SWFWMD (1975). Urban ET data was obtained from MacVicar et al. (1984). For the purpose of the water budget calculations, the natural and urban ET monthly values were averaged, then the monthly averages were adjusted to match the annual total ET for the Orlando area (34.31 inches) reported by Bartel and Barksdale (1985). The natural and urban ET were averaged because the monthly distribution of ET (or shape of the curves [Figure 2.1.2-3]) were different for each and it was desirable to have the influence of each land use type present in the ET distribution to represent the mix of land use types in the watershed. The monthly values were all scaled to equal the value for the Orlando area since the other ET distributions were obtained from different parts of Florida. Monthly adjusted Orlando ET ranged from 1.78 inches in January to 3.69 inches in August (Figure 2.1.2-3). Lake-pan evaporation coefficients were calculated from data presented in Lichtler et al. (1968) for Orlando area lakes. The lake-pan coefficients allow estimated lake evaporation to be calculated from measured pan evaporation data. Annual rainfall averaged 47.83 inches while annual lake evaporation averaged 50.94 inches. This represents an annual net loss to the atmosphere of over 3 inches for lakes within the watershed for 1980 through 1990.

2.1.3 Hydrologic Data

Stage and discharge data was compiled for selected United States Geological Survey (USGS) surface water stations in the vicinity of the Lake Jessup watershed (Table 2.1.3-1, Figure 2.1.3-1). Gaging stations were selected to supply discharge data for tributaries to Lake Jessup and stage data for St. Johns River stations upstream and downstream of the Lake Jessup confluence. Howell Creek had the largest average discharge of the three gaged Lake Jessup tributaries with a 1972 to 1990 average of 21,951 acre-feet per year. Gee Creek had an average discharge of 10,722 acre-feet per year. Soldier Creek is gaged at three locations, the downstream gage averaged 7,390 acre-feet per year. Average stages (1980 through 1990) of lakes Harney, Jessup, and Monroe were 2.32, 1.86, and 1.60 feet NGVD. This reflects the intermediate position of Lake Jessup between the St. Johns River lakes, Harney and Monroe.

Analysis of Lake Jessup stage data and modeling of the St. Johns River stage at the confluence with Lake Jessup revealed that lake stage (and, therefore,

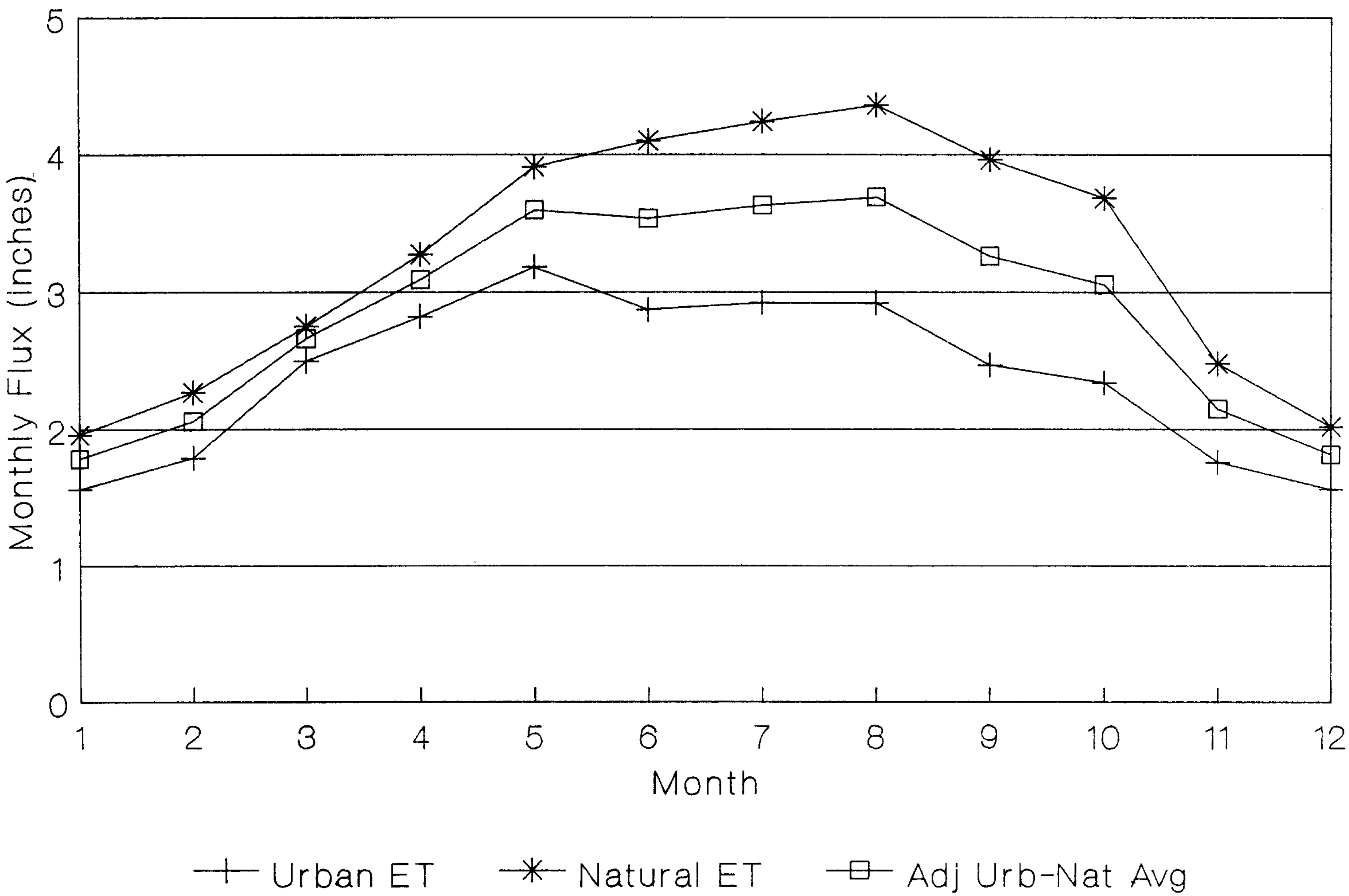

FIGURE 2.1.2-3. Average Monthly Urban Evapotranspiration, Natural Evapotranspiration, and Adjusted Urban-Natural Average, January 1980 to December 1990.

SOURCE: WAR 1991

Table 2.1.3-1. Selected USGS Gaging Stations in the Lake Jessup Watershed and Vicinity.

USGS Station I.D.	Name	Drainage Area (mi^2)	Stage Data Type	Discharge Data Type	Period of Record	Period of Record: Stage (feet)	Period of Record: Discharge (cfs)	Period of Record: Discharge (acre-ft/yr)
02234400	Gee Creek nr Longwood	12.8	N/A	Daily	1972 to Present	N/A	14.8	10722
02234000	St. Johns R. above Lk Harney	2043	Daily	Daily	1941 to Present	2.32 (*)	1606	1163487
02234324	Howell Creek nr Slavia	29.2	Daily	Daily	1972 to Present	N/R	30.3	21951
02234434	Lk Jessup nr Sanford	156	Weekly	N/A	1941 to Present	1.86 (*)	N/A	N/A
02234499	Lk Monroe nr Sanford	2582	Daily	N/A	1941 to Present	1.60 (*)	N/A	N/A
02234365	Soldier Creek nr Headwaters	7.86	Daily	Daily	1987 to Present	N/R	0.30 (**)	217
02234367	Soldier Creek at Lk Mary	9.16	Daily	Daily	1987 to Sept 1990	N/R	0.40 (**)	290
02234384	Soldier Creek nr Longwood	21.2	Daily	Daily	1972 to Present	N/R	10.2	7390

Notes:
(*) = Calculated average for period of record, 1980 through 1990
(**) = Average for water year 1990
N/A = Data not available
N/R = Data not reported in USGS 1990

Source: USGS 1990
WAR 1991

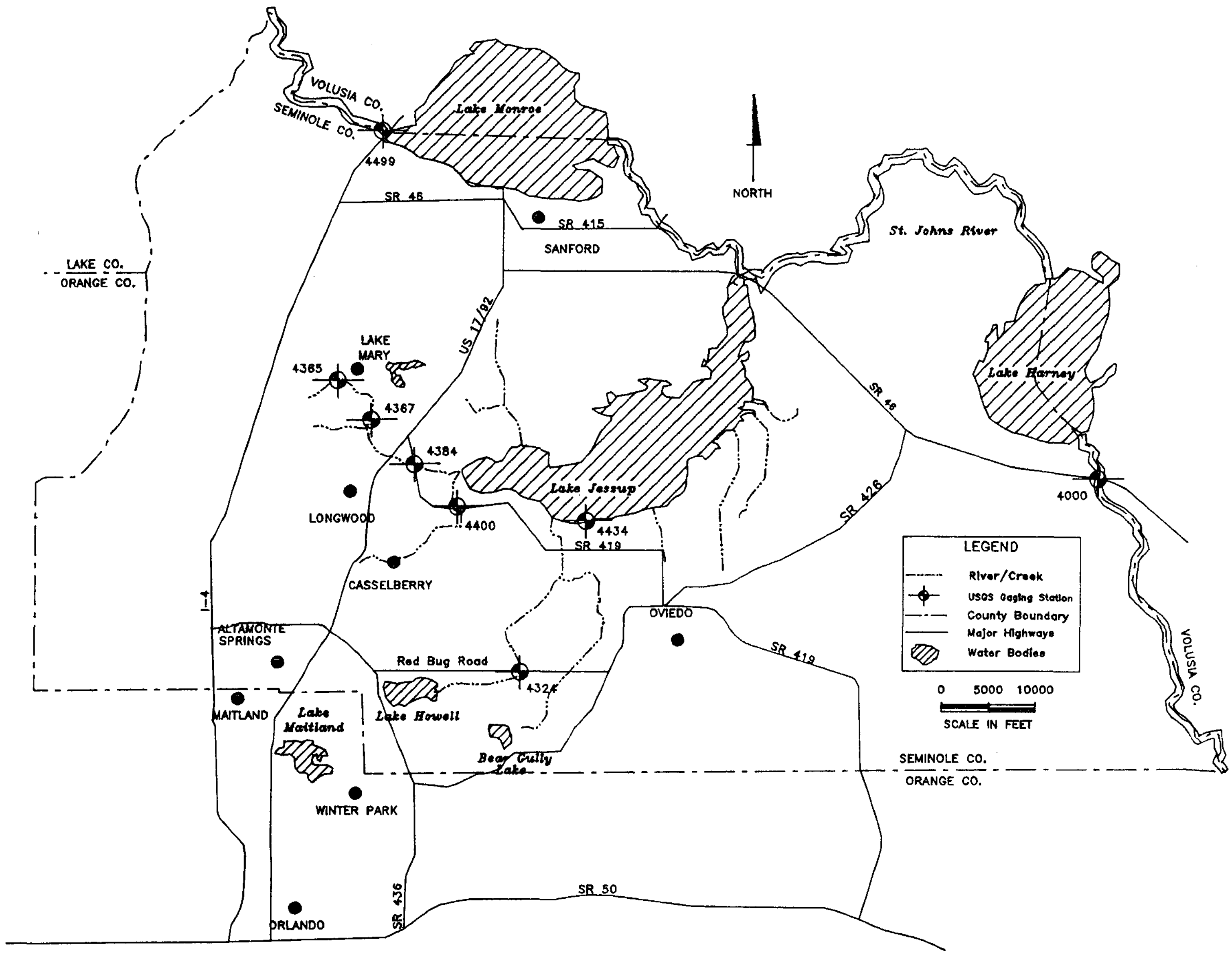

FIGURE 2.1.3-1. Location of USGS Stream and Lake Gaging Stations in the Vicinity of Lake Jessup.

SOURCE: WAR 1991

volume) is dependent on St. Johns River stage and not the watershed hydrodynamics. The high correlation (r-squared = 0.95) between the monthly stage at gages upstream (Lake Harney) and downstream (Lake Monroe) indicated that it should be possible to accurately determine the stage at a point on the river between the two gages (the confluence with Lake Jessup) by interpolation. The St. Johns River monthly average stage at the confluence was interpolated between the monthly average stages at the upstream and downstream gages according to the proportion of the river channel distance (open lake reaches were excluded) to the upstream gage to the total distance between the upstream and downstream gages. The calculated monthly average stage at the confluence correlated closely with monthly average stage in Lake Jessup (r-squared = 0.97, Figure 2.1.3-2), indicating that the St. Johns River water acts as dam or weir across the mouth of Lake Jessup whose elevation changes independently of the hydrologic inflows and outflows for the Lake Jessup watershed. The average (1980 through 1990) monthly stage of the St. Johns River at the confluence was 1.82 feet NGVD indicating that the predominant condition was discharge of Lake Jessup (1.86 feet NGVD) to the St. Johns River. River stage occasionally exceeds Lake Jessup stage (particularly during peaks) indicating flow from the river into Lake Jessup.

A stage-area-volume relationship for Lake Jessup was prepared by the Florida Game and Freshwater Fish Commission (Snyder et al. 1990). Stages ranged from -8 feet NGVD to +1 feet NGVD. This range was extended to +7 feet NGVD by determining the area below the 5-foot NGVD contour on the USGS topographic maps and interpolating for each of the 1-foot intervals between +1 and +5 feet NGVD and extrapolating for elevations +6 and +7 feet NGVD. The average end area method was used to determine the incremental volume for each elevation. Lake area increased from 9,150 acres at 0 feet NGVD (sea level) to 13,034 acres at 5 feet NGVD (Table 2.1.3-2). Corresponding volumes were 23,225 acre-feet and 78926 acre-feet, respectively. Area and volume at the 1980 through 1990 average stage of 1.86 feet NGVD was interpolated to be 10,661 acres and 42,216 acre-feet, respectively.

Runoff coefficients were calculated for subbasins GEESOLD and HOWELL from existing USGS discharge and NOAA rainfall data (Table 2.1.3-3). The most downstream USGS station for each tributary was chosen to reflect the hydrologic effects of as large an area as possible. The available daily

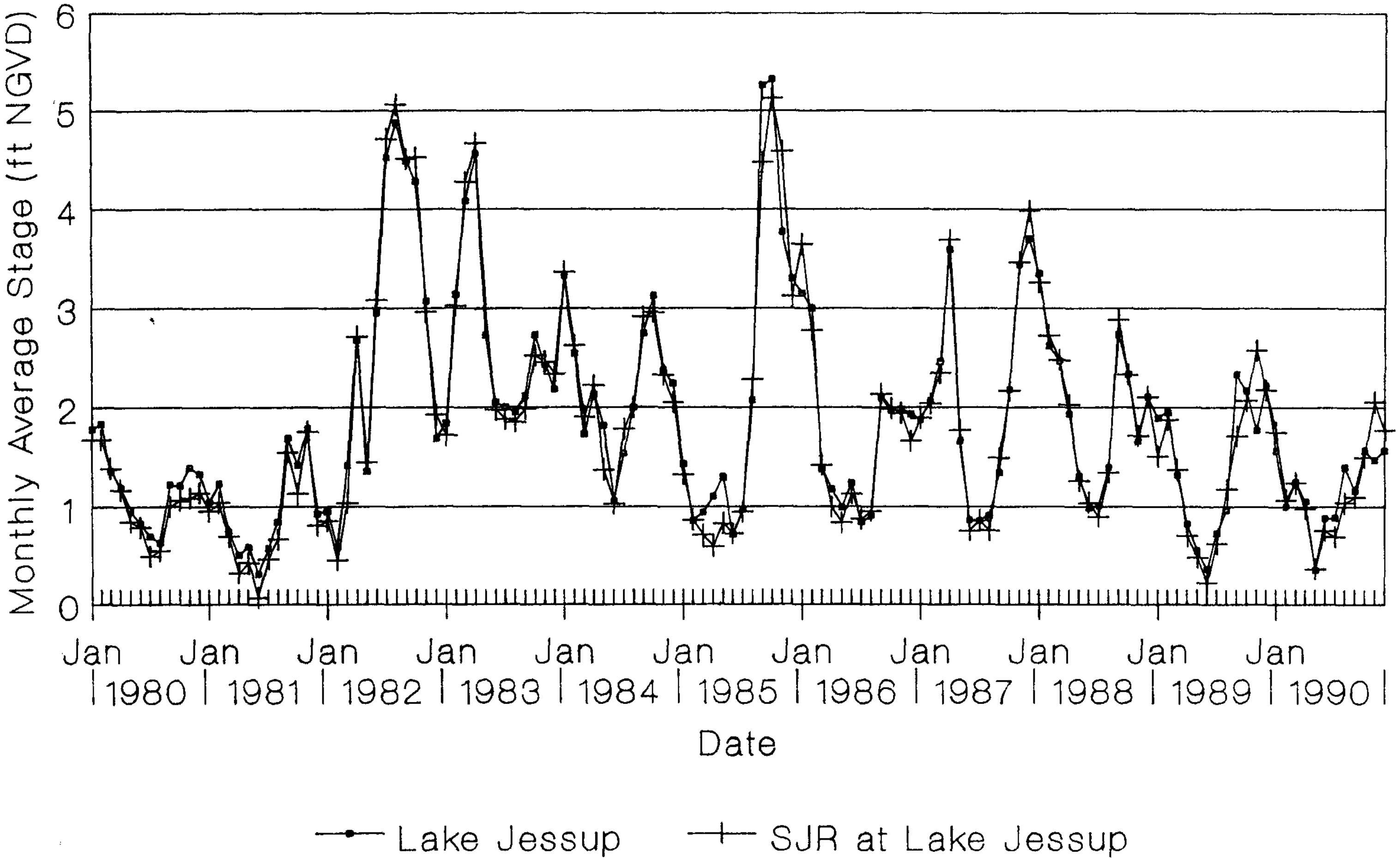

FIGURE 2.1.3-2. Lake Jessup Stage and Estimated Stage of St. Johns River at the Mouth of Lake Jessup.

SOURCE: WAR 1991

Table 2.1.3-2. Depth-Area-Volume Relationship for Lake Jessup.

Water Elevation (ft NGVD)	Surface Area (acres)	Increm'l Volume (acre-ft)	Cumulative Volume (acre-ft)	Reported Volume (acre-ft)
-8	0	0	0	0
-7	50	25	25	25
-6	140	95	120	120
-5	380	260	380	380
-4	1331	856	1236	1236
-3	3194	2263	3498	3499
-2	6007	4601	8099	8099
-1	7578	6793	14891	14891
0	9150	8364	23255	23256
1	10011	9581	32836	32836
2	10767	10389	43224	
3	11523	11145	54369	
4	12278	11900	66269	
5	13034	12656	78926	
6	13790	13412	92337	
7	14546	14168	106505	

Source: Snyder et al. 1990
WAR 1991

Table 2.1.3-3. Runoff Coefficients for Subbasins GEESOLD and HOWELL Calculated from Existing Hydrologic Data.

Parameter	Subbasin GEESOLD:		Subbasin HOWELL:
Tributary Name	Gee Creek	Soldier Creek	Howell Creek
USGS Station Number	02234400	02234384	02234324
USGS Station Name	Gee Crk nr Longwood	Soldier Crk nr Longwood	Howell Creek nr Slavia
Drainage Area (acres)	8192	13568	18688
Period of Record	1/72 to 9/79	1/72 to 9/90	1/72 to 9/90
Total Discharge (acre-ft)	89880	68995	148395
Total Sanford Rainfall (acre-ft)	273203	554524	574640
Runoff Coefficient, C	0.329	0.124	0.258
Weighting Factor (acres)	2695.14	1687.86	
Weighted Composite C		0.201	
Water Budget C		0.20	0.26

Source: WAR 1991
USGS 1990

discharge data for each station was summed for its period of record. Sanford daily rainfall for the corresponding time period was then summed. The quotient of total discharge to total rainfall was considered the runoff coefficient for the drainage area for that particular station. Since there were two gaged tributaries in GEESOLD, a weighted average coefficient was determined based on drainage area. The coefficients for GEESOLD (0.20) and HOWELL (0.26) were used instead of land-use-based runoff coefficients (Section 2.1.4).

2.1.4 Land Use and Cover Data

Land use and cover data was used primarily to determine runoff coefficients for the watershed subbasins. Irrigated land acreage was also used in determination of irrigation water application for runoff computations (Section 3.1.3), and lake acreage was used in determination of infiltration to groundwater and bank seepage (Section 3.1.4).

Drainage subbasins for the Lake Jessup watershed area were delineated from USGS 7.5-minute quadrangle topographic maps at a scale of 1:24,000 with contour intervals of 5 and 10 feet (Figure 1.2-1). Topographic maps used for delineation of the study area included Oviedo South West (USGS 1970b), Orlando East (USGS 1956), Orlando West (USGS 1980b), Oviedo (USGS 1970a), Casselberry (USGS 1980a), Forest City (USGS 1959), Osteen (USGS 1965a), Sanford (USGS 1965b), and Sanford South West (USGS 1965c). Digital mapping techniques were employed to create subbasin overlays for the topographic and land use maps as well as to determine lake and wetland acreage within the study basin.

The initial land use classification and corresponding land areas were compiled from the Seminole County Real Features Base Maps (Seminole County 1990) and the Seminole County Planning Area database (Seminole County 1989) (Table 2.1.4-1). Initial land use classification was then reduced to ten major land use categories corresponding to those developed for the Urban Stormwater Analysis and Improvement Study for the Tampa Bay Watershed (Dames & Moore 1990). Land use reduction was necessary because verifiable loading rate information is available for a limited number of land use types. To facilitate this reduction, commercial land use was converted to low-intensity commercial; general rural converted to open; high density residential converted to multi-family residential; medium density residential converted

Table 2.1.4-1 Subbasin Land Use Analyses for Composite Hydrologic Characteristics.

Subbasin ID.	Total Subbasin (acres)	Initial Land Use List	Composite Land Use Area (acres)	Final Land Use List	Adjusted Land Use Area (acres)	Runoff Coeff.	Imperv Fractn	Area Weighted Runoff Coeff.	Area Weighted Impervious Fraction	Irrigated Land Area (acres)
BLACKHMK	4046.56	AG	997.25	AG	1111.16	0.304	0.000	0.083	0.000	160.01
		COM	24.51	LIC	27.31	0.828	0.897	0.006	0.006	
		GR	272.13	OPEN	303.21	0.175	0.015	0.013	0.001	
		HDR	0.55	MFR	0.61	0.678	0.674	0.000	0.000	
		IND	1.66	IND	1.85	0.793	0.846	0.000	0.000	
		LDR	172.13	LDR	191.79	0.272	0.146	0.013	0.007	191.79
		MDR	0.70	MFR	0.78	0.678	0.674	0.000	0.000	0.78
		OPUB	11.65	SFR	12.98	0.369	0.276	0.001	0.001	
		PUB	13.04	OPEN	385.84	0.175	0.015	0.017	0.001	
		REC	4.19	REC	4.67	0.175	0.015	0.000	0.000	4.67
		SE	155.88	LDR	173.68	0.272	0.146	0.012	0.006	
		WETLAND	460.30	WETLAND	1832.70	0.225	0.000	0.102	0.000	
		WOODS	1517.76	LAKE	0.00	0.500	0.000	0.000	0.000	
		LAKES	0.00					-----	-----	------
								0.247	0.023	357.24
SWEETCRK	2856.65	AG	607.67	AG	548.31	0.304	0.000	0.058	0.000	78.96
		COM	35.86	LIC	32.36	0.828	0.897	0.003	0.010	
		GR	215.54	OPEN	194.48	0.175	0.015	0.021	0.001	
		HDR	0.68	MFR	0.61	0.678	0.674	0.000	0.000	
		IND	32.87	IND	29.66	0.793	0.846	0.003	0.009	
		LDR	258.83	LDR	233.54	0.272	0.146	0.025	0.012	233.54
		MDR	27.84	MFR	25.12	0.678	0.674	0.003	0.006	25.12
		OPUB	23.26	SFR	20.99	0.369	0.276	0.002	0.002	
		PUB	23.69	OPEN	586.81	0.175	0.015	0.062	0.003	
		REC	22.62	REC	20.41	0.175	0.015	0.002	0.000	20.41
		SCHOOLS	70.74	SFR	63.83	0.369	0.276	0.007	0.006	
		SE	177.45	LDR	160.11	0.272	0.146	0.017	0.008	
		UTIL	1.87	IND	1.69	0.793	0.846	0.000	0.000	
		VAC	480.14	WETLAND	919.41	0.225	0.000	0.098	0.000	
		WETLAND	919.411	LAKE	19.33	0.500	0.000	0.002	0.000	
		WOODS	1165.48		2856.65			-----	-----	------
		LAKES	19.33					0.304	0.058	358.02
EUREKA	963.55	AG	347.73	AG	299.36	0.304	0.000	0.094	0.000	47.35
		COM	2.62	LIC	2.48	0.828	0.897	0.002	0.002	
		GR	77.55	OPEN	73.33	0.175	0.015	0.013	0.001	
		IND	17.71	IND	16.75	0.793	0.846	0.014	0.015	
		LDR	17.09	LDR	16.16	0.272	0.146	0.005	0.002	16.16
		OPUB	1.89	SFR	1.78	0.369	0.276	0.001	0.001	
		PUB	0.74	OPEN	0.00	0.175	0.015	0.000	0.000	
		REC	44.03	REC	41.64	0.175	0.015	0.008	0.001	41.64
		SE	61.81	LDR	58.45	0.272	0.146	0.017	0.009	
		UTIL	0.61	IND	0.58	0.793	0.846	0.000	0.001	
		VAC	102.09	WETLAND	453.02	0.225	0.000	0.106	0.000	
		WETLAND	453.021	LAKE	0.00	0.500	0.000	0.000	0.000	
		WOODS	345.10					-----	-----	------
		LAKES	0.00					0.259	0.031	105.15
MARLBED	1410.65	AG	485.12	AG	6.77	0.304	0.000	0.001	0.000	73.25
		GR	98.57	OPEN	103.36	0.175	0.015	0.013	0.001	
		IND	10.25	IND	10.75	0.793	0.846	0.006	0.006	
		LDR	9.26	LDR	9.70	0.272	0.146	0.002	0.001	9.70
		REC	66.05	OPEN	0.00	0.175	0.015	0.000	0.000	
		SE	71.93	REC	0.00	0.175	0.015	0.000	0.000	69.26
		VAC	108.54	LDR	75.43	0.272	0.146	0.015	0.008	
		WETLAND	1204.649	WETLAND	1204.65	0.225	0.000	0.192	0.000	
		WOODS	495.54	LAKE	0.00	0.500	0.000	0.000	0.000	
		LAKES	0.00					-----	-----	------
								0.229	0.016	152.21

Table 2.1.4-1 Subbasin Land Use Analyses for Composite Hydrologic Characteristics (Continued).

Subbasin ID.	Total Subbasin (acres)	Initial Land Use List	Composite Land Use Area (acres)	Final Land Use List	Adjusted Land Use Area (acres)	Runoff Coeff.	Imperv Fractn	Area Weighted Runoff Coeff.	Area Weighted Impervious Fraction	Irrigated Land Area (acres)
SALTCRK	7046.37	AG	517.264	AG	423.71	0.304	0.000	0.018	0.000	61.01
		COM	2.817	LIC	2.31	0.828	0.897	0.000	0.000	
		GR	677.604	OPEN	555.05	0.175	0.015	0.014	0.001	
		HDR	0.109	MFR	0.09	0.678	0.674	0.000	0.000	
		LDR	14.107	LDR	11.56	0.272	0.146	0.000	0.000	11.56
		MDR	0.06	MFR	0.05	0.678	0.674	0.000	0.000	0.05
		OPUB	125.432	SFR	102.75	0.369	0.276	0.005	0.004	
		PUB	2980.11	OPEN	1737.68	0.175	0.015	0.043	0.004	
		REC	0.1	REC	0.08	0.175	0.015	0.000	0.000	0.08
		SE	268.3	LDR	219.77	0.272	0.146	0.008	0.005	
		UTIL	0.735	IND	0.60	0.793	0.846	0.000	0.000	
		VAC	1137.486	WETLAND	3869.32	0.225	0.000	0.124	0.000	
		WETLAND	3869.32	LAKE	123.40	0.500	0.000	0.009	0.000	
		WOODS	2727.425					-----	-----	------
		LAKES	123.4					0.222	0.014	72.70
AIRPORT	8649.34	AG	2035.973	AG	2012.94	0.304	0.000	0.071	0.000	289.86
		COM	25.613	LIC	25.32	0.828	0.897	0.002	0.003	
		GR	304.035	OPEN	300.60	0.175	0.015	0.006	0.001	
		HDR	3.25	MFR	3.21	0.678	0.674	0.000	0.000	
		IND	1309.272	IND	1294.46	0.793	0.846	0.119	0.127	
		LDR	202.939	LDR	200.64	0.272	0.146	0.006	0.003	200.64
		MDR	14.583	MFR	14.42	0.678	0.674	0.001	0.001	14.42
		OPUB	4.201	SFR	4.15	0.369	0.276	0.000	0.000	
		PUB	1698.042	OPEN	1342.98	0.175	0.015	0.027	0.002	
		REC	76.3	REC	75.44	0.175	0.015	0.002	0.000	75.44
		SCHOOLS	10.775	SFR	10.65	0.369	0.276	0.000	0.000	
		SE	331.416	LDR	327.67	0.272	0.146	0.010	0.006	
		UTIL	2.16	IND	2.14	0.793	0.846	0.000	0.000	
		VAC	1710.432	WETLAND	2947.62	0.225	0.000	0.077	0.000	
		WETLAND	2947.617	LAKE	87.11	0.500	0.000	0.005	0.000	
		WOODS	931.216					-----	-----	------
		LAKES	87.11					0.327	0.143	580.36
SANFDAVE	5611.81	AG	375.86	AG	403.91	0.304	0.000	0.022	0.000	58.16
		COM	276.88	LIC	297.55	0.828	0.897	0.044	0.048	
		GR	158.59	OPEN	170.42	0.175	0.015	0.005	0.000	
		HDR	65.70	MFR	70.60	0.678	0.674	0.009	0.008	
		IND	49.66	IND	53.36	0.793	0.846	0.008	0.008	
		LDR	988.00	LDR	1061.75	0.272	0.146	0.051	0.028	1061.75
		MDR	143.66	MFR	154.38	0.678	0.674	0.019	0.019	154.38
		OPUB	73.51	SFR	79.00	0.369	0.276	0.005	0.004	
		PUB	119.38	OPEN	1391.45	0.175	0.015	0.043	0.004	
		REC	79.08	REC	84.98	0.175	0.015	0.003	0.000	84.98
		SCHOOLS	215.06	SFR	231.11	0.369	0.276	0.015	0.011	
		SE	280.56	LDR	301.51	0.272	0.146	0.015	0.008	
		UTIL	15.10	IND	16.23	0.793	0.846	0.002	0.002	
		VAC	986.89	WETLAND	977.84	0.225	0.000	0.039	0.000	
		WETLAND	977.836	LAKE	317.72	0.500	0.000	0.028	0.000	
		WOODS	1098.45					-----	-----	-------
		LAKES	317.72					0.308	0.140	1359.27

Table 2.1.4-1 Subbasin Land Use Analyses for Composite Hydrologic Characteristics (Continued).

Subbasin ID.	Total Subbasin (acres)	Initial Land Use List	Composite Land Use Area (acres)	Final Land Use List	Adjusted Land Use Area (acres)	Runoff Coeff.	Imperv Fractn	Area Weighted Runoff Coeff.	Area Weighted Impervious Fraction	Irrigated Land Area (acres)
GEESOLD	27267.51	AG	855.957	AG	921.12	0.304	0.000	0.010	0.000	132.64
		COM	1214.401	LIC	1304.20	0.828	0.897	0.040	0.043	
		GR	907.24	OPEN	976.63	0.175	0.015	0.006	0.001	
		HDR	309.849	MFR	333.07	0.678	0.674	0.008	0.008	
		IND	622.54	IND	668.64	0.793	0.846	0.019	0.021	
		LDR	6221.823	LDR	6687.93	0.272	0.146	0.067	0.036	6687.93
		MDR	973.305	MFR	1046.13	0.678	0.674	0.026	0.026	1046.13
		OPUB	231.146	SFR	248.35	0.369	0.276	0.003	0.003	
		PUB	215.041	OPEN	9933.38	0.175	0.015	0.064	0.005	
		REC	1006.011	REC	1080.74	0.175	0.015	0.007	0.001	1080.74
		SCHOOLS	294.407	SFR	316.64	0.369	0.276	0.004	0.003	
		SE	1435.536	LDR	1543.92	0.272	0.146	0.015	0.008	
		UTIL	136.447	IND	146.69	0.793	0.846	0.004	0.005	
		VAC	5149.632	WETLAND	545.47	0.225	0.000	0.005	0.000	
		WETLAND	545.469	LAKE	1747.17	0.500	0.000	0.032	0.000	
		WOODS	4582.154					-----	-----	-------
		LAKES	1747.167					0.311	0.159	8947.44
HOWELL	32153.42	OPEN		OPEN	491.27	0.175	0.015	0.003	0.000	491.27
		LDR		LDR	1584.21	0.272	0.146	0.016	0.008	1584.21
		HDR		MFR	11139.16	0.678	0.674	0.277	0.275	
		AG		AG	3792.17	0.304	0.000	0.042	0.000	546.07
		WOODS		OPEN	8390.25	0.175	0.015	0.054	0.005	
		WETLAND		WETLAND	3433.38	0.225	0.000	0.028	0.000	
		LAKES		LAKE	3322.98	0.500	0.000	0.061	0.000	
								-----	-----	------
								0.481	0.289	2621.56

Notes:
- Initial land use data obtained from the Seminole County Planning Dept except for HOWELL
- HOWELL land use data obtained from Suphunvorranop and Clapp (1984)
- Runoff coefficients and impervious fractions data obtained from Dames & Moore (1990)
- Irrigated land use data obtained from Shermyen et al. (1990)

Key to Final Land Use Categories:

AG = Agricultural
LIC = Low Intensity Commercial
OPEN = Open (ie. Parks, Ball Fields, etc)
LDR = Low Density Residential
SFR = Single-Family Residential
REC = Recreational
IND = Industrial
MFR = Multi-Family Residential
LAKE = Lake
WETLAND = Wetland

Source: WAR 1991

multi-family residential; other public land converted to single family residential; public, vacancy, and woods converted to open; and suburban estates converted to low density residential.

The Seminole County Wetlands map (SJRWMD 1987) was used in conjunction with subbasin overlays to determine the area of wetlands in each subbasin. Lake areas were digitized from the topographic maps at a scale of 1:24,000 (Table 2.1.4-1).

Area-weighted runoff coefficients and impervious fractions (areal proportion of impervious surfaces) were estimated by multiplying the individual land use areas by their associated runoff coefficients and impervious fractions reported by Dames & Moore (1990) (Table 2.1.4-1). Runoff coefficients for the study area ranged from a maximum of 0.481 for subbasin HOWELL to a minimum of 0.222 for subbasin SALTCRK. Likewise, SALTCRK had the lowest impervious fraction at 0.014 as opposed to HOWELL which had the highest impervious fraction of 0.289. Runoff coefficients used in the water budget calculations for GEESOLD and HOWELL subbasins were determined from existing rainfall and discharge records by dividing the period of record total rainfall by the period of record total discharge at USGS gaging stations.

Irrigated land area was calculated by adding the areas for land uses most likely to be irrigated (Table 2.1.4-1). These land uses included agricultural, low density residential, multi-family residential, and recreational. Only a fraction of the agricultural land use classification was used for irrigated area. The irrigated area ratio for agriculture land was determined from the ratio of cropland area within Seminole County to the total farmland area within the county reported by Shermyen, et al. (1990). The irrigation factor for each subbasin was the ratio of the total irrigated land area to the total subbasin area.

Area-weighted pollutant loading rates were estimated by multiplying the individual land use areas by their associated total nitrogen, total phosphorus, and ortho-phosphorus stormwater concentrations as developed in the Urban Stormwater Analysis and Improvement Study for the Tampa Bay Watershed (Dames & Moore 1990) (Table 2.1.4-2). Total subbasin pollutant loading rates were then calculated by summing the pollutant contributions of each land use

Table 2.1.4-2. Determination of Land Use Based Runoff Nutrient Loading Concentrations for the Lake Jessup Watershed.

Subbasin ID.	Total Subbasin (acres)	Final Land Use List	Adjusted Subbasin Land Use (acres)	D & M Land Use List	D & M Recommended Nutrient Loading Conc.'s: Total N (mg/L)	Ortho-P (mg/L)	Total P (mg/L)	Weighting Factors and Area-Weighted Nutrient Conc.'s: Total N (mg/L)	Ortho-P (mg/L)	Total P (mg/L)
BLACKHMK	4047	AG	1111.16	AG	2.320	0.227	0.344	0.637	0.062	0.094
		COM	27.31	LIC	1.060	0.050	0.140	0.007	0.000	0.001
		GR	303.21	OPEN	1.250	0.004	0.053	0.094	0.000	0.004
		HDR	0.61	MFR	2.280	0.380	0.510	0.000	0.000	0.000
		IND	1.85	IND	1.790	0.130	0.310	0.001	0.000	0.000
		LDR	191.79	LDR	1.680	0.097	0.215	0.080	0.005	0.010
		MDR	0.78	MFR	2.280	0.380	0.510	0.000	0.000	0.000
		OPUB	12.98	SFR	2.170	0.190	0.350	0.007	0.001	0.001
		OPEN	385.84	OPEN	1.250	0.004	0.053	0.119	0.000	0.005
		REC	4.67	REC	1.250	0.004	0.053	0.001	0.000	0.000
		SE	173.68	LDR	1.680	0.097	0.215	0.072	0.004	0.009
		WETLAND	1832.70	WETLAND	1.600	0.130	0.190	0.725	0.059	0.086
		LAKES	0.00	LAKE	1.250	0.130	0.110	0.000	0.000	0.000
								-----	-----	-----
		BLACKHMK Subbasin Composite Loading Concentrations:						1.743	0.132	0.211
SWEETCRK	2857	AG	548.31	AG	2.320	0.227	0.344	0.445	0.044	0.066
		COM	32.36	LIC	1.060	0.050	0.140	0.012	0.001	0.002
		GR	194.48	OPEN	1.250	0.004	0.053	0.085	0.000	0.004
		HDR	0.61	MFR	2.280	0.380	0.510	0.000	0.000	0.000
		IND	29.66	IND	1.790	0.130	0.310	0.019	0.001	0.003
		LDR	233.54	LDR	1.680	0.097	0.215	0.137	0.008	0.018
		MDR	25.12	MFR	2.280	0.380	0.510	0.020	0.003	0.004
		OPUB	20.99	SFR	2.170	0.190	0.350	0.016	0.001	0.003
		OPEN	586.81	OPEN	1.250	0.004	0.053	0.257	0.001	0.011
		REC	20.41	REC	1.250	0.004	0.053	0.009	0.000	0.000
		SCHOOLS	63.83	SFR	2.170	0.190	0.350	0.048	0.004	0.008
		SE	160.11	LDR	1.680	0.097	0.215	0.094	0.005	0.012
		UTIL	1.69	IND	1.790	0.130	0.310	0.001	0.000	0.000
		WETLAND	919.41	WETLAND	1.600	0.130	0.190	0.515	0.042	0.061
		LAKES	19.33	LAKE	1.250	0.130	0.110	0.008	0.001	0.001
								-----	-----	-----
		SWEETCRK Subbasin Composite Loading Concentrations:						1.668	0.112	0.192
EUREKA	964	AG	299.36	AG	2.320	0.227	0.344	0.721	0.071	0.107
		COM	2.48	LIC	1.060	0.050	0.140	0.003	0.000	0.000
		GR	73.33	OPEN	1.250	0.004	0.053	0.095	0.000	0.004
		IND	16.75	IND	1.790	0.130	0.310	0.031	0.002	0.005
		LDR	16.16	LDR	1.680	0.097	0.215	0.028	0.002	0.004
		OPUB	1.78	SFR	2.170	0.190	0.350	0.004	0.000	0.001
		OPEN	0.00	OPEN	1.250	0.004	0.053	0.000	0.000	0.000
		REC	41.64	REC	1.250	0.004	0.053	0.054	0.000	0.002
		SE	58.45	LDR	1.680	0.097	0.215	0.102	0.006	0.013
		UTIL	0.58	IND	1.790	0.130	0.310	0.001	0.000	0.000
		WETLAND	453.02	WETLAND	1.600	0.130	0.190	0.752	0.061	0.089
		LAKES	0.00	LAKE	1.250	0.130	0.110	0.000	0.000	0.000
								-----	-----	-----
		EUREKA Subbasin Composite Loading Concentrations:						1.791	0.142	0.226

Table 2.1.4-2. Determination of Land Use Based Runoff Nutrient Loading Concentrations for the Lake Jessup Watershed (Continued).

Subbasin ID.	Total Subbasin (acres)	Final Land Use List	Adjusted Subbasin Land Use (acres)	D & M Land Use List	D & M Recommended Nutrient Loading Conc.'s: Total N (mg/L)	Ortho-P (mg/L)	Total P (mg/L)	Weighting Factors and Area-Weighted Nutrient Conc.'s: Total N (mg/L)	Ortho-P (mg/L)	Total P (mg/L)
MARLBED	1411	AG	6.77	AG	2.320	0.227	0.344	0.011	0.001	0.002
		GR	103.36	OPEN	1.250	0.004	0.053	0.092	0.000	0.004
		IND	10.75	IND	1.790	0.130	0.310	0.014	0.001	0.002
		LDR	9.70	LDR	1.680	0.097	0.215	0.012	0.001	0.001
		OPEN	0.00	OPEN	1.250	0.004	0.053	0.000	0.000	0.000
		REC	0.00	REC	1.250	0.004	0.053	0.000	0.000	0.000
		SE	75.43	LDR	1.680	0.097	0.215	0.090	0.005	0.011
		WETLAND	1204.65	WETLAND	1.600	0.130	0.190	1.366	0.111	0.162
		LAKES	0.00	LAKE	1.250	0.130	0.110	0.000	0.000	0.000
								-----	-----	-----
		MARLBED Subbasin Composite Loading Concentrations:						1.584	0.119	0.183
SALTCRK	7046	AG	423.71	AG	2.320	0.227	0.344	0.140	0.014	0.021
		COM	2.31	LIC	1.060	0.050	0.140	0.000	0.000	0.000
		GR	555.05	OPEN	1.250	0.004	0.053	0.098	0.000	0.004
		HDR	0.09	MFR	2.280	0.380	0.510	0.000	0.000	0.000
		LDR	11.56	LDR	1.680	0.097	0.215	0.003	0.000	0.000
		MDR	0.05	MFR	2.280	0.380	0.510	0.000	0.000	0.000
		OPUB	102.75	SFR	2.170	0.190	0.350	0.032	0.003	0.005
		OPEN	1737.68	OPEN	1.250	0.004	0.053	0.308	0.001	0.013
		REC	0.08	REC	1.250	0.004	0.053	0.000	0.000	0.000
		SE	219.77	LDR	1.680	0.097	0.215	0.052	0.003	0.007
		UTIL	0.60	IND	1.790	0.130	0.310	0.000	0.000	0.000
		WETLAND	3869.32	WETLAND	1.600	0.130	0.190	0.879	0.071	0.104
		LAKES	123.40	LAKE	1.250	0.130	0.110	0.022	0.002	0.002
								-----	-----	-----
		SALTCRK Subbasin Composite Loading Concentrations:						1.534	0.095	0.156
AIRPORT	8649	AG	2012.94	AG	2.320	0.227	0.344	0.540	0.053	0.080
		COM	25.32	LIC	1.060	0.050	0.140	0.003	0.000	0.000
		GR	300.60	OPEN	1.250	0.004	0.053	0.043	0.000	0.002
		HDR	3.21	MFR	2.280	0.380	0.510	0.001	0.000	0.000
		IND	1294.46	IND	1.790	0.130	0.310	0.268	0.019	0.046
		LDR	200.64	LDR	1.680	0.097	0.215	0.039	0.002	0.005
		MDR	14.42	MFR	2.280	0.380	0.510	0.004	0.001	0.001
		OPUB	4.15	SFR	2.170	0.190	0.350	0.001	0.000	0.000
		OPEN	1342.98	OPEN	1.250	0.004	0.053	0.194	0.001	0.008
		REC	75.44	REC	1.250	0.004	0.053	0.011	0.000	0.000
		SCHOOLS	10.65	SFR	2.170	0.190	0.350	0.003	0.000	0.000
		SE	327.67	LDR	1.680	0.097	0.215	0.064	0.004	0.008
		UTIL	2.14	IND	1.790	0.130	0.310	0.000	0.000	0.000
		WETLAND	2947.62	WETLAND	1.600	0.130	0.190	0.545	0.044	0.065
		LAKES	87.11	LAKE	1.250	0.130	0.110	0.013	0.001	0.001
								-----	-----	-----
		AIRPORT Subbasin Composite Loading Concentrations:						1.729	0.126	0.218

Table 2.1.4-2. Determination of Land Use Based Runoff Nutrient Loading Concentrations for the Lake Jessup Watershed (Continued).

Subbasin ID.	Total Subbasin (acres)	Final Land Use List	Adjusted Subbasin Land Use (acres)	D & M Land Use List	D & M Recommended Nutrient Loading Conc.'s: Total N (mg/L)	Ortho-P (mg/L)	Total P (mg/L)	Weighting Factors and Area-Weighted Nutrient Conc.'s: Total N (mg/L)	Ortho-P (mg/L)	Total P (mg/L)
SANFDAVE	5612	AG	403.91	AG	2.320	0.227	0.344	0.167	0.016	0.025
		COM	297.55	LIC	1.060	0.050	0.140	0.056	0.003	0.007
		GR	170.42	OPEN	1.250	0.004	0.053	0.038	0.000	0.002
		HDR	70.60	MFR	2.280	0.380	0.510	0.029	0.005	0.006
		IND	53.36	IND	1.790	0.130	0.310	0.017	0.001	0.003
		LDR	1061.75	LDR	1.680	0.097	0.215	0.318	0.018	0.041
		MDR	154.38	MFR	2.280	0.380	0.510	0.063	0.010	0.014
		OPUB	79.00	SFR	2.170	0.190	0.350	0.031	0.003	0.005
		OPEN	1391.45	OPEN	1.250	0.004	0.053	0.310	0.001	0.013
		REC	84.98	REC	1.250	0.004	0.053	0.019	0.000	0.001
		SCHOOLS	231.11	SFR	2.170	0.190	0.350	0.089	0.008	0.014
		SE	301.51	LDR	1.680	0.097	0.215	0.090	0.005	0.012
		UTIL	16.23	IND	1.790	0.130	0.310	0.005	0.000	0.001
		WETLAND	977.84	WETLAND	1.600	0.130	0.190	0.279	0.023	0.033
		LAKES	317.72	LAKE	1.250	0.130	0.110	0.071	0.007	0.006
								-----	-----	-----
		SANFDAVE Subbasin Composite Loading Concentrations:						1.581	0.101	0.183
GEESOLD	27268	AG	921.12	AG	2.320	0.227	0.344	0.078	0.008	0.012
		COM	1304.20	LIC	1.060	0.050	0.140	0.051	0.002	0.007
		GR	976.63	OPEN	1.250	0.004	0.053	0.045	0.000	0.002
		HDR	333.07	MFR	2.280	0.380	0.510	0.028	0.005	0.006
		IND	668.64	IND	1.790	0.130	0.310	0.044	0.003	0.008
		LDR	6687.93	LDR	1.680	0.097	0.215	0.412	0.024	0.053
		MDR	1046.13	MFR	2.280	0.380	0.510	0.087	0.015	0.020
		OPUB	248.35	SFR	2.170	0.190	0.350	0.020	0.002	0.003
		OPEN	9933.38	OPEN	1.250	0.004	0.053	0.455	0.001	0.019
		REC	1080.74	REC	1.250	0.004	0.053	0.050	0.000	0.002
		SCHOOLS	316.64	SFR	2.170	0.190	0.350	0.025	0.002	0.004
		SE	1543.92	LDR	1.680	0.097	0.215	0.095	0.005	0.012
		UTIL	146.69	IND	1.790	0.130	0.310	0.010	0.001	0.002
		WETLAND	545.47	WETLAND	1.600	0.130	0.190	0.032	0.003	0.004
		LAKES	1747.17	LAKE	1.250	0.130	0.110	0.080	0.008	0.007
								-----	-----	-----
		GEESOLD Subbasin Composite Loading Concentrations:						1.512	0.079	0.160
HOWELL	32153	OPEN	491.27	OPEN	1.250	0.004	0.053	0.023	0.000	0.001
		LDR	1584.21	LDR	1.680	0.097	0.215	0.098	0.006	0.012
		HDR	11139.16	MFR	2.280	0.380	0.510	0.931	0.155	0.208
		AG	3792.17	AG	2.320	0.227	0.344	0.323	0.032	0.048
		WOODS	8390.25	OPEN	1.250	0.004	0.053	0.385	0.001	0.016
		WETLAND	3433.38	WETLAND	1.600	0.130	0.190	0.201	0.016	0.024
		LAKES	3322.98	LAKE	1.250	0.130	0.110	0.152	0.016	0.013
								-----	-----	-----
		HOWELL Subbasin Composite Loading Concentrations:						2.113	0.226	0.323

Table 2.1.4-2. Determination of Land Use Based Runoff Nutrient Loading Concentrations for the Lake Jessup Watershed (Continued).

Subbasin ID.	Total Subbasin (acres)	Final Land Use List	Adjusted Subbasin Land Use (acres)	D & M Land Use List	D & M Recommended Nutrient Loading Conc.'s: Total N (mg/L)	Ortho-P (mg/L)	Total P (mg/L)	Weighting Factors and Area-Weighted Nutrient Conc.'s: Total N (mg/L)	Ortho-P (mg/L)	Total P (mg/L)

Notes:

Initial land use data obtained from Seminole County Planning Dept, except for HOWELL
HOWELL land use data obtained from Suphunvorranop and Clapp (1984)
Nutrient loading concentrations data obtained from Dames & Moore (1990)

Key to Final Land Use Categories:

AG = Agricultural
LIC = Low Intensity Commercial
OPEN = Open (ie. Parks, Ball Fields, etc)
LDR = Low Density Residential
SFR = Single-Family Residential
REC = Recreational
IND = Industrial
MFR = Multi-Family Residential
LAKE = Lake
WETLAND = Wetland

Source: WAR 1991

type within the subbasin for each of the three parameters. Inorganic nitrogen was determined from total nitrogen by the average ratio of inorganic nitrogen to total nitrogen (0.1725) for various land uses in data presented by Hardee et al. (1979) (Table 2.1.4-2). Agricultural, single family residential, and multi-family residential land uses had the highest runoff pollutant concentrations. Land uses with low runoff pollutant concentrations included low-intensity commercial, open, and recreational. Subbasin composite loading concentrations did not vary dramatically. Subbasin GEESOLD had the lowest loading concentrations of total nitrogen (1.512 mg/L), inorganic nitrogen (0.261 mg/L), total phosphorus (0.160 mg/L), and ortho-phosphorus (0.079 mg/L). Subbasin HOWELL had the highest loading concentrations of total nitrogen (2.113 mg/L), inorganic nitrogen (0.364 mg/L), total phosphorus (0.323 mg/L), and ortho-phosphorus (0.226 mg/L).

2.1.5 <u>On-site Sewage Disposal System (OSDS) Data</u>

OSDSs are treatment facilities for individual residential structures. OSDSs consist primarily of septic tanks for single- or multiple-family residences. Septic tank data was gathered from the Sanitary Sewer Element of the Seminole County 1991 Comprehensive Plan (Seminole County 1991) and the Support Document, Volume III, of the Seminole County 1991 Comprehensive Plan Update in order to determine the quantity of water and nitrogen contributed to Lake Jessup by septic tanks within the watershed subbasins.

Total wastewater demand met by septic tanks is approximately 5.4 MGD, or about 18 percent of the total wastewater demand in Seminole County (1991 Seminole County Comprehensive Plan). According to the <u>Septic Tank Density Analysis</u> prepared by Post, Buckley, Schuh and Jernigan, Inc. (PBS&J) in September 1987, there were approximately 26,000 septic tanks in the county. This study did not geographically determine the location of those septic tanks. Further investigation revealed that little information was available on location of septic tanks within the county. Thus, an area-weighted approach based on city population was used to estimate the location and number of septic tanks within the watershed to determine the contribution of septic tanks to the water budget (their discharge is an addition of water to the watershed from the deep aquifer and enters the lake through the shallow groundwater pathway) (Section 3.1.5) and nutrient budget (Section 4.1.4).

It was assumed that approximately half or 15,000 of the 26,000 septic tanks in Seminole County were located in the Lake Jessup watershed. City population projections for a select number of cities in Seminole County were obtained from the Florida Statistical Abstract 1990 (Shermyen et al. 1990). The number and relative location of septic tanks in the watershed was estimated by applying an area-weighting methodology based on city location within or between subbasins and population projections. The ratio of each subbasin population to total population was used to distribute the total number of OSDSs between the subbasins. Additional data were incorporated from the 1990 Comprehensive Plan for the city of Casselberry, which reported approximately 2,100 septic tanks within the city limits split between GEESOLD and HOWELL subbasins.

Subbasin GEESOLD (Figure 1.2-1) had the highest number of OSDSs (3,471) (Table 2.1.5-1) due to its high degree of urbanization, followed by AIRPORT (2,437), SANFDAVE (2,068), HOWELL (1,738), SALTCRK (1,599), and SWEETCRK (1,288). Subbasins MARLBED, BLACKHMK, and EUREKA had 800 OSDSs each. It should be noted that the results of this distribution were determined more by the assumptions used than by use of actual detailed data, which does not exist.

2.1.6 Wastewater Treatment Plant (WWTP) Data

WWTP data was compiled from the Sanitary Sewer Element of the Seminole County 1991 Comprehensive Plan and the Support Document, Volume III, of the Seminole County 1991 Comprehensive Plan Update. Within the county, there are a total of 20 city, private, and county central system collecting plants that collect, treat, and discharge a total of 25.4 million gallons of wastewater per day (MGD). There are 20 treatment plants in the county, but only six plants operate and discharge within the Lake Jessup watershed. These include Shadow Hills, Tuscawilla, Des Pinar, Greenwood Lakes, Winter Springs, and Casselberry (Table 2.1.6-1). Operating capacity of the wastewater treatment plants within the watershed totals 8.7 MGD, which is about 71 percent of the design capacity of 12.3 MGD. Effluent disposal methods include percolation ponds, spray fields, and reclaimed water systems. None of the facilities discharge directly to surface waters. However, their discharge affects the water budget (Section 3.1.6) as an addition of water from the deep aquifer, entering the lake through the shallow groundwater pathway, and the nutrient budget

Table 2.1.5-1 Estimated Distribution of Septic Tanks in the Lake Jessup Watershed.

Number of Septic Tanks in Study Area = 15,000

City/Area	Population Projection 1989	Lake Jessup Subbasin	% City Within Subbasin	Area Weighted Population	Septic Tanks Per Subbasin
Seminole Co.	281049				
Alt. Springs	37502	HOWELL	0.50	18,751	1,035
		GEESOLD	0.25	9,376	518
Casselberry	18230	GEESOLD	0.50	9,115	503
		HOWELL	0.50	9,115	503
Lake Mary	5686	GEESOLD	0.90	5,117	283
		SANFDAVE	0.10	569	31
Longwood	13948	GEESOLD	1.00	13,948	770
Oviedo	8844	SWEETCRK	1.00	8,844	488
Sanford	30346	SANFDAVE	0.50	15,173	838
		AIRPORT	0.50	15,173	838
Winter Springs	21682	GEESOLD	1.00	21,682	1,197
Unincorporated	144811	AIRPORT	0.20	28,962	1,599
		BLACKHMK	0.10	14,481	800
		EUREKA	0.10	14,481	800
		GEESOLD	0.03	3,620	200
		HOWELL	0.03	3,620	200
		MARLBED	0.10	14,481	800
		SALTCRK	0.20	28,962	1,599
		SANFDAVE	0.15	21,722	1,199
		SWEETCRK	0.10	14,481	800
					15,000

Estimated Distribution of Septic Tanks within Watershed:

AIRPORT	2,437
BLACKHMK	800
EUREKA	800
GEESOLD	3,471
HOWELL	1,738
MARLBED	800
SALTCRK	1,599
SANFDAVE	2,068
SWEETCRK	1,288
	15,000

Notes:

Septic tank data obtained from Seminole County Comprehensive Plan 1990
Population data extracted from Shermyen et al. (1990)

Source: WAR 1991

Table 2.1.6-1 Wastewater Treatment Plants that Discharge Within Lake Jessup Watershed.

Wastewater Treatment Plant	Owner/ Operator	Subbasin	Effluent Treatment Disposal	Design Capacity (MGD)	Operating Capacity (MGD)	Daily Flow (MGD)
Shadow Hills	Longwood Util.	GEESOLD	Percolation	0.500	0.315	0.315
Tuscawilla	Seminole Util.	HOWELL	Percolation/ Spray Fields	2.200	0.800	0.800
Des Pinar	Sanlando Util.	GEESOLD	On-site	0.500	0.444	0.434
Greenwood Lakes	Seminole Co.	GEESOLD	Percolation/ Reclaimed Water	3.500	2.876	1.179
Winter Springs	Winter Springs	GEESOLD	Percolation/ Spray Fields	1.500	0.791	0.791
Casselberry	Casselberry	GEESOLD	Percolation	4.043	3.450	3.450
		Watershed Totals:		12.243	8.676	6.969

Notes:
WWTP data obtained from Seminole County Comprehensive Plan 1990

Source: WAR 1991

(Section 4.1.5) as an additional source of nitrogen (phosphorus is removed by the soils). Five of the six facilities are located within subbasin GEESOLD with the sixth located in HOWELL (Figure 2.1.6-1).

Effluent water quality data for the Winter Springs and Casselberry WWTPs was compiled to determine average TN and TP concentrations (Table 2.1.6-2). The average concentrations for both plants were 17.44 mg/L for TN and 9.31 for TP during the years 1973 and 1974.

2.1.7 <u>Surface Water Quality Data</u>

Water quality monitoring stations within the Lake Jessup watershed include stations located in Lake Jessup and tributaries within three of the nine subbasins (Figure 2.1.7-1). HOWELL, GEESOLD, and BLACKHMK subbasins contain nine water quality stations. Within HOWELL subbasin, the following four water quality stations are located along Howell Creek: SSE42330, SSE42310, SSE42320, and SSE42350. Station SSE42340, on Bear Creek, is also located in the HOWELL subbasin. Water quality stations located along Gee creek within GEESOLD subbasin include 20010185, SSE42210, and SSE42230. BLACKHMK contains one water quality station, Station 122361, which is located on Sweetwater Creek.

Six water quality stations in the watershed are located within Lake Jessup. These include Station 31902, near the discharge of Howell Creek into Lake Jessup, Stations 31901 and SSE42170, near the combined discharge of Gee and Soldier Creeks into the lake, stations GFCCR0477 and 31903 adjacent to Bird Island, and Station 20010183 located near the discharge of Sweetwater Creek into Lake Jessup.

Unpublished water quality data measured at the water quality stations listed above were compiled from various sources by the St. Johns River Water Management District (Table 2.1.7-1). Period of record for the data dates back as far as March of 1973 for Sweetwater Creek station in BLACKHMK subbasin to as recently as May of 1991 for stations in Lake Jessup.

Average TN concentrations ranged from 1.34 mg/L for GEESOLD to 8.86 mg/L for BLACKHMK. Average TP concentrations ranged from 0.147 mg/L for GEESOLD to 1.296 mg/L for BLACKHMK. The nutrient concentrations for BLACKHMK were

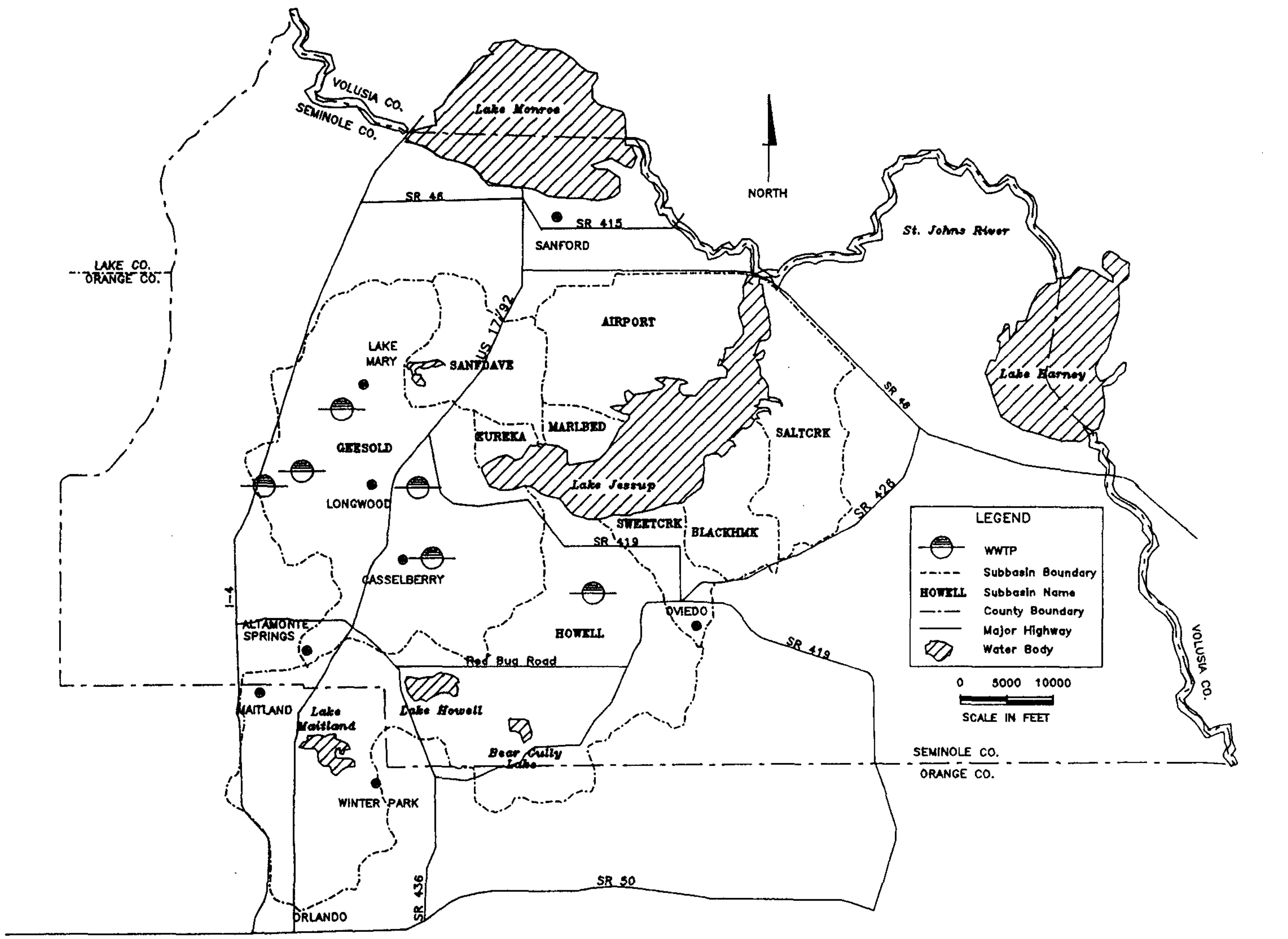

FIGURE 2.1.6-1. Location of Waste Water Treatment Plants in the Lake Jessup Watershed.

SOURCE: WAR 1991

Table 2.1.6-2. Determination of Average Nitrogen and Phosphorus Effluent Concentrations from Winter Springs and Casselberry Waste Water Treatment Plants.

Winter Springs WWTP

	NH3 (mg/l)	NO3-NO2 (mg/l)	Inorg-N (mg/l)	Total-N (mg/l)	Ortho-P (mg/l)	Total-P (mg/l)
	11.00	0.05	11.05	18.95	7.30	9.10
	6.30	0.19	6.49	28.19	9.85	10.00
	0.09	0.20	0.29	21.20	8.75	10.00
	4.90	0.04	4.94	20.54	8.60	9.90
	0.89	0.32	1.21	15.72	7.43	9.30
	0.27	0.08	0.35	26.08	10.00	11.50
	0.15	0.32	0.47	31.32	10.40	12.50
	0.42	0.04	0.46	29.04	6.50	13.50
	0.21	0.12	0.33	24.12	9.45	12.00
	0.15	0.04	0.19	15.04	7.90	10.50
	-----	-----	-----	-----	-----	-----
Average:	2.44	0.14	22.88	23.02	8.62	10.83
Minimum:	0.09	0.04	15.00	15.04	6.50	9.10
Maximum:	11.00	0.32	31.00	31.32	10.40	13.50

Casselberry WWTP(1)

	Inorg-N (mg/l)	Total-N (mg/l)	Ortho-P (mg/l)	Total-P (mg/l)
		24.01	6.20	7.00
		17.68	4.40	6.20
		8.20	9.60	10.50
		15.32	8.90	9.30
		7.54	8.50	8.50
		6.30	10.50	11.50
		4.35	7.10	7.50
		15.30	5.60	6.00
		7.65	4.35	4.85
		12.20	5.25	6.50
		-----	-----	-----
Average:		11.85	7.04	7.79
Minimum:		4.35	4.35	4.85
Maximum:		24.01	10.50	11.50
Overall Average:	1.95	17.44	7.83	9.31

Notes:

(1) Overall inorganic N was calculated from overall Total-N by the ratio of Inorg-N to Total-N (0.11) for the Winter Springs WWTP

Source: WAR 1991
U.S. EPA 1977

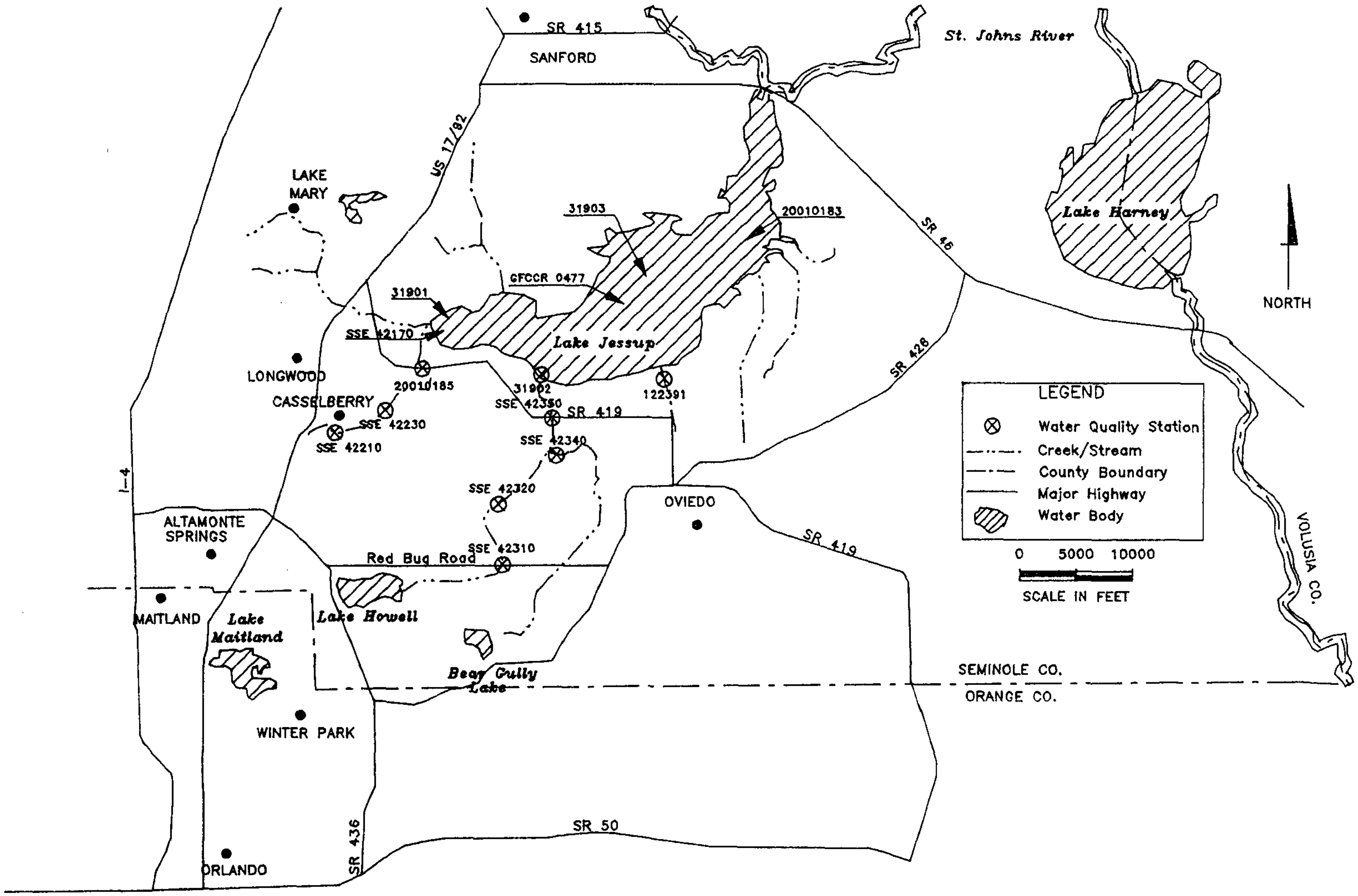

FIGURE 2.1.7-1. Location of Surface Water Quality Stations in the Lake Jessup Watershed.

SOURCE: WAR 1991
SJRWMD 1991

Table 2.1.7-1. Summary of Surface Water Quality Data for Stations in the Lake Jessup Watershed.

Subbasin	Major Tributary	Water Quality Station	Sampling Date	Total Organic (mg N/L)	Total NH3+NH4 (mg N/L)	TKN (NH3+Org) (mg N/L)	Nitrite NO2 (mg N/L)	Nitrate NO3 (mg N/L)	Total NO2+NO3 (mg N/L)	Total Inorg Nitrogen (mg N/L)	Total Nitrogen (mg N/L)	Total Phosphorus (mg P/L)	Total Ortho-P (mg P/L)
BLACKHMK	Sweet-	1223G1	18-Mar-73	2.4	2.3	4.7	0.46	11.6	12	14.36	16.7	0.55	0.52
	Water Cr.	1223G1	07-Apr-73	2.2	1.37	3.57	0.67	16.4	17.2	18.44	20.77	0.66	0.56
		1223G1	13-May-73	0.85	0.55	1.4	0.24	4.2	4.4	4.99	5.8	0.56	0.54
		1223G1	17-Jun-73	0.81	0.99	1.8	0.7	9	9.7	10.69	11.5	1.1	0.34
		1223G1	07-Jul-73	1.4	3	4.4	0.54	10	10.9	13.54	15.3	3.9	3.6
		1223G1	05-Aug-73	2.343	0.357	2.7	0.004	0.016	0.02	0.377	2.72	0.525	0.35
		1223G1	08-Sep-73	1.462	0.138	1.6	0.009	1.7	1.7	1.847	3.3	0.63	0.59
		1223G1	04-Nov-73	1.446	0.104	1.55	0.014	0.076	0.09	0.194	1.64	0.69	0.57
		1223G1	08-Dec-73	1.76	2.64	4.4	0.65	5.8	6.5	9.09	10.9	2.6	1.84
		1223G1	15-Dec-73	1.76	3.64	5.4	0.64	5.94	6.6	10.22	12	2.4	1.9
		1223G1	12-Jan-74	1.4	0.3	1.7	0.093	1.34	1.44	1.733	3.14	1.1	0.96
		1223G1	03-Feb-74	1.77	0.23	2	0.07	0.46	0.53	0.76	2.53	0.84	0.77
Subbasin Statistics				------	------	------	------	------	------	------	------	------	------
		Average:		1.63	1.30	2.94	0.34	5.54	5.92	7.19	8.86	1.296	1.045
		Minimum:		0.81	0.10	1.40	0.00	0.02	0.02	0.19	1.64	0.525	0.340
		Maximum:		2.40	3.64	5.40	0.70	16.40	17.20	18.44	20.77	3.900	3.600
GEESOLD	Gee Cr.	20010185	06-Mar-89										
		20010185	06-Mar-89			0.7			0.61		1.31	0.32	
		20010185	17-Oct-89			1.01			0.16		1.17	0.11	
		20010185	17-Oct-89										
		SSE42210	08-Sep-83	0.63	0.09	0.72	0.005	0.18	0.185	0.275	0.905	0.057	0.024
		SSE42210	29-Nov-83	1.01	0.68	1.69	0.016	0.983	0.999	1.679	2.689		
		SSE42210	06-Mar-84	0.85	0.13	0.98	0.007	0.072	0.079	0.209	1.059		
		SSE42230	08-Sep-83	0.77	0.15	0.92	0.009	0.23	0.239	0.389	1.159	0.101	0.048
		SSE42230	29-Nov-83	0.84	0.12	0.96	0.014	0.256	0.27	0.39	1.23		
		SSE42230	06-Mar-84	0.9	0.15	1.05	0.02	0.097	0.117	0.267	1.167		
Subbasin Statistics,				------	------	------	------	------	------	------	------	------	------
		Average:		0.83	0.22	1.00	0.01	0.30	0.33	0.53	1.34	0.147	0.036
		Minimum:		0.63	0.09	0.70	0.01	0.07	0.08	0.21	0.91	0.057	0.024
		Maximum:		1.01	0.68	1.69	0.02	0.98	1.00	1.68	2.69	0.320	0.048
HOWELL	Howell Cr.	SSE42300	05-Oct-83	1.04	0.27	1.31	0.018	0.28	0.298	0.568	1.608	0.175	0.116
		SSE42300	25-Jan-84	1.3	0.29	1.59	0.006	0.125	0.131	0.421	1.721	0.253	0.111
		SSE42310	05-Oct-83	0.96	0.14	1.1	0.017	0.38	0.397	0.537	1.497	0.17	0.128
		SSE42310	25-Jan-84	1.37	0.28	1.65	0.008	0.129	0.137	0.417	1.787	0.192	0.113
		SSE42320	05-Oct-83	0.88	0.2	1.08	0.023	0.45	0.473	0.673	1.553	0.143	0.114
		SSE42320	25-Jan-84	1.35	0.29	1.64	0.011	0.169	0.18	0.47	1.82	0.203	0.116
		SSE42340	28-Mar-84	0.71	0.07	0.78	0.013	0.316	0.329	0.399	1.109	0.316	
		SSE42350	05-Oct-83	0.8	0.11	0.91	0.012	0.41	0.422	0.532	1.332	0.164	0.14
		SSE42350	25-Jan-84	1.48	0.16	1.64	0.01	0.309	0.319	0.479	1.959	0.244	0.196
Subbasin Statistics				------	------	------	------	------	------	------	------	------	------
		Average:		1.10	0.20	1.30	0.01	0.29	0.30	0.50	1.60	0.207	0.129
		Minimum:		0.71	0.07	0.78	0.01	0.13	0.13	0.40	1.11	0.143	0.111
		Maximum:		1.48	0.29	1.65	0.02	0.45	0.47	0.67	1.96	0.316	0.196

Table 2.1.7-1. Summary of Surface Water Quality Data for Stations in the Lake Jessup Watershed (Continued).

Subbasin	Major Tributary	Water Quality Station	Sampling Date	Total Organic (mg N/L)	Total NH3+NH4 (mg N/L)	TKN (NH3+Org) (mg N/L)	Nitrite NO2 (mg N/L)	Nitrate NO3 (mg N/L)	Total NO2+NO3 (mg N/L)	Total Inorg Nitrogen (mg N/L)	Total Nitrogen (mg N/L)	Total Phosphorus (mg P/L)	Total Ortho-P (mg P/L)
Lake Jessup		20010183	21-Oct-83	4.66	0.08	4.74	0.01	0.001	0.011	0.091	4.751	0.47	
		20010183	18-Jan-84	1.26	0	1.26	0	0.02	0.02	0.02	1.28	0.12	
		20010183	24-Jan-84			1.98			0.01		1.99	0.21	
		31901	15-Feb-84	1.76	0.3	2.06	0.002	0.003	0.005	0.305	2.065	0.145	0.003
		31902	15-Feb-84	1.22	0.38	1.6	0.016	0.603	0.619	0.999	2.219	0.252	0.016
		31903	15-Feb-84	1.31	0.31	1.62	0.011	0.048	0.059	0.369	1.679	0.202	0.010
		SSE42170	15-Feb-84	1.76	0.3	2.06	0.002	0.003	0.005	0.305	2.065	0.145	0.013
		20010183	10-Apr-84	2.86	0.09	2.95	0.002	0.089	0.091	0.181	3.098	0.211	
		31901	30-Apr-84	2.46	0.05	2.51	0.004	0.144	0.148	0.198	2.658	0.35	0.055
		31902	30-Apr-84	2.63	0.04	2.67	0.003	0.137	0.14	0.18	2.81	0.25	0.039
		31903	30-Apr-84	3.44	0.04	3.48	0.004	0.163	0.167	0.207	3.647	0.276	0.039
		SSE42170	30-Apr-84	2.46	0.05	2.51	0.004	0.144	0.148	0.198	2.658	0.35	0.168
		20010183	16-Jul-84			4.41	0.002	0.29	0.292		4.702	0.21	
		20010183	28-Aug-84	4.53	0.36	4.89			0.01	0.37	4.9	0.46	
		31901	12-Sep-84			2	0.001	0.286	0.287		2.287	0.371	0.046
		31902	12-Sep-84			1.23	0.006	0.303	0.309		1.539	0.216	0.029
		31903	12-Sep-84			2.79	0.001	0.298	0.299		3.089	0.315	0.016
		20010183	11-Oct-84			2.49	0.01	0.17	0.18		2.67	0.26	
		20010183	04-Feb-85	2.41	0.07	2.48	0.001	0.12	0.121	0.191	2.601	0.13	
		31901	05-Mar-85				0.003	0.085	0.088			0.328	0.059
		31902	05-Mar-85	2.5	0.04		0.006	0.074	0.08	0.12	2.62	0.217	0.042
		31903	05-Mar-85	3.48	0.07	3.55	0.001	0.126	0.127	0.197	3.677	0.158	0.020
		20010183	30-May-85			4.13	0.002	0.16	0.162		4.292	0.27	
		31901	22-Jul-85			1.88	0.01	0.025	0.035		1.915	0.002	0.001
		31902	22-Jul-85									0	0.000
		31903	22-Jul-85			2.15	0.003	0.045	0.048		2.198	0	0.000
		20010183	19-Aug-85			3.88	0	0.09	0.09		3.97	0.3	
		20010183	29-Oct-85			1.26	0.001	0.03	0.031		1.291	0.21	
		31901	14-Nov-85	1.21	0.12	1.33	0.002	0.004	0.006	0.126	1.336	0.186	0.001
		31902	14-Nov-85	1.34	0.08	1.42	0.004	0.023	0.027	0.107	1.447	0.18	0.002
		31903	14-Nov-85	1.54	0.13	1.67	0.002	0.025	0.027	0.157	1.697	0.14	0.003
		31901	10-Feb-86	1.15	0.15	1.3	0.009	0.158	0.167	0.317	1.467	0.287	0.003
		31902	10-Feb-86	1.48	0.15	1.63	0.01	0.02	0.03	0.18	1.66	0.304	0.007
		31903	10-Feb-86	2.88	0.08	2.96	0.001	0.026	0.027	0.107	2.987	0.276	0.001
		20010183	17-Feb-86			2.22	0.003	0.02	0.023		2.243	0.17	
		20010183	15-Jul-86			1.8	0.0041	0	0.01		1.81		
		20010183	13-Oct-86			4.69			0.04		4.73	1.12	
		20010183	02-Feb-87	5.44	0.32	5.76			0	0.32	5.76	0.61	
		20010183	23-Feb-87			4.5			0.04		4.54	0.42	
		20010183	04-May-87	2.27	0.15	2.42						0.17	
		20010183	29-Jun-87	5.51	0.05	5.56			0.04	0.09	5.6	0.56	
		20010183	27-Aug-87			3.92			0.02		3.94	0.44	
		20010183	31-Aug-87	9.7	0.18	9.88						0.33	

Table 2.1.7-1. Summary of Surface Water Quality Data for Stations in the Lake Jessup Watershed (Continued).

Subbasin	Major Tributary	Water Quality Station	Sampling Date	Total Organic (mg N/L)	Total NH3+NH4 (mg N/L)	TKN (NH3+Org) (mg N/L)	Nitrite NO2 (mg N/L)	Nitrate NO3 (mg N/L)	Total NO2+NO3 (mg N/L)	Total Inorg Nitrogen (mg N/L)	Total Nitrogen (mg N/L)	Total Phosphorus (mg P/L)	Total Ortho-P (mg P/L)
Lake Jessup (Cont.)		20010183	13-Jan-88	98	0.17	98.17						0.11	
		20010183	14-Mar-88	5.34	0.19	5.53						0.36	
		20010183	26-Apr-88	3.3	0.42	3.72						0.335	
		31901	21-Jun-88			2.28							0.049
		31902	21-Jun-88			3.96							0.033
		31903	21-Jun-88			7.4							0.023
		20010183	15-Aug-88	5.6	0.01	5.61						0.391	
		31901	14-Nov-88			0.93		0.13				0.199	
		31902	14-Nov-88			1.67		0.12				0.209	
		31903	14-Nov-88			1.58		0.11				0.214	
		20010183	06-Jun-89			5.79			0.02		5.81	0.4	
		20010183	30-Aug-89			6.84			0.02		6.86	0.4	
		20010183	26-Sep-89			5.65			0.02		5.67	0.4	
		20010183	28-Feb-90			6.28			0.02		6.3	0.43	
		GFCCR0477	27-Aug-90	3.78	0	3.78	0.004	0.03	0.034	0.034			0.003
		20010183	04-Sep-90										
		GFCCR0477	19-Nov-90	4	0.02	4.02	0.004	0.01	0.014	0.034			0.020
		20010183	26-Nov-90										
		GFCCR0477	18-Feb-91	5.3	0	5.3	0.004	0.01	0.014	0.014			0.007
		GFCCR0477	13-May-91	3.22	0.28	3.5	0.004	0.01	0.014	0.294			0.020
Lk Jessup Statistics				------	------	------	------	------	------	------	------	------	------
		Average:		6.05	0.14	4.99	0.004	0.10	0.09	0.21	3.18	0.284	0.024
		Minimum:		1.15	0.00	0.93	0.000	0.00	0.00	0.01	1.28	0.000	0.000
		Maximum:		98.00	0.42	98.17	0.016	0.60	0.62	1.00	6.86	1.120	0.168

Source: SJRWMD 1991
WAR 1991

considerably higher than those for the other subbasins or Lake Jessup. Lake Jessup TN and TP concentrations (3.18 mg/L and 0.284 mg/L, respectively) were higher than GEESOLD or HOWELL (1.6mg/L and 0.207 mg/L).

In spite of the apparently long period of record from which data was collected, there exist large gaps in information, both in terms of constituents and sampling periods. In such cases, constituents that lacked recorded data were calculated using other parameters within the same chemical family. For example, total inorganic nitrogen, if not recorded, was determined by combining all other reported forms of inorganic nitrogen. Total nitrogen could be calculated from all individual forms (organic, ammonia, nitrate, nitrite) or TKN plus nitrate plus nitrite, etc.

Water quality monitoring stations for a given subbasin were composited so that parameter statistics (i.e., average, maximum, and minimum) could be calculated for each subbasin that had monitoring stations. Subbasin composite nutrient concentration data based on actual data was used instead of the nutrient loading concentrations based on land use distribution (Section 2.1.4, Table 2.1.4-2) in the nutrient budget calculations. The Lake Jessup stations were used to create a time series of lake water quality to determine the storage of nutrients in lake waters for the nutrient budget (Section 4.1.10).

3.0 WATER BUDGET

3.0 WATER BUDGET

3.1 METHODOLOGY

The water budget for Lake Jessup was determined using the law of Conservation of Mass, which, assuming water is incompressible, can be given by the following general equation:

$$\text{CHANGE IN VOLUME} = \text{INFLOWS} - \text{OUTFLOWS} \qquad \text{eq. 3-1}$$

Equation 3-1 can be broken down into the main water budget inflows and outflows for Lake Jessup to determine DVOL, the change in Lake Jessup volume, according to the following equation:

$$DVOL = ARTES+PC_{LJ}+RO+SEEP+ST+STP+SJR_{IN} - SJR_{OUT} - EV \qquad \text{eq.3-2}$$

where the inflows consist of:

- ARTES = Springflow (SPFLOW) within the watershed plus upward leakage (LEAK) from the Floridan aquifer through the lake bottom;
- PC_{LJ} = Direct precipitation onto the surface of Lake Jessup;
- RO = Land surface runoff from the contributing drainage area to Lake Jessup resulting from rainfall (R) and/or irrigation (IRR);
- SEEP = Lateral groundwater inflow as bank seepage from the contributing drainage area to Lake Jessup from the infiltration (I) of rainfall (R) and/or irrigation (IRR);
- ST = Septic tank inflows to Lake Jessup from homes within the contributing drainage area;
- STP = WWTP effluent discharged by means of land application or percolation ponds within the contributing drainage area; and
- SJR_{IN} = Inflow from the St. Johns River;

and the outflows consist of:

- SJR_{OUT} = Surface outflow to the St. Johns River;
- EV = Evaporation from the surface of Lake Jessup and lakes within the contributing drainage area.

The equations, data, and analyses used to quantify each of the components of the water budget for Lake Jessup are summarized in the following sections.

Calculations were performed using a monthly time step. Most physical constants and subbasin hydrologic characteristics remained constant for the period of record (Table 3.1-1).

3.1.1 <u>Springflow and Upward Leakage</u>

Lake Jessup and approximately half of the watershed lie in an area of artesian conditions with respect to the Floridan aquifer. Water in the aquifer is under sufficient pressure to potentially rise to the ground surface or higher. Springs occur where there is a discrete breach in the relatively impermeable confining layer that overlies the aquifer that allows water to flow to the surface. Water can also flow upward through the confining layer as diffuse leakage. This flow is very slow due to the low permeability of the confining layer but it can be significant over a sufficiently large area.

Springs flowing into Lake Jessup are few in number and have small discharges. Elder Spring discharges from the shallow, or water table aquifer. It is not considered separately in the water budget since shallow aquifer discharge is taken into account in the bank seepage equations (Section 3.1.4). Floridan aquifer springs include Clifton Springs and Lake Jessup Spring. Their flows are given by Rosenau et al. (1977) as 1.7 cfs and 1.36 cfs, respectively. These values are from single measurements since no long-term data is available. The sum of the individual flow rates was assumed constant over the period of record and was converted to a monthly flow volume within the water budget model according to the following equation:

$$SPFLOW = (1.7 + 1.36) * CONVS * days/month$$

where:

SPFLOW = Monthly Floridan aquifer springflow to Lake Jessup (acre-feet)
1.7 = Clifton Springs discharge (cfs)
1.36 = Lake Jessup Spring discharge (cfs).
CONVS = 3600 sec/hour * 24 hours/day * 1 acre/43560 ft^2

Areas of upward leakage (discharge) and downward leakage (recharge) through the confining layer above the Floridan aquifer system in east-central Florida were mapped by Tibbals (1990). Within the Lake Jessup watershed, these areas are approximately equal. Therefore, it was assumed that there was no net

Table 3.1-1. Summary of Subbasins and Lake Constants and Characteristics Used in the Water Budget Calculations.

	Description		AIRPORT	BLACKHMK	EUREKA	GEESOLD	HOWELL	MARLBED	SALTCRK	SANFDAVE	SWEETCRK
AREA	Total Drainage Area	(acres)	8649	4047	964	27268	32153	1411	7046	5612	2857
AIMP	Total Impervious Area	(acres)	1237	93	30	4336	7880	23	99	786	166
ALAKE	Lake Surface Area	(acres)	87.1	0.0	0.0	1747.2	2515.0	0.0	123.4	317.7	19.3
AIrrLJ	Lake Area Factor	(acres)	0.010	0.000	0.000	0.064	0.078	0.000	0.018	0.057	0.007
C	Runoff Coefficient	- -	0.33	0.25	0.26	0.20	0.26	0.23	0.22	0.31	0.30
LEAKC	Aquiclude Leakage Coeff.	(ft/dy/ft)	0.000025								
PSURF	Avg. Pot. Surface in Jessup	(ft NGVD)	25								
RAINEF(*)	Rain Efficiency	- -	0.717	0.717	0.717	0.717	0.717	0.717	0.717	0.717	0.717
IRRIGEF(*)	Irrigation Efficiency	- -	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
IRRIGF(*)	Irrigation Factor	- -	0.07	0.09	0.11	0.33	0.08	0.11	0.01	0.12	0.06
NST(*)	Number of Septic Tanks	- -	2437	800	800	3471	1738	800	1599	2068	1288
DCU(*)	Septic Tank Factor	(gpd/lot)	117.0	117.0	117.0	117.0	117.0	117.0	117.0	117.0	117.0
ALJ(*)	Lake Jessup Surface Area	(acres)	10661								

Subbasins: AIRPORT through SWEETCRK.

(*)Notes:
RAINEF = Rain efficiency (fraction of rain used for ET) = (34.31/47.83)
IRRIGEF = Irrigation efficiency (fraction of applied water used for ET)
IRRIGF = Irrigation factor (fraction of irrigated land in Subbasin)
DCU = Septic tank factor (gpd per lot, from Clements and Otis, 1980 in Univ of Fla/IFAS study for HRS)
ALJ: From volume table at average Lake Jessup stage of 1.86 feet NGVD

Source: WAR 1991

exchange (recharge or discharge) between the subbasins and the Floridan aquifer. The resolution of the available data is not sufficient for a detailed analysis of direction and quantity of exchange with the Floridan aquifer for all areas of the watershed. However, diffuse upward leakage through the confining layer into Lake Jessup was determined for the area directly below Lake Jessup:

$$LEAK = LEAKC*(PSURF-LJSTG) * days/month * A_{LJ} \qquad \text{eq. 3-3}$$

where:

- LEAK = Monthly upward leakage through the bottom of Lake Jessup (acre-feet)
- LEAKC = Leakage coefficient (ft/day per foot head difference between PSURF and STG_{LJ})
- PSURF = Average potentiometric surface of the Floridan aquifer (feet NGVD)
- STG_{LJ} = Lake Jessup monthly average stage (feet NGVD)
- A_{LJ} = 1980 to 1990 average surface area of Lake Jessup (acres).

LEAKC (0.000025 ft/day/ft) is the median of the range of values given by Tibbals (1990) for the area occupied by Lake Jessup. PSURF (25 feet NGVD) is an estimate of the average potentiometric surface of the Floridan aquifer over the lake surface (Spechler et al. 1991). The potentiometric surface slopes downward from west to east from approximately 40 feet NGVD to 15 feet NGVD. This value was assumed constant for the period of record. STG_{LJ} was determined from existing stage data for Lake Jessup (Section 2.1.3).
A_{LJ} (10661 acres) was determined using the stage-area-volume relationship for the lake (Table 2.1.3-2) and interpolating for the period of record average stage for the lake of 1.86 feet NGVD (Table 3.1-1).

3.1.2 Direct Precipitation

Rainfall that falls on the surface of Lake Jessup is a direct inflow. The monthly total inflow was computed using the following equation:

$$PC_{LJ} = (R * A_{LJ}) * CONVS \qquad \text{eq. 3-4}$$

where:

PC_{LJ} = Monthly inflow due to direct precipitation (acre-feet)

R = Monthly rainfall depth (inches)

A_{LJ} = Surface area of Lake Jessup (acres).

CONVS = 1 foot/12 inches

Monthly rainfall totals were computed from daily rainfall data for the Sanford Experimental Station obtained in spreadsheet format from the SJRWMD and hard copy format from the National Climatic Data Center monthly summaries for Florida.

3.1.3 Land Surface Runoff

Land surface runoff was derived from the inputs of rainfall and irrigation. The proportion of these inputs that discharges to surface waters was determined using subbasin hydrologic characteristics based on land use (Section 2.1.4, Table 3.1-1) since limited hydrologic data was available for only three of the tributaries. Existing data was incorporated into calculations where possible. Surface runoff volume is a function of subbasin surface area, and was calculated for each subbasin using the following equations:

$$RO = C *((R * AREA)+(IRR * IRRF * AREA)) * CONVS \qquad \text{eq. 3-5}$$

where:

RO = Monthly subbasin surface runoff to Lake Jessup (acre-feet)

C = Subbasin-specific runoff coefficient (inches per inch)

R = Monthly rainfall depth (inches)

AREA = Subbasin-specific surface area (acres).

IRR = Monthly irrigation water application depth (inches)

IRRF = Irrigation factor (irrigated acres/AREA)

CONVS = 1 foot/12 inches

Values of C for subbasins were estimated using a modification of the method developed for the Urban Stormwater Analysis and Improvement Study for the Tampa Bay Watershed (Dames & Moore 1990). This method uses empirically derived runoff coefficients for different land use types to determine an area-weighted composite runoff coefficient based on the land use distribution within each subbasin. Land use analyses were based on existing data and maps provided by the Seminole County Planning Department (Section 2.1.4, Table 2.1.4-1, Table 3.1-1). Other methods of estimating runoff volumes such as the rational method or SCS methods were not used since they are primarily used to estimate runoff for single rainfall events, and they require watershed data of greater detail, that could not practically be assembled within the scope of this study.

C was also determined for subbasins GEESOLD and HOWELL using existing rainfall and discharge data (Section 2.1.3, Table 2.1.3-3). These coefficients were used instead of the land-use-based runoff coefficients. R was compiled from daily rainfall data for Sanford Experimental Station (Section 2.1.2). AREA was determined using 1:24,000 scale USGS topographic quadrangle maps (Table 3.1-1, Figure 1.2-1). IRRF is the ratio of irrigated land within a subbasin to the total subbasin area (Section 2.1.4, Table 2.1.4-1).

IRR was estimated using the following equations:

$$IRR = (ET - R_{eff}*R)/(R_{eff}*Irr_{eff}), \quad \text{if } ET > R_{eff}*R \qquad \text{eq. 3-6}$$

$$IRR = 0.0, \quad \text{if } ET < \text{or} = R_{eff}*R \qquad \text{eq. 3-7}$$

where:

- ET = Monthly evapotranspiration from land surface (inches)
- R_{eff} = Rain efficiency (fraction of rainfall consumed by ET)
- IRR_{eff} = Irrigation efficiency (fraction of applied irrigation water consumed by ET).

R_{eff} (0.717 inches/inch) is equivalent to the ratio of average yearly ET (34.31 inches, Bartel and Barksdale 1985) to average annual total rainfall (47.8 inches, Sanford rainfall average 1980 - 1990). The estimated value of Irr_{eff} is 0.7 (Huber 1990).

3.1.4 Shallow Groundwater Inflow

Groundwater conceptually follows two divergent pathways. One portion percolates vertically to recharge the deep aquifer. The other portion follows a generally horizontal pathway to enter Lake Jessup as bank seepage. For this study, all groundwater within the surface drainage area of Lake Jessup was assumed to enter the lake as bank seepage (Section 3.1.1). Bank seepage was estimated as the long-term average of infiltration, assuming that groundwater storage volume remains fairly constant over long periods of time. Due to the high elevations of the land surface around Lake Jessup, water would not be expected to flow out from the lake, but remain a fairly constant inflow. Swings in infiltration would be dampened by changes in groundwater storage. Monthly bank seepage was assumed constant for the period of record.

$$SEEP = I_{avg} \qquad \text{eq. 3-8}$$

where:

SEEP = Monthly bank seepage (acre-feet)

I_{avg} = Subbasin period of record average monthly groundwater infiltration (acre-feet)

The infiltration equation incorporates the subbasin water losses of land surface evapotranspiration and subbasin lake evaporation. Infiltration into the ground within a subbasin in a given month (I) was estimated by the following equation:

$$I = \{[(R*AREA) + (IRR*AREA*IRRF) - (ET*(AREA-A_{LAKE}-A_{IMP})) - (EV*C_{PAN}*A_{LAKE})] * CONVS\} - RO \qquad \text{eq. 3-9}$$

where:

I = Monthly infiltration (acre-feet)

R = Monthly rainfall (inches)

AREA = Surface area of subbasin (acres)

IRRF = Irrigation factor = proportion of subbasin in irrigated land

ET = Monthly evapotranspiration from land surface (inches).

A_{LAKE} = Total area of lakes within subbasin (acres)

A_{IMP} = Total impervious area within subbasin (acres)

EV = Lisbon monthly total pan evaporation (inches)

C_{PAN} = Lake pan evaporation coefficient.

CONVS = 1 foot/12 inches

This equation takes the total volume of rainfall plus irrigation, subtracts out the loss to ET for land surface and EV for water surfaces, then subtracts the runoff, which leaves the amount of water that is available to infiltrate to the shallow groundwater. IRRF is the ratio of the irrigated land area within a subbasin to the total land area for that subbasin (Section 2.1.4). ET was calculated as the average of natural evapotranspiration values (Southwest Florida Water Management District [SWFWMD 1975]), and values reported for urban areas (MacVicar et al. 1984). These values were then adjusted to the yearly total evapotranspiration for the Orlando area reported by Bartel and Barksdale (1985) (Table 3.1-1, Figure 2.1.2-3).

The areas of lakes within each subbasin (Table 2.1.4-1, Table 3.1-1) were digitized using the USGS 1:24,000 scale topographic quadrangle maps. The area of impervious surfaces within each subbasin were determined during the land use analyses (Section 2.1.4, Table 2.1.4-1). Lake pan evaporation coefficients were calculated from Orlando area data as the ratio of estimated average monthly lake evaporation to pan evaporation (Section 2.1.2, Table 2.1.2-1).

3.1.5 <u>Septic Tank (OSDS) Inflows</u>

Septic tank effluent is generally discharged to a subsurface soil absorption system. These systems allow the effluent to seep into the surrounding soil where the effluent follows the same pathways as the groundwater. All septic tank discharge within the watershed was assumed to contribute to bank seepage inflow to Lake Jessup. Septic tank inflow was calculated by the following equation:

$$ST = N_{ST} * DCU * CONVS \qquad \text{eq. 3-10}$$

where:

ST = Monthly septic tank inflow volume (acre-feet)

N_{ST} = Number of septic tanks in subbasin

DCU = Average monthly consumptive use per tank (gallons per day)

$CONVS$ = $(1\ ft^3/7.48\ gal)*(1\ acre/43560\ ft^2)*(days/month)$

N_{ST} for each subbasin of the Lake Jessup watershed was estimated according to the distribution of population within the watershed (Section 2.1.5, Table 2.1.5-1, Table 3.1-1).

DCU was estimated by multiplying the average per capita daily flow of 44 gallons per day from various studies (Clements and Otis 1980) by 2.66 persons per household (Shermyen et al. 1990).

3.1.6 Wastewater Treatment Plant Effluent

Land application systems and percolation ponds allow the wastewater effluent to seep into the surrounding soil where it follows the groundwater pathway to Lake Jessup. WWTP effluent discharged to land application systems or percolation ponds within the contributing drainage area was estimated using the following equation:

$$STP = STP_O * CONVS \qquad \text{eq. 3-11}$$

where:

STP = Monthly subbasin WWTP effluent inflow volume (acre-feet)

STP_O = Facility monthly average observed flow (gpd)

$CONVS$ = $(1\ ft^3/7.48\ gal)*(1\ acre/43560\ ft^2)$

STP was assumed equal to the sum of the observed flows for all facilities within a subbasin (Section 2.1.6, Table 2.1.6-1). All WWTP discharge was assumed to flow to Lake Jessup via groundwater.

3.1.7 Surface Evaporation

Evaporation from the water surface of Lake Jessup was estimated using the following equation:

$$EV_{LJ} = EV * C_{PAN} * A_{LJ} * CONVS \qquad \text{eq. 3-12}$$

where:

EV_{LJ} = Monthly Lake Jessup surface evaporation (acre-feet)

EV = Monthly Lisbon pan evaporation (inches)

C_{PAN} = Lake-pan evaporation coefficient.

A_{LJ} = Surface area of Lake Jessup (acres)

$CONVS$ = 1 foot/12 inches

Monthly pan evaporation data was obtained from the SJRWMD for the meteorological station at Lisbon, Florida in spreadsheet format (Section 2.1.2).

Average monthly lake evaporation for Orange County lakes was estimated by Lichtler et. al. (1968).

The lake-pan evaporation coefficients (Table 2.1.2-1) were calculated as the ratio of estimated average monthly evaporation from Orange County lakes to average monthly pan evaporation at Lisbon.

3.1.8 Surface Water Outflows

Surface water outflow (Lake Jessup discharge to the St. Johns River) was estimated using a mass balance approach. Equation 3-1 can be rearranged to state that if the total inflows and change in volume are known, the difference will determine the total outflows:

$$\text{OUTFLOWS} = \text{INFLOWS} - \text{CHANGE IN VOLUME} \qquad \text{eq. 3-13}$$

To apply this concept to the Lake Jessup water budget, Equation 3-2 was rearranged to isolate surface water outflows from the other components of the water budget. The following equation, broken down into individual water budget components, determined the lake's discharge to the St. Johns River:

$$SJR_{OUT} = ARTES+PC_{LJ}+ST+STP+RO+SEEP+SJR_{IN} - DVOL - EV_{LJ} \qquad \text{eq.3-14}$$

where:

- SJR_{OUT} = Monthly Lake Jessup discharge to the St. Johns River (acre-feet)
- ARTES = Monthly Floridan aquifer discharge to Lake Jessup from springs (SPFLOW) and upward leakage (LEAK) (acre-feet)
- PC_{LJ} = Monthly direct precipitation onto Lake Jessup (acre-feet)
- ST = Monthly septic tank inflow volume (acre-feet)
- STP = Monthly WWTP effluent inflow volume (acre-feet)
- RO = Monthly inflow from surface runoff (acre-feet)
- SEEP = Monthly bank seepage into Lake Jessup (acre-feet)
- DVOL = Change in monthly average Lake Jessup volume (acre-feet)
- EV_{LJ} = Monthly surface evaporation from Lake Jessup (acre-feet)
- SJR_{IN} = Monthly surface inflow from the St. Johns River (acre-feet).

Change in lake volume is an important part of this equation due to the large size of Lake Jessup. Changes in lake stage (and therefore, volume) are governed primarily by the St. Johns River stage at its confluence with Lake Jessup (Section 2.1.3). Monthly changes is lake volume can occasionally equal or exceed monthly inflows to the lake. When monthly inflows to the lake are exceeded by the increase in lake volume required by an increase in river stage, water will flow into the lake from the St. Johns River. This case is accounted for separately in the water budget model since the St. Johns River nutrient concentrations will be accounted for separately in the nutrient budget. SJR_{IN} and SJR_{OUT} do not occur within the same month. The equation is the same, but if monthly flow is toward the river the flow is called SJR_{OUT}, if the flow is toward the lake it is SJR_{IN}.

3.2 RESULTS - WATER BUDGET

The results of the monthly water budget calculations for the period of record, January 1980 through December 1990, were summarized as annual water budgets with averages and extremes for the annual water budgets and monthly water budgets (Appendix A). The annual values were either 12 month totals (for flow components), or 12 month averages (for volumes components and percentages).

There were many more inflow components to Lake Jessup than outflow components (Figure 3.2-1). The inflow components consisted of the subbasin inflows [surface runoff (95,117 acre-ft/year), bank seepage (68,060 acre-ft/year), and WWTPs plus septic tanks (9,780 acre-ft/year)], artesian inflow from springflow (2,217 acre-ft/year) and upward leakage (2,253 acre-ft/year), direct precipitation (42,490 acre-ft/year), inflow from the SJR (2,943 acre-ft/year). Outflow components consisted of outflow to the SJR (177,807 acre-ft/year) and direct evaporation (45,252 acre-ft/year) (Appendix A).

These results of the water budget will be presented in more detail in the following section.

The direct inflows of artesian water to the lake averaged 2,217 acre-ft/year for springflow and 2,253 acre-ft/year for upward leakage through the bottom of the lake. Meteorological water exchange showed a net inflow to the watershed (Table 3.2-1). Average rainfall (R, 47.83 inches/year) exceeded average ET (34.31 inches/year) by approximately 13.5 inches. Although pan evaporation

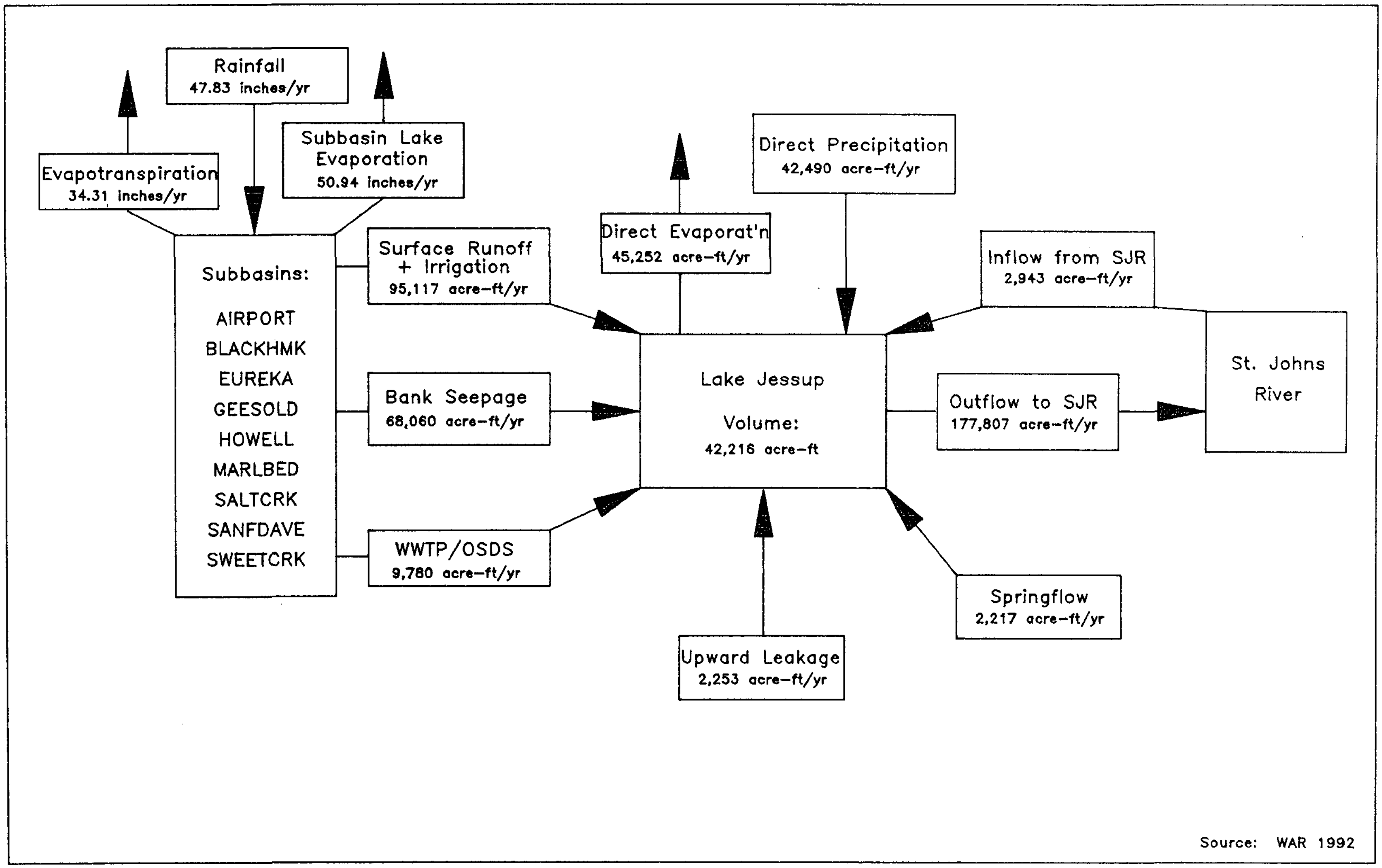

FIGURE 3.2-1. Schematic Diagram of Lake Jessup Water Budget Components with Average Annual Flows (acre-ft/yr) and Volumes (acre-ft), for 1980 through 1990.

Table 3.2-1. Inputs and Outputs to the Lake Jessup Annual Water Budget from Artesian Sources and Meteorological Sources and Sinks for the Years 1980 through 1990 with Monthly and Annual Means and Extremes.

Year	Artesian:			Meteorological:				Lake Jessup Surface:	
	Average Daily Springflow (cfs)	SPFLOW Spring-flow (acre-ft)	LEAK Upward Leakage (acre-ft)	R Sanford Rainfall (inches)	IRR Calculated Irrigation Demand (inches)	EV Lisbon Pan Evap-oration (inches)	ET Evapo-transpir-ation (inches)	PCLJ Direct Precip-itation (acre-ft)	EVLJ Surface Evapor-ation (acre-ft)
Annual Totals or Averages(1):									
1980	3.1	2,217	2,317	48.41	16.32	59.88	34.31	43,008	46,017
1981	3.1	2,217	2,339	42.88	30.67	59.63	34.31	38,095	45,811
1982	3.1	2,217	2,166	59.91	17.22	54.38	34.31	53,225	41,749
1983	3.1	2,217	2,176	62.85	14.03	56.00	34.31	55,837	43,101
1984	3.1	2,217	2,218	47.71	26.43	60.81	34.31	42,386	46,655
1985	3.1	2,217	2,214	44.27	23.07	59.20	34.31	39,330	45,388
1986	3.1	2,217	2,267	43.90	26.44	57.77	34.31	39,001	44,430
1987	3.1	2,217	2,231	46.23	30.92	56.58	34.31	41,071	43,542
1988	3.1	2,217	2,240	55.97	15.27	58.24	34.31	49,724	44,793
1989	3.1	2,217	2,295	37.37	28.40	61.69	34.31	33,200	47,583
1990	3.1	2,217	2,318	36.59	28.22	63.45	34.31	32,507	48,703
Annual and Monthly Means and Extremes:									
Annual Average:	3.06	2,217	2,253	47.83	23.36	58.88	34.31	42,490	45,252
Annual Minimum:	3.06	2,217	2,166	36.59	14.03	54.38	34.31	32,507	41,749
Annual Maximum:	3.06	2,217	2,339	62.85	30.92	63.45	34.31	55,837	48,703
Monthly Minimum:	3.06	158	158	0.10	0.00	1.37	1.78	89	1,060
Monthly Maximum:	3.06	204	204	15.10	6.48	8.88	3.69	13,415	7,323
Monthly Average:	3.06	186	188	3.99	1.95	4.91	2.86	3,541	3,771

Notes:
(1) Annual flows are sums of the monthly values, Annual storages are averages of the monthly values

Source: WAR 1991

(58.88 inches/year) exceeded rainfall, this value is reduced by the lake-pan evaporation coefficient and only occurs in open lake areas which make up only a small part of the total watershed area. The yearly flux across the Lake Jessup surface averaged 42,490 acre-feet for rainfall, PC_{LJ}, and 45,252 acre-feet for lake evaporation, EV_{LJ}. Irrigation (irrigation is not really a meteorological inflow but it is, determined by meteorological conditions, Section 3.1.3) is applied only to limited areas of the watershed (Section 2.1.4), but assists in maintaining a net influx of water to the watershed and ultimately to Lake Jessup. Years of low rainfall such as 1989 (37.37 inches) had high irrigation demands (28.40 inches) and pan evaporation (61.69 inches). Conversely, 1983 with 62.85 inches of rainfall had low irrigation demand (14.03 inches) and pan evaporation (56.00 inches, Table 3.2-1).

Subbasin inputs to the watershed consisted of surface runoff (RO), bank seepage (SEEP, = long-term average infiltration I), septic tanks (ST), and WWTPs (STP) (Table 3.2-2).

Runoff and seepage were the major subbasin inputs. Runoff averaged from 34,405 acre-feet/year for HOWELL to 1,048 acre-feet/year for EUREKA. Bank seepage averaged from 32,701 acre-feet/year for GEESOLD to 327 acre-feet/year for EUREKA (Table 3.2-2). The magnitude of the input is primarily a function of subbasin area (Table 3.1-1). The ratio between the two inputs for a subbasin is primarily a function of the subbasin runoff coefficient. Larger runoff coefficients result in higher proportions of runoff to seepage. SEEP was determined by the period of record average annual infiltration (I). In all the subbasins except HOWELL and GEESOLD the years 1989 and 1990 resulted in negative annual total infiltration. This yearly net loss to the atmosphere from the land surface and shallow groundwater storage was offset by other subbasin inputs which maintained a positive inflow to the lake.

ST and STP were the smaller subbasin inputs (Table 3.2-2). These inputs were not modeled to change over time, and were a function of the numbers of septic tanks and WWTPs within the subbasin (Table 3.1-1). GEESOLD and HOWELL were the only subbasins with inputs from WWTPs. The annual totals averaged 6,915 and 897 acre-feet, respectively. Septic tank inflows ranged from

Table 3.2-2. Inputs to the Lake Jessup Annual Water Budget from Watershed Subbasins for the Years 1980 through 1990 with Monthly and Annual Means and Extremes (Continued).

	Subbasin AIRPORT:						Subbasin: BLACKHMK					
Year	RO Surface Runoff (acre-ft)	I Infil-tration (acre-ft)	SEEP Bank Seepage Inflow (acre-ft)	ST Septic Tank Inflows (acre-ft)	STP WWTP Inflows (acre-ft)	Net Subbasin Inflow (acre-ft)	RO Surface Runoff (acre-ft)	I Infil-tration (acre-ft)	SEEP Bank Seepage Inflow (acre-ft)	ST Septic Tank Inflows (acre-ft)	STP WWTP Inflows (acre-ft)	Net Subbasin Inflow (acre-ft)
Annual Totals or Averages(1):												
1980	9,582	(1,600)	2,643	320	0	14,631	4,152	1,353	1,363	105	0	5,620
1981	10,592	477	2,643	320	0	13,554	3,797	270	1,363	105	0	5,265
1982	14,393	8,333	2,643	320	0	17,356	5,117	4,293	1,363	105	0	6,584
1983	15,035	9,645	2,643	320	0	17,998	5,338	4,968	1,363	105	0	6,806
1984	11,663	2,675	2,643	320	0	14,626	4,168	1,402	1,363	105	0	5,636
1985	10,799	907	2,643	320	0	13,762	3,857	453	1,363	105	0	5,325
1986	10,765	845	2,643	320	0	13,728	3,851	434	1,363	105	0	5,318
1987	11,385	2,129	2,643	320	0	14,348	4,078	1,127	1,363	105	0	5,545
1988	13,433	6,334	2,643	320	0	16,396	4,774	3,249	1,363	105	0	6,242
1989	9,257	(2,284)	2,643	320	0	12,220	3,321	(1,180)	1,363	105	0	4,789
1990	9,070	(2,678)	2,643	320	0	12,033	3,255	(1,382)	1,363	105	0	4,723
Annual and Monthly Means and Extremes:												
Annual Average:	11,452	2,253	2,643	320	0	14,605	4,155	1,363	1,363	105	0	5,623
Annual Minimum:	9,070	(2,678)	2,643	320	0	12,033	3,255	(1,382)	1,363	105	0	4,723
Annual Maximum:	15,035	9,645	2,643	320	0	17,998	5,338	4,968	1,363	105	0	6,806
Monthly Minimum:	85	(1,624)	220	25	0	332	37	(827)	114	8	0	159
Monthly Maximum:	3,559	5,062	220	27	0	3,806	1,258	2,638	114	9	0	1,380
Monthly Average:	970	220	220	27	0	1,217	346	114	114	9	0	469

Notes:
(1) Annual flows are sums of the monthly values, Annual storages are averages of the monthly values
Parentheses indicate negative values

Source: WAR 1991

Table 3.2-2. Inputs to the Lake Jessup Annual Water Budget from Watershed Subbasins for the Years 1980 through 1990 with Monthly and Annual Means and Extremes (Continued).

	Subbasin: EUREKA						Subbasin: GEESOLD					
Year	RO Surface Runoff (acre-ft)	I Infil-tration (acre-ft)	SEEP Bank Seepage Inflow (acre-ft)	ST Septic Tank Inflows (acre-ft)	STP WWTP Inflows (acre-ft)	Net Subbasin Inflow (acre-ft)	RO Surface Runoff (acre-ft)	I Infil-tration (acre-ft)	SEEP Bank Seepage Inflow (acre-ft)	ST Septic Tank Inflows (acre-ft)	STP WWTP Inflows (acre-ft)	Net Subbasin Inflow (acre-ft)
Annual Totals or Averages(1):												
1980	1,044	316	327	105	0	1,476	24,608	29,439	32,701	455	6,915	64,680
1981	961	81	327	105	0	1,394	24,233	27,987	32,701	455	6,915	64,305
1982	1,285	1,007	327	105	0	1,717	30,008	51,546	32,701	455	6,915	70,080
1983	1,339	1,161	327	105	0	1,771	30,874	54,758	32,701	455	6,915	70,946
1984	1,052	340	327	105	0	1,485	25,807	34,087	32,701	455	6,915	65,879
1985	973	114	327	105	0	1,405	23,728	26,053	32,701	455	6,915	63,800
1986	973	114	327	105	0	1,405	24,064	27,541	32,701	455	6,915	64,136
1987	1,032	281	327	105	0	1,464	25,803	34,584	32,701	455	6,915	65,876
1988	1,199	759	327	105	0	1,631	27,911	42,737	32,701	455	6,915	67,984
1989	842	(262)	327	105	0	1,274	21,370	16,346	32,701	455	6,915	61,442
1990	825	(310)	327	105	0	1,257	20,986	14,638	32,701	455	6,915	61,058
Annual and Monthly Means and Extremes:												
Annual Average:	1,048	327	327	105	0	1,480	25,399	32,701	32,701	455	6,915	65,471
Annual Minimum:	825	(310)	327	105	0	1,257	20,986	14,638	32,701	455	6,915	61,058
Annual Maximum:	1,339	1,161	327	105	0	1,771	30,874	54,758	32,701	455	6,915	70,946
Monthly Minimum:	11	(188)	27	8	0	47	628	(2,161)	2,725	35	535	3,979
Monthly Maximum:	314	616	27	9	0	350	6,911	20,057	2,725	39	587	10,262
Monthly Average:	87	27	27	9	0	123	2,117	2,725	2,725	38	576	5,456

Notes:
(1) Annual flows are sums of the monthly values, Annual storages are averages of the monthly values
Parentheses indicate negative values

Source: WAR 1991

Table 3.2-2. Inputs to the Lake Jessup Annual Water Budget from Watershed Subbasins for the Years 1980 through 1990 with Monthly and Annual Means and Extremes (Continued).

	Subbasin: HOWELL						Subbasin: MARLBED					
Year	RO Surface Runoff (acre-ft)	I Infil-tration (acre-ft)	SEEP Bank Seepage Inflow (acre-ft)	ST Septic Tank Inflows (acre-ft)	STP WWTP Inflows (acre-ft)	Net Subbasin Inflow (acre-ft)	RO Surface Runoff (acre-ft)	I Infil-tration (acre-ft)	SEEP Bank Seepage Inflow (acre-ft)	ST Septic Tank Inflows (acre-ft)	STP WWTP Inflows (acre-ft)	Net Subbasin Inflow (acre-ft)
Annual Totals or Averages(1):												
1980	34,412	25,789	25,951	228	897	61,488	1,351	578	594	105	0	2,049
1981	31,395	17,172	25,951	228	897	58,471	1,243	217	594	105	0	1,942
1982	42,419	49,800	25,951	228	897	69,495	1,663	1,629	594	105	0	2,362
1983	44,273	54,808	25,951	228	897	71,349	1,733	1,864	594	105	0	2,432
1984	34,498	25,886	25,951	228	897	61,574	1,361	613	594	105	0	2,060
1985	31,928	18,803	25,951	228	897	59,004	1,259	269	594	105	0	1,958
1986	31,862	18,839	25,951	228	897	58,938	1,259	268	594	105	0	1,957
1987	33,727	24,405	25,951	228	897	60,803	1,334	523	594	105	0	2,033
1988	39,583	40,935	25,951	228	897	66,659	1,551	1,253	594	105	0	2,250
1989	27,455	5,434	25,951	228	897	54,531	1,088	(305)	594	105	0	1,787
1990	26,905	3,590	25,951	228	897	53,981	1,067	(377)	594	105	0	1,766
Annual and Monthly Means and Extremes:												
Annual Average:	34,405	25,951	25,951	228	897	61,481	1,355	594	594	105	0	2,054
Annual Minimum:	26,905	3,590	25,951	228	897	53,981	1,067	(377)	594	105	0	1,766
Annual Maximum:	44,273	54,808	25,951	228	897	71,349	1,733	1,864	594	105	0	2,432
Monthly Minimum:	288	(5,317)	2,163	18	69	2,546	14	(278)	49	8	0	72
Monthly Maximum:	10,447	22,085	2,163	19	76	12,705	406	949	49	9	0	465
Monthly Average:	2,867	2,163	2,163	19	75	5,123	113	49	49	9	0	171

Notes:
(1) Annual flows are sums of the monthly values, Annual storages are averages of the monthly values
Parentheses indicate negative values

Source: WAR 1991

Table 3.2-2. Inputs to the Lake Jessup Annual Water Budget from Watershed Subbasins for the Years 1980 through 1990 with Monthly and Annual Means and Extremes (Continued).

Year	Subbasin: SALTCRK						Subbasin: SANFDAVE					
	RO Surface Runoff (acre-ft)	I Infil-tration (acre-ft)	SEEP Bank Seepage Inflow (acre-ft)	ST Septic Tank Inflows (acre-ft)	STP WWTP Inflows (acre-ft)	Net Subbasin Inflow (acre-ft)	RO Surface Runoff (acre-ft)	I Infil-tration (acre-ft)	SEEP Bank Seepage Inflow (acre-ft)	ST Septic Tank Inflows (acre-ft)	STP WWTP Inflows (acre-ft)	Net Subbasin Inflow (acre-ft)
Annual Totals or Averages(1):												
1980	6,333	2,145	1,921	210	0	8,463	7,255	2,036	2,144	271	0	9,670
1981	5,631	(311)	1,921	210	0	7,761	6,706	810	2,144	271	0	9,122
1982	7,833	7,453	1,921	210	0	9,963	8,927	5,920	2,144	271	0	11,342
1983	8,212	8,765	1,921	210	0	10,342	9,295	6,707	2,144	271	0	11,710
1984	6,255	1,866	1,921	210	0	8,385	7,329	2,183	2,144	271	0	9,744
1985	5,802	293	1,921	210	0	7,932	6,775	978	2,144	271	0	9,190
1986	5,758	151	1,921	210	0	7,889	6,780	1,017	2,144	271	0	9,195
1987	6,068	1,247	1,921	210	0	8,198	7,193	1,972	2,144	271	0	9,608
1988	7,317	5,608	1,921	210	0	9,447	8,326	4,479	2,144	271	0	10,741
1989	4,910	(2,859)	1,921	210	0	7,040	5,874	(1,114)	2,144	271	0	8,289
1990	4,808	(3,230)	1,921	210	0	6,938	5,758	(1,407)	2,144	271	0	8,173
Annual and Monthly Means and Extremes:												
Annual Average:	6,266	1,921	1,921	210	0	8,396	7,293	2,144	2,144	271	0	9,708
Annual Minimum:	4,808	(3,230)	1,921	210	0	6,938	5,758	(1,407)	2,144	271	0	8,173
Annual Maximum:	8,212	8,765	1,921	210	0	10,342	9,295	6,707	2,144	271	0	11,710
Monthly Minimum:	18	(1,690)	160	16	0	196	81	(995)	179	21	0	283
Monthly Maximum:	1,968	4,768	160	18	0	2,146	2,175	3,353	179	23	0	2,377
Monthly Average:	522	160	160	17	0	700	608	179	179	23	0	809

Notes:
(1) Annual flows are sums of the monthly values, Annual storages are averages of the monthly values
Parentheses indicate negative values

Source: WAR 1991

Table 3.2-2. Inputs to the Lake Jessup Annual Water Budget from Watershed Subbasins for the Years 1980 through 1990 with Monthly and Annual Means and Extremes (Continued).

Subbasin: SWEETCRK

Year	RO Surface Runoff (acre-ft)	I Infil-tration (acre-ft)	SEEP Bank Seepage Inflow (acre-ft)	ST Septic Tank Inflows (acre-ft)	STP WWTP Inflows (acre-ft)	Net Subbasin Inflow (acre-ft)
Annual Totals or Averages(1):						
1980	3,568	447	416	169	0	4,153
1981	3,226	(338)	416	169	0	3,810
1982	4,404	2,368	416	169	0	4,989
1983	4,604	2,824	416	169	0	5,189
1984	3,558	422	416	169	0	4,143
1985	3,296	(176)	416	169	0	3,880
1986	3,282	(205)	416	169	0	3,867
1987	3,469	223	416	169	0	4,054
1988	4,111	1,692	416	169	0	4,696
1989	2,818	(1,275)	416	169	0	3,402
1990	2,761	(1,408)	416	169	0	3,345
Annual and Monthly Means and Extremes:						
Annual Average:	3,554	416	416	169	0	4,139
Annual Minimum:	2,761	(1,408)	416	169	0	3,345
Annual Maximum:	4,604	2,824	416	169	0	5,189
Monthly Minimum:	23	(606)	35	13	0	72
Monthly Maximum:	1,093	1,683	35	14	0	1,142
Monthly Average:	296	35	35	14	0	345

Notes:
(1) Annual flows are sums of the monthly values, Annual storages are averages of the monthly values
Parentheses indicate negative values

Source: WAR 1991

455 acre-feet/year for GEESOLD to 105 acre-feet/year for subbasins BLACKHMK, EUREKA, and MARLBED.

The sum of the individual inputs represented the net subbasin inflow to Lake Jessup (Table 3.2-2, Table 3.2-3, Figure 3.2-2). The net subbasin inflow was primarily a function of subbasin size. Net subbasin inflow averaged from 65,471 acre-feet/year (GEESOLD) to 1,480 acre-feet/year (EUREKA). Annual net inflow had a fairly narrow range compared to the range of monthly net inflow. The subbasin annual maximums and minimums were within a factor of 2 which reflects the magnitude of change from wet to dry years. The monthly maximums were approximately 5 to 10 times the minimums which indicates the increased variability due to seasonality within a year, combined with the effects of dry and wet years (Table 3.2-3). The range of average annual inflow volume from individual subbasins encompassed the direct flows of PC_{LJ}, EV_{LJ}, and ARTES (Figure 3.2-2). ARTES, the average artesian input of springflow plus upward leakage were of approximately the same magnitude as the seven smaller subbasins. The fact that the subbasin flows are on the same order of magnitude as direct inflows indicate that both types may be of similar importance in the nutrient budget.

The subbasins were combined to determine the actual contribution (acre-ft/year) and relative contribution (percent) of the various inflows and outflows for the entire watershed and Lake Jessup (Table 3.2-4).

Total inflow to Lake Jessup was the sum of the watershed inflows (runoff, seepage, septic tank, and WWTP), and the direct inflows [artesian = springflow plus upward leakage, precipitation, and St. Johns River (SJR) inflow] (Figure 3.2-3, Table 3.2-4). Total inflows averaged 222,859 acre-ft/year and ranged from 265,285 acre-ft to 190,317 acre-ft in 1983 and 1990, respectively.

The watershed inflows contributed the highest percentages contribution to the average annual inflow (Figure 3.2-3, Table 3.2-4). The largest single inflow to Lake Jessup was from surface runoff which averaged 39.19 percent. The next largest inflow was bank seepage discharged from the shallow groundwater table aquifer with 35.44 percent of the total inflows. Septic tanks and WWTPs averaged 1.02 percent, and 4.06 percent, respectively.

Table 3.2-3 Summary of Subbasin Net Annual Inflow to Lake Jessup with Annual and Monthly Means and Extremes.

Subbasin	Annual Average	Annual Minimum	Annual Maximum	Monthly Minimum	Monthly Maximum	Monthly Average
AIRPORT	14605	12033	17998	332	3806	1217
BLACKHMK	5623	4723	6806	159	1380	469
EUREKA	1480	1257	1771	47	360	123
GEESOLD	65471	61058	70946	3979	10262	5456
HOWELL	61481	53981	71349	2546	12705	5123
MARLBED	2054	1766	2432	72	465	171
SALTCRK	8396	6938	10342	196	2146	700
SANFDAVE	9708	8173	11710	283	2377	809
SWEETCRK	4139	3345	5189	72	1142	345

Source: WAR 1992

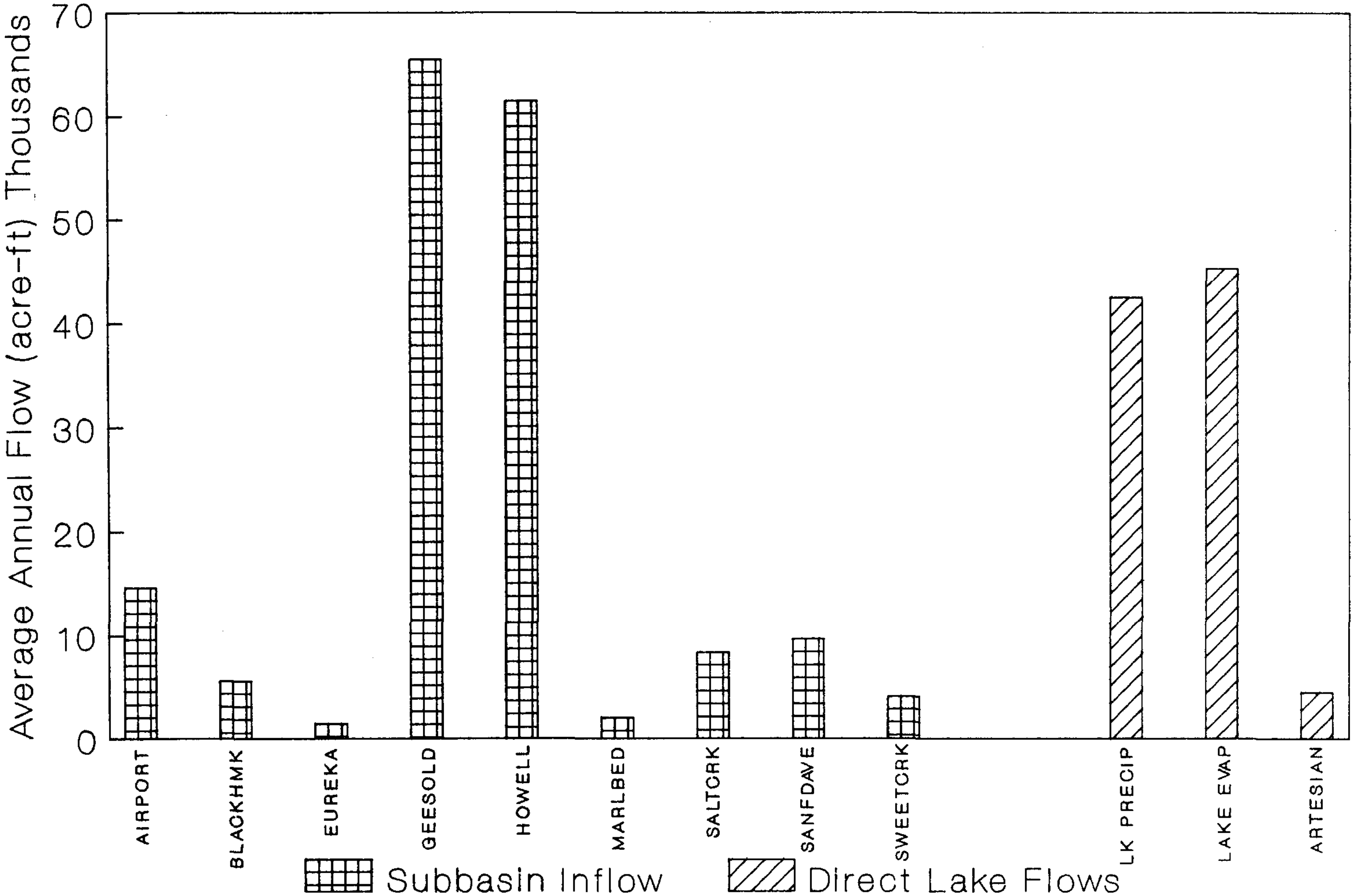

FIGURE 3.2-2. Comparison of Average Subbasin Net Inflows and Direct Lake Inflows and Outflows for Lake Jessup. SOURCE: WAR 1992

Table 3.2-4. *Annual Inflow and Outflow Volumes and Percent Contribution for Components of the* Lake Jessup Water Budget with Period of Record Monthly and Annual Means and Extremes.

Year	Inflow Volumes:										Outflow Volumes:			
	ARTES SPFLOW plus LEAK (acre-ft)	PCLJ Direct Precip-itation (acre-ft)	RO Surface Runoff (acre-ft)	I Infil-tration (acre-ft)	SEEP Bank Seepage Inflow (acre-ft)	ST Septic Tank Inflows (acre-ft)	STP WWTP Inflows (acre-ft)	ST + STP Septic Tks and WWTP Effluent (acre-ft)	SJRIN Inflow from SJ River (acre-ft)	Total Inflows to Lake (acre-ft)	EVLJ Surface Evapor-ation (acre-ft)	SJROUT Discharge to SJ River (acre-ft)	Total Outflows from Lake (acre-ft)	Surface Discharge to SJ River (cfs)
Annual Totals or Averages(1):														
1980	4,534	43,008	94,390	64,794	68,060	1,968	7,812	9,780	0	219,771	46,017	178,409	224,426	245
1981	4,556	38,095	87,785	46,365	68,060	1,968	7,812	9,780	0	208,276	45,811	166,585	212,396	230
1982	4,383	53,225	116,048	132,350	68,060	1,968	7,812	9,780	0	251,495	41,749	201,929	243,677	279
1983	4,393	55,837	120,703	145,500	68,060	1,968	7,812	9,780	0	258,772	43,101	210,379	253,480	290
1984	4,434	42,386	95,691	69,474	68,060	1,968	7,812	9,780	2,099	222,450	46,655	175,115	221,770	240
1985	4,431	39,330	88,417	47,693	68,060	1,968	7,812	9,780	9,060	219,077	45,388	161,705	207,093	211
1986	4,484	39,001	88,594	49,004	68,060	1,968	7,812	9,780	2,478	212,397	44,430	183,339	227,770	248
1987	4,448	41,071	94,089	66,491	68,060	1,968	7,812	9,780	8,770	226,219	43,542	162,544	206,086	211
1988	4,457	49,724	108,205	107,046	68,060	1,968	7,812	9,780	6,829	247,055	44,793	220,492	265,285	294
1989	4,512	33,200	76,935	12,501	68,060	1,968	7,812	9,780	3,136	195,622	47,583	146,832	194,415	198
1990	4,535	32,507	75,435	7,437	68,060	1,968	7,812	9,780	0	190,317	48,703	148,553	197,257	205
Annual and Monthly Means and Extremes:														
Annual Average:	4,470	42,490	95,117	68,060	68,060	1,968	7,812	9,780	2,943	222,859	45,252	177,807	223,059	241
Annual Minimum:	4,383	32,507	75,435	7,437	68,060	1,968	7,812	9,780	0	190,317	41,749	146,832	194,415	198
Annual Maximum:	4,556	55,837	120,703	145,500	68,060	1,968	7,812	9,780	9,060	258,772	48,703	220,492	265,285	294
Monthly Minimum:	336	89	1,186	(13,686)	5,672	152	604	756	0	8,152	1,060	0	1,361	(152)
Monthly Maximum:	392	13,415	28,131	61,211	5,672	167	663	830	9,060	48,430	7,323	37,733	43,443	614
Monthly Average:	372	3,541	7,926	5,672	5,672	164	651	815	245	18,572	3,771	14,817	18,588	241

Notes:
(1) Annual flows are sums of the monthly values, Annual storages are averages of the monthly values
SEEP = Infiltration(I) Period of Record Average
Infiltration(I) is not Accounted for in Budget
Parentheses indicate negative values

Source: WAR 1991

Table 3.2-4. Annual Inflow and Outflow Volumes and Percent Contribution for Components of the Lake Jessup Water Budget with Period of Record Monthly and Annual Means and Extremes (Continued).

	Inflow Percentages:								Outflow Percentages:		
Year	ARTES SPFLOW plus LEAK	PCLJ Direct Precip-itation	RO Surface Runoff	SEEP Bank Seepage Inflow	ST Septic Tank Inflows	STP WWTP Inflows	SJRIN Inflow from SJ River	Total Inflows to Lake	EVLJ Surface Evapor-ation	SJROUT Discharge to SJ River	Total Outflows from Lake
Annual Totals or Averages(1):											
1980	2.33%	17.68%	39.93%	35.04%	1.01%	4.01%	0.00%	100.00%	20.61%	79.39%	100.00%
1981	2.54%	15.67%	38.39%	37.94%	1.10%	4.36%	0.00%	100.00%	29.06%	70.94%	100.00%
1982	2.16%	18.23%	41.42%	33.39%	0.96%	3.83%	0.00%	100.00%	18.62%	81.38%	100.00%
1983	1.85%	20.48%	44.92%	28.62%	0.83%	3.29%	0.00%	100.00%	17.70%	82.30%	100.00%
1984	2.45%	15.71%	37.72%	37.51%	1.09%	4.31%	1.22%	100.00%	31.24%	68.76%	100.00%
1985	2.47%	15.60%	36.89%	37.82%	1.09%	4.33%	1.79%	100.00%	31.16%	68.84%	100.00%
1986	2.34%	16.62%	39.04%	35.63%	1.03%	4.07%	1.27%	100.00%	26.27%	73.73%	100.00%
1987	2.23%	16.15%	38.49%	34.11%	0.99%	3.92%	4.12%	100.00%	28.16%	71.84%	100.00%
1988	1.99%	18.64%	41.41%	30.55%	0.88%	3.49%	3.05%	100.00%	22.52%	77.48%	100.00%
1989	2.62%	14.74%	36.00%	39.56%	1.15%	4.55%	1.39%	100.00%	30.02%	69.98%	100.00%
1990	2.63%	15.12%	36.87%	39.70%	1.14%	4.54%	0.00%	100.00%	27.43%	72.57%	100.00%
Annual and Monthly Means and Extremes:											
Annual Average:	2.33%	16.78%	39.19%	35.44%	1.02%	4.06%	1.17%	100.00%	25.71%	74.29%	100.00%
Annual Minimum:	1.85%	14.74%	36.00%	28.62%	0.83%	3.29%	0.00%	100.00%	17.70%	68.76%	100.00%
Annual Maximum:	2.63%	20.48%	44.92%	39.70%	1.15%	4.55%	4.12%	100.00%	31.24%	82.30%	100.00%
Monthly Minimum:	0.79%	1.00%	11.13%	11.71%	0.34%	1.37%	0.00%	100.00%	3.83%	0.00%	100.00%
Monthly Maximum:	4.64%	27.70%	58.09%	69.57%	2.05%	8.13%	49.40%	100.00%	100.00%	96.17%	100.00%
Monthly Average:	2.33%	16.78%	39.19%	35.44%	1.02%	4.06%	1.17%	100.00%	25.71%	74.29%	100.00%

Notes:
(1) Annual flows are sums of the monthly values, Annual storages are averages of the monthly values

Source: WAR 1991

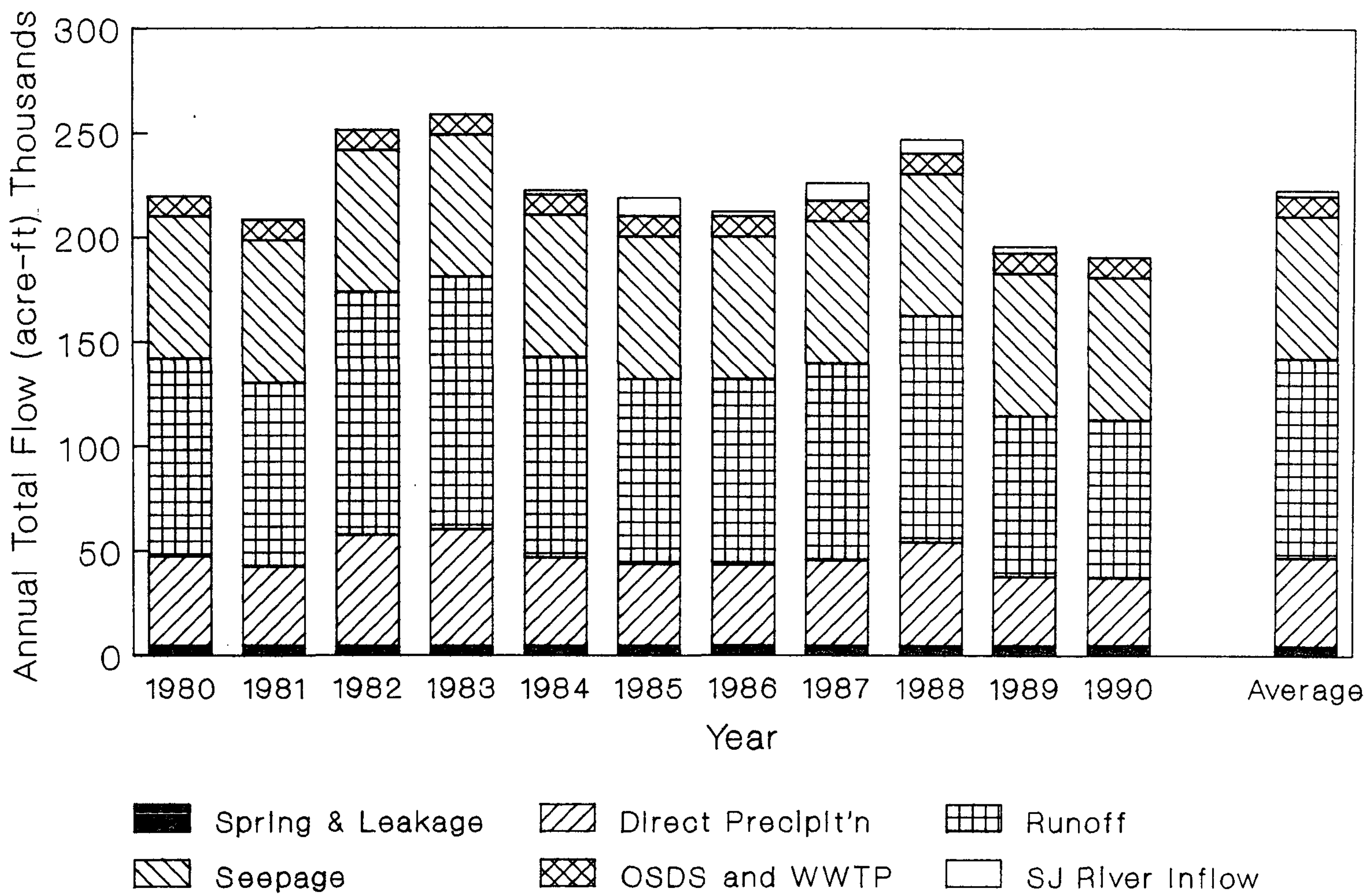

FIGURE 3.2-3. Contribution of Individual Annual Inflows to Annual Total Inflow into Lake Jessup.

SOURCE: WAR 1991

The largest direct input was direct precipitation which averaged 16.78 percent of total inflows. The inputs of springflow and upward leakage were approximately equal. Together they averaged 2.33 percent of the net annual inflows. Inflow from the SJR accounted for 1.17 percent and occurred in only 6 years of the 11-year period of record.

The magnitude of average annual inflows ranged from 96,117 acre-ft for runoff to 1,968 acre-ft for septic tanks (Table 3.2-4, Figure 3.2-4). Annual runoff volume averaged 96,117 acre-ft and ranged from 75,435 in 1990 to 120,703 acre-feet in 1983. Annual direct precipitation inflow onto the lake surface ranged from 32,507 acre-ft in 1990 to 55,837 acre-ft in 1983 and averaged 42,490 acre-ft/year.

Monthly values for runoff and direct precipitation (Figure 3.2-5, Table 3.2-4) showed a higher degree of variability due to the shorter time step of computation reflecting the influence of seasonality and the sporadic nature of rainfall. Monthly total runoff volumes averaged 7,926 acre-ft and ranged from 1,186 acre-ft in to 28,131 acre-ft in July, 1984. The monthly rainfall totals ranged from 89 acre-ft in December, 1984 to 13,419 acre-ft in July, 1984 with an average of 3,541 acre-feet. Since runoff is directly dependent on rainfall, there is a positive relationship between rainfall and runoff (Figures 3.2-4 and 3.2-5).

Bank seepage remained constant at 5,672 acre-feet per month (68,060 acre-ft/year) which was the period of record average for infiltration of rainfall and irrigation into the groundwater. The bank seepage equation (eq. 3-8) was used to approximate groundwater inflow to Lake Jessup instead of the infiltration equation (eq.3-9) (Section 3.1.4) in the summary water budget calculations for the subbasins and watershed because infiltration values ranged over such a broad range of positive to negative numbers (Table 3.2-4). The degree of variability for infiltration values was much higher than meteorologic parameters such as direct precipitation and direct evaporation (Figure 3.2-6). The dynamics of infiltration were sensitive to the balance between rainfall and evaporation but seemed to respond mostly to rainfall since evaporation was more constant. Annual infiltration ranged from 7,437 to 145,500 acre-feet with an average of 68,060 acre-feet. Monthly infiltration ranged from -13,686 to 61,211 acre-feet with an average of 5,672 acre-feet.

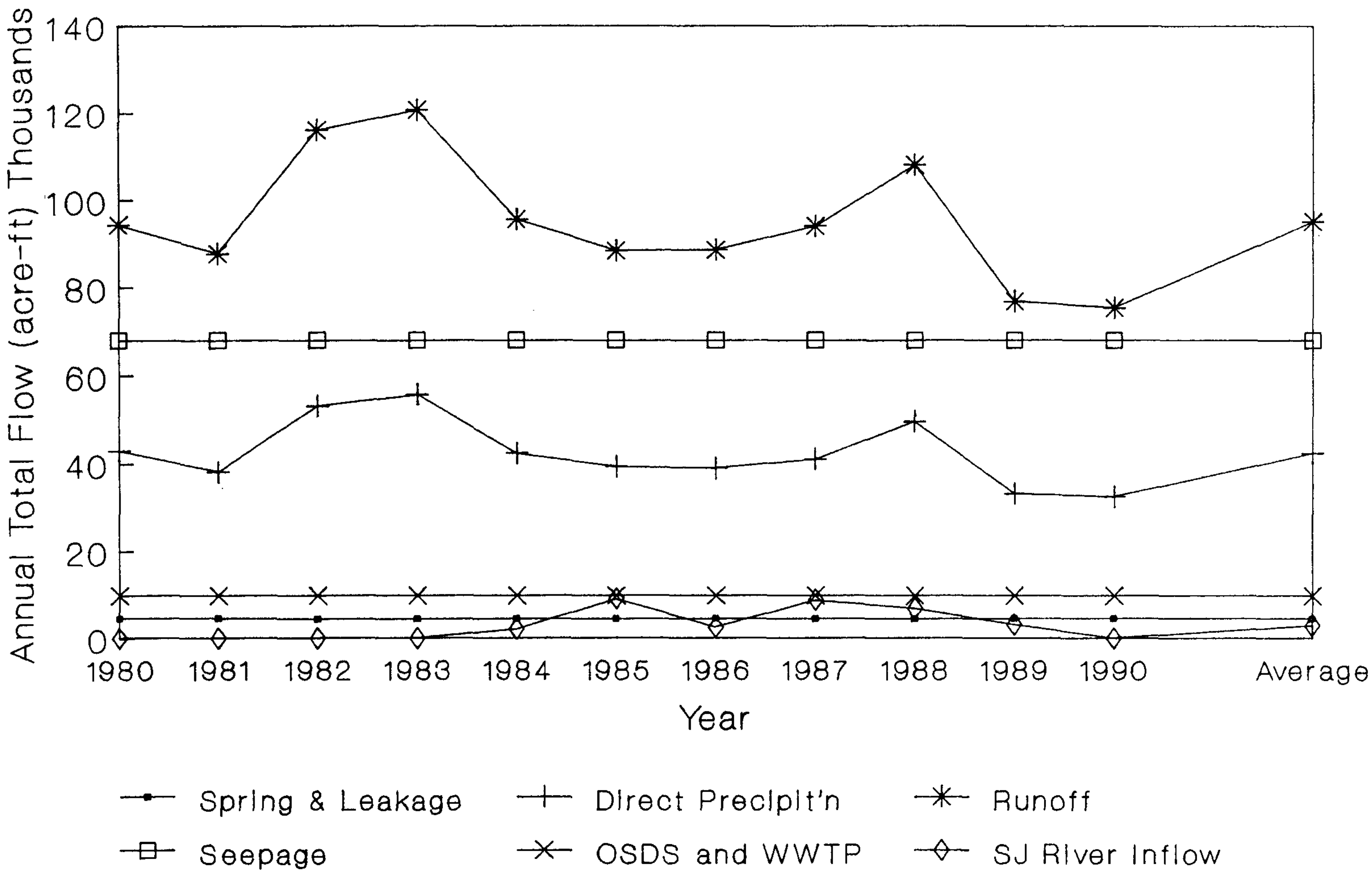

FIGURE 3.2-4. Annual Totals and Period of Record Annual Averages of Individual Inflows to Lake Jessup.

SOURCE: WAR 1991

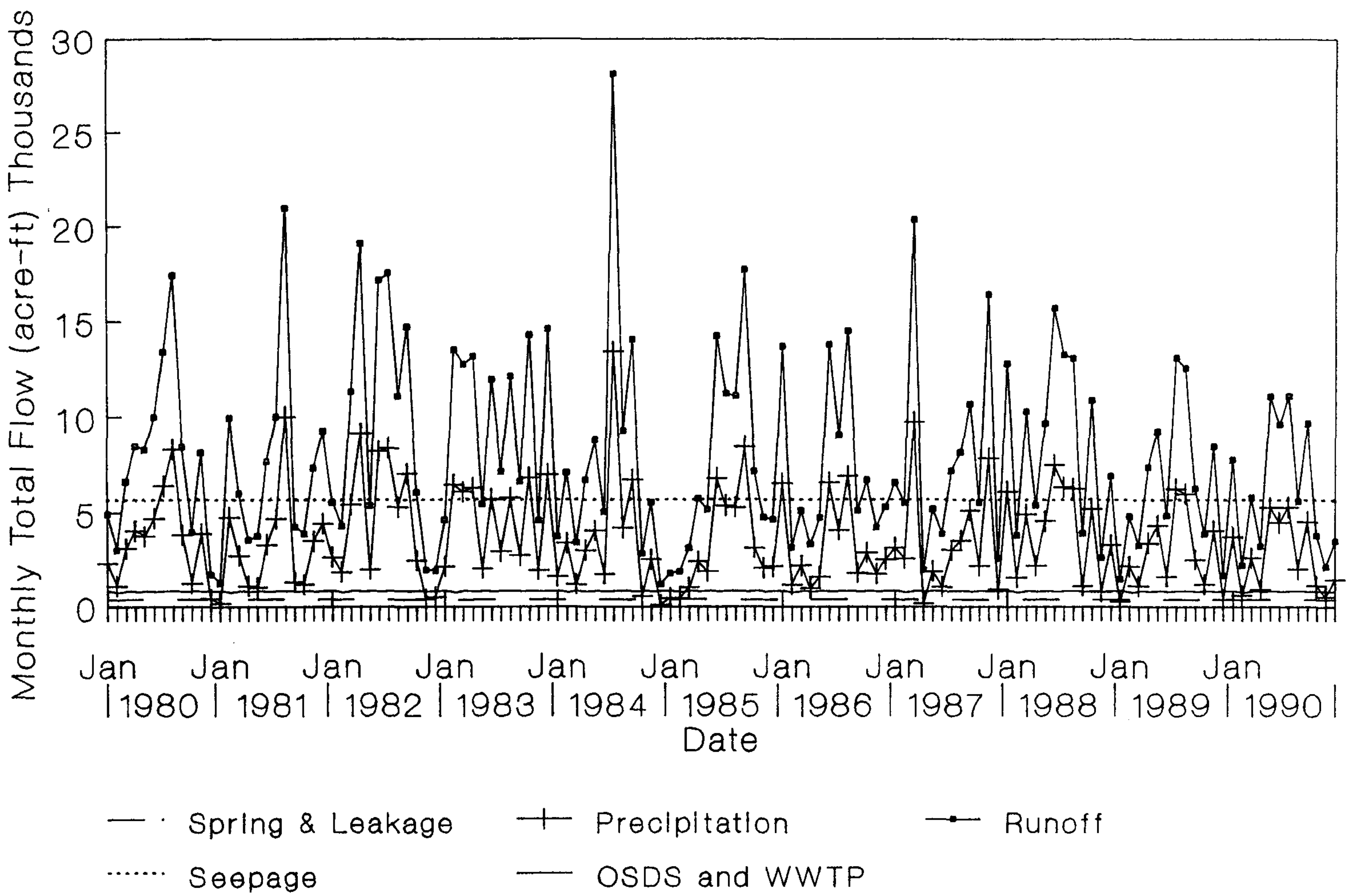

FIGURE 3.2-5. Monthly Totals of Individual Inflows to Lake Jessup for the Period 1/80 to 12/90.

SOURCE: WAR 1991

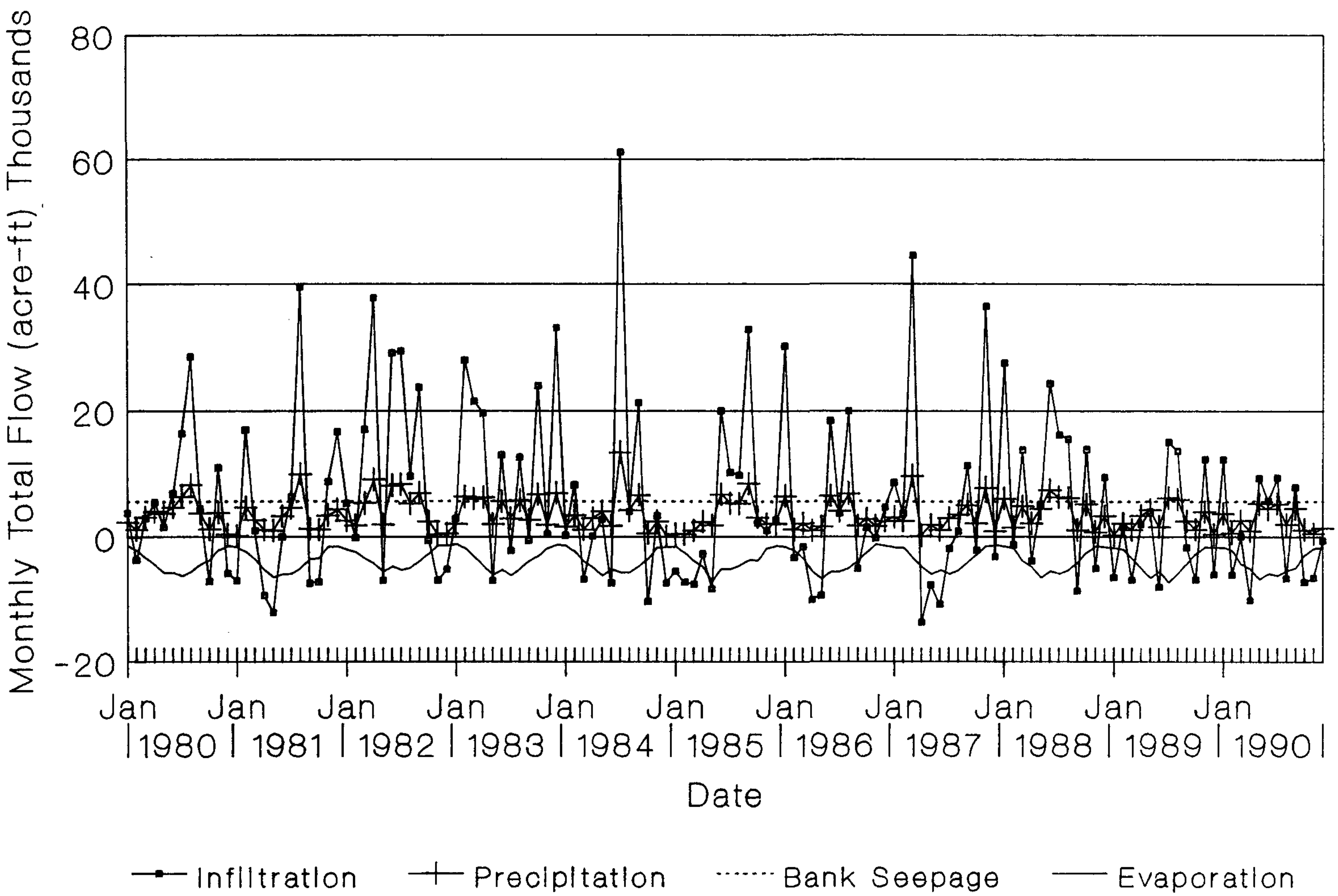

FIGURE 3.2-6. Monthly Total Infiltration, Precipitation, Evaporation and Bank Seepage to Lake Jessup.

SOURCE: WAR 1992

Monthly infiltration negative values occurred when subbasin losses due to runoff, evapotranspiration, and evaporation exceeded rainfall inputs to the subbasin. The period of record low occurred in April, 1987 which only totaled 0.2 inches of rainfall.

ARTES, ST, and STP remained fairly constant through the period of record (Table 3.2-4, Figures 3.2-4 and 3.2-5). ARTES varied slightly as a function of Lake Jessup stage, but remained near the annual average of 4,470 acre-ft. Septic tanks maintained a constant annual inflow of 1,968 acre-ft (164 acre-ft/month) since the number of septic tanks was not modeled to change over time, nor were the number of WWTPs which averaged 7,812 acre-ft/year (651 acre-ft/month). ST and STP did vary slightly monthly according to the number of days in the month.

Inflow from the St. Johns River (SJR) to Lake Jessup occurs when river stage increases and the watershed and direct inputs to Lake Jessup are not sufficient to increase lake stage to the same level. This did not occur frequently nor were the inflows of a large magnitude. The largest annual SJR inflows to the lake occurred in 1985 and 1987 (9,060 and 8,770 acre-feet, respectively) (Figure 3.2-4, Table 3.2-4) in response to the large increases in lake stage forced by the increases in stage of the SJR at the confluence with Lake Jessup.

Total outflows from Lake Jessup was comprised of losses to direct evaporation and to surface water outflow to the SJR (Table 3.2-4, Figure 3.2-7). Total outflows averaged 223,059 acre-ft/year, and ranged from 194,415 acre-ft/year in 1988 to 265,285 acre-ft/year in 1990. Surface evaporation averaged 25.71 percent of the annual total outflows and ranged between 17.70 and 31.24 percent. Monthly percentages ranged from 3.38 to 100 percent. Monthly discharge to the SJR ranged from 0 to 96.17 of the total outflows. Annual discharge to the SJR ranged from 68.76 to 82.30 percent.

Outflow to the SJR is the surplus of water that enters Lake Jessup after evaporative losses and changes in storage are considered. Discharge to the SJR averaged 177,807 acre-ft/year and ranged from 146,832 to 220,492 acre-ft/year (Table 3.2-4, Figure 3.2-8). Variations responded partly to changes in rainfall but were modified by other factors such as evaporation as well.

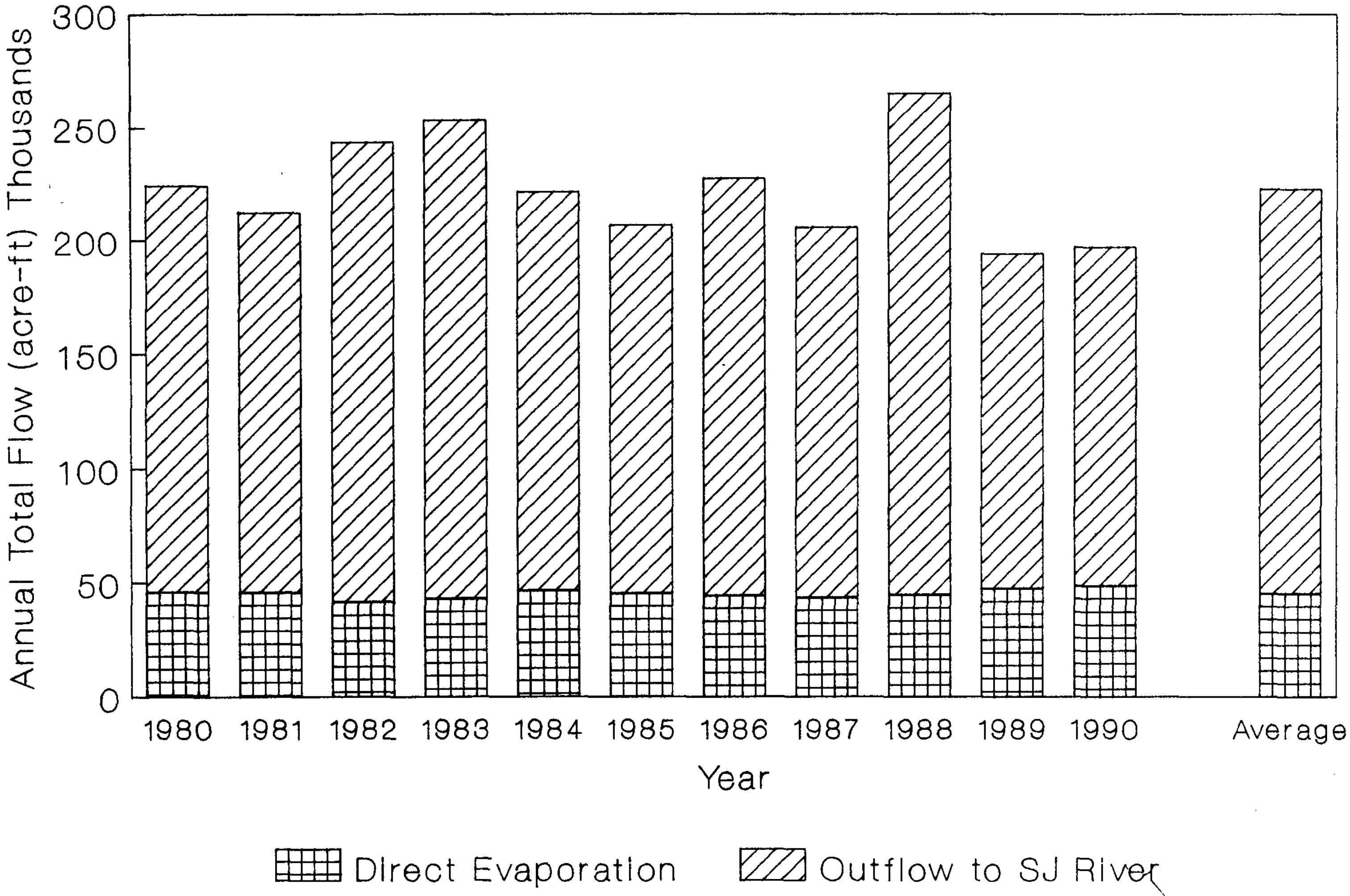

FIGURE 3.2-7. Contribution of Annual Direct Evaporation and Annual Lake Jessup Outflow to St. Johns River.

SOURCE: WAR 1992

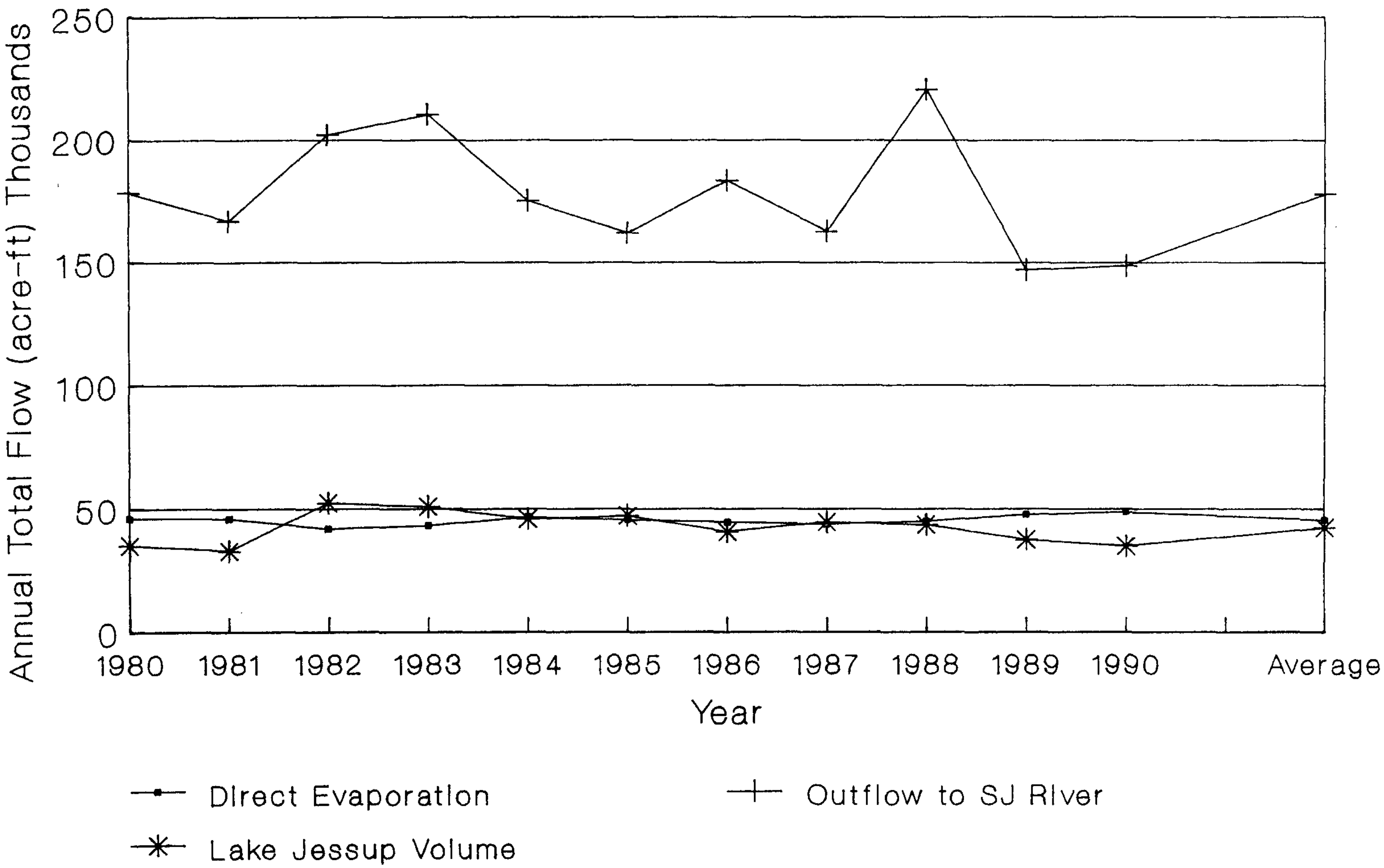

FIGURE 3.2-8. Annual Totals and Period of Record Annual Averages of Individual Outflows from Lake Jessup and Annual Average Lake Volume.

SOURCE: WAR 1992

Annual Lake Jessup surface evaporation averaged 45,252 acre-ft/year and ranged from 41,749 acre-ft to 48,703 acre-ft (Table 3.2-4, Figure 3.2-8). The average surface evaporation of 45,252 acre-ft/year is greater than the annual average direct rainfall input of 42,490 acre-ft resulting in an average annual net loss to the atmosphere of 2762 acre-ft from the lake surface. Since evaporation is predominantly a function of solar radiation, it does not vary considerably from year to year. It does, however, vary seasonally.

The average annual direct evaporation of 45,252 acre-ft was slightly larger than the average Lake Jessup volume of 42,216 acre-feet (Appendix A, Figure 3.2-8). This means that approximately the entire volume of Lake Jessup is lost to evaporation each year. There also appears to be a negative relationship between evaporation and lake volume whereby periods of decreasing evaporation coincide with periods of increasing lake volume. There was conversely a positive relationship between lake volume and rainfall as might have been expected but the correlation with evaporation appeared to be stronger. This was expected since river stage determines lake stage and, therefore, lake volume was influenced more by the regional evaporation pattern that affects river stage over its length than the local rainfall pattern.

Monthly outflows were more variable than annual outflows (Figure 3.2-9). Discharge to the SJR averaged 14,817 acre-feet per month. Monthly discharge ranged from 0 to 37,733 acre-feet. This variability was in response to changes in rainfall and lake volume. Zero monthly discharge corresponds to months of inflow from the SJR to Lake Jessup. Monthly evaporation averaged 3,771 acre-feet and ranged from 1,060 to 7,323 acre-feet, primarily in response to seasonal changes in solar radiation.

Total outflows tend to relate fairly well with total inflows for both annual (Figure 3.2-10) and monthly (Figure 3.2-11) time step calculations (Table 3.2-4). The long-term averages are almost equal; however, individual monthly or annual pairs can be noticeably different (still within 5 to 10 percent). The differences between the inflow and outflow can be attributed to the difference between initial and final Lake Jessup volume for the time period.

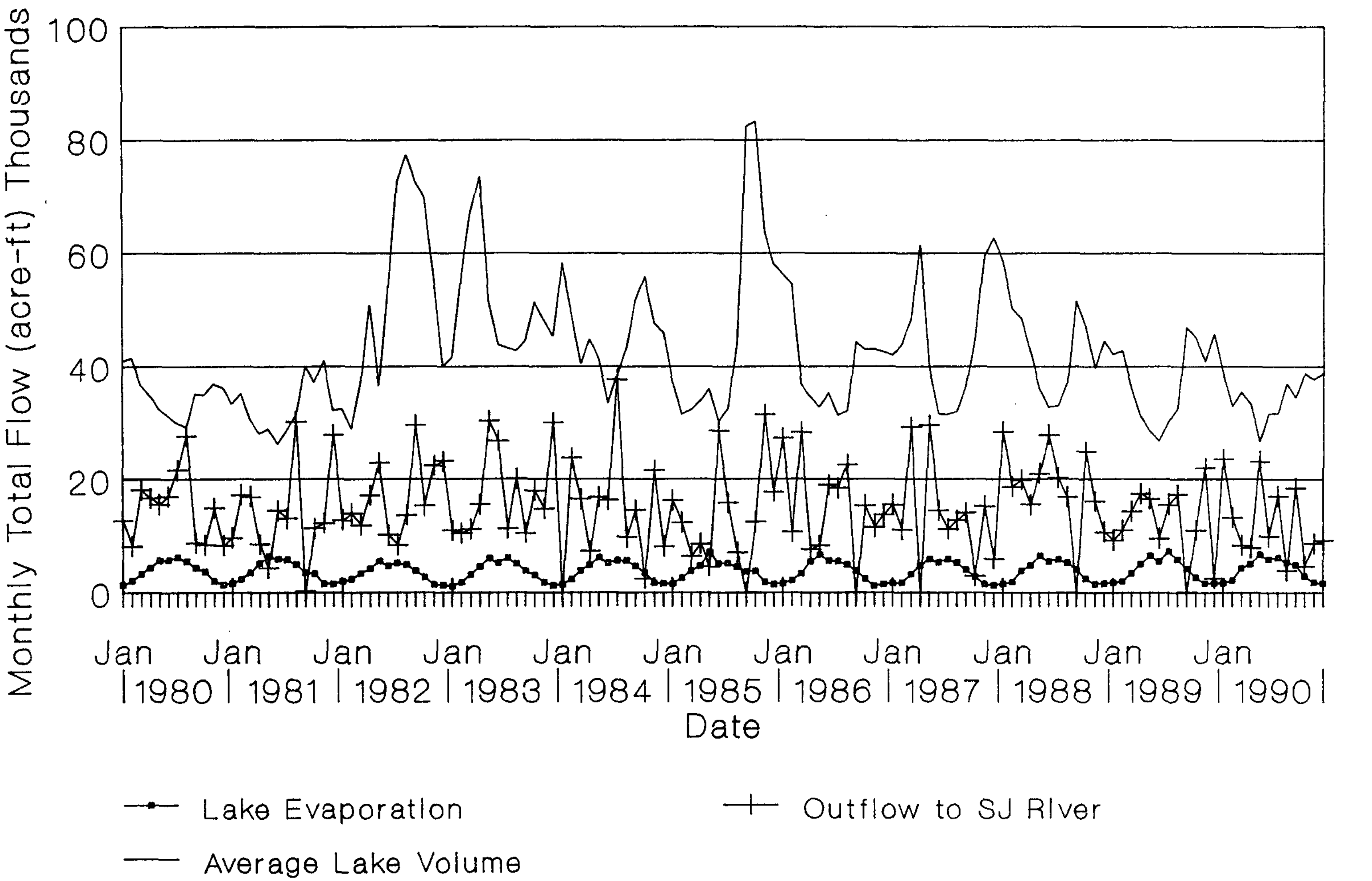

FIGURE 3.2.-9. Monthly Totals of Individual Outflows from Lake Jessup and Monthly Average Lake Volume.

SOURCE: WAR 1991

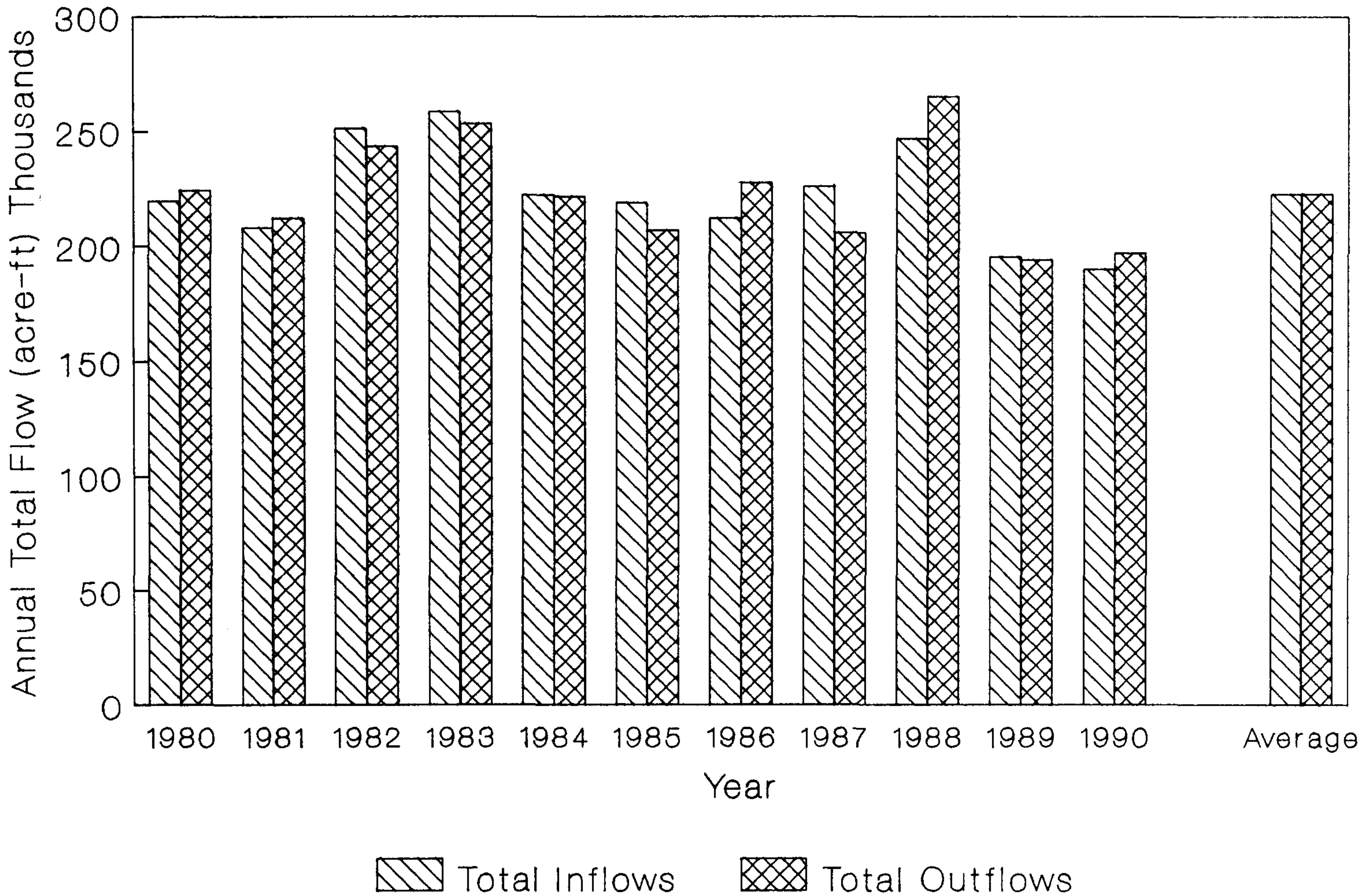

FIGURE 3.2-10. Lake Jessup Total Annual Inflows and Outflows

SOURCE: WAR 1991

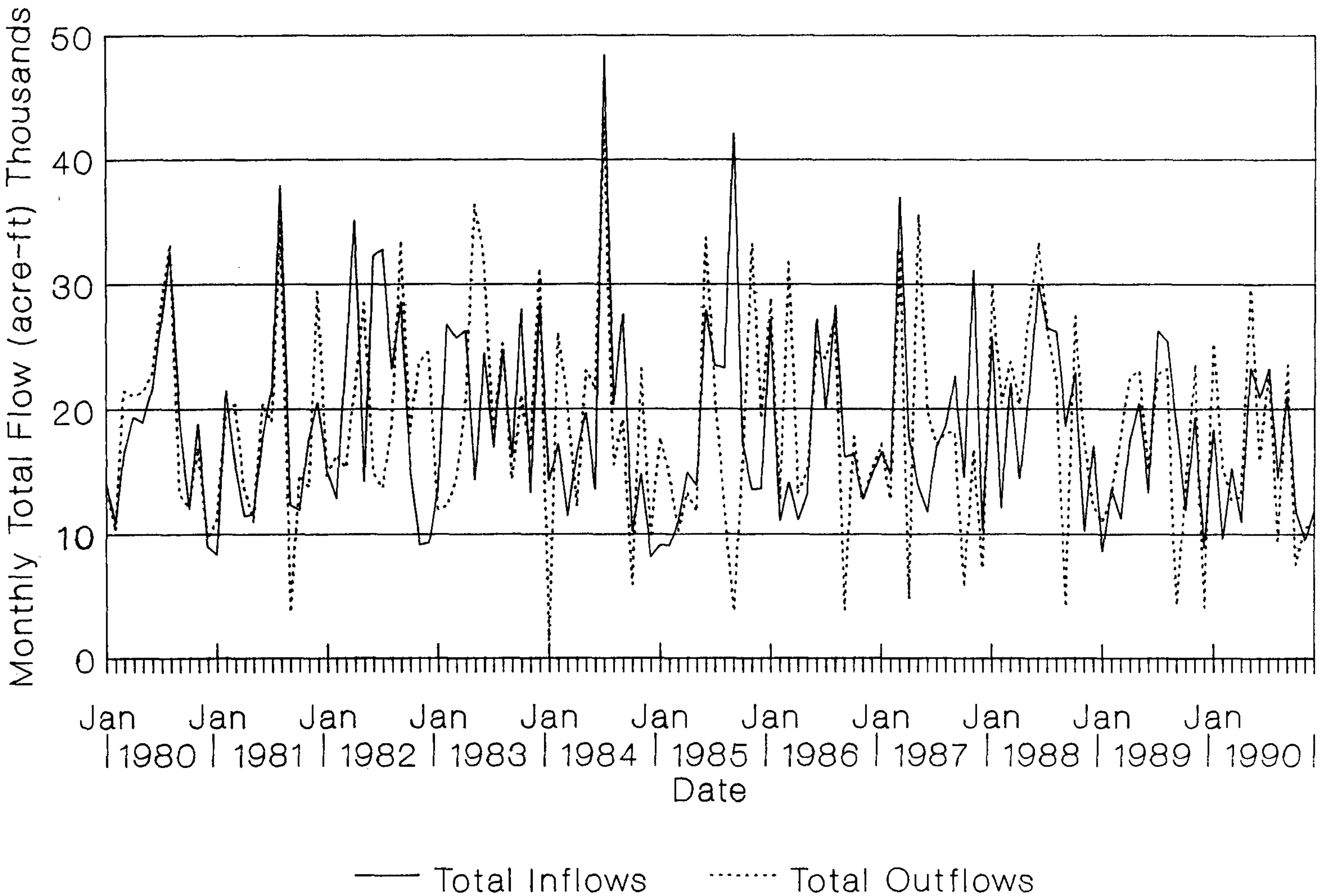

FIGURE 3.2-11. Lake Jessup Total Monthly Inflows and Total Monthly Outflows.

SOURCE: WAR 1991

The average change in annual Lake Jessup volume (DVOL) was -200 acre-feet and ranged from -18,230 to 20,133 acre-feet (Appendix A). Monthly values of DVOL averaged -17 acre-ft and ranged from -22,076 to 38,364 acre-ft. It can be seen that change in annual average volume is not the same as the annual total of monthly DVOL by comparing the annual DVOL value to the corresponding annual volume and the previous year's volume. The sum of the monthly volume changes is not the same as the average of monthly volumes. The average change of -200 acre-ft/year over the period of record (11 years) totals 2,204 acre-feet. This is equivalent to the difference between the initial and final volumes in the monthly budget calculations indicating a balanced water budget for the period of record.

Comparison of average seasonal changes in monthly total inflow, total outflow, and lake volume reveals some possible relationships (Figure 3.2-12). An inverse relationship exists between total outflow and lake volume indicating that changes in lake volume forced by the SJR stage were forcing either releases of water from the lake when stage (volume) decreased or storage of water within the lake when stage (volume) increased. The total inflow and total outflow showed a positive relationship but with inflow lagging approximately one month behind. Normally, lake outflow to the SJR would respond to inflow to the lake and lag behind to some degree. It is possible that the weather patterns that affect river water levels in the headwaters to the south have a different seasonal timing than those in the vicinity of Lake Jessup.

3.3 DISCUSSION

Lake Jessup is a large, shallow lake that discharges surplus water directly to the St. Johns River through a short outlet channel. The outflow to the St. Johns River is largely regulated by the river itself through its effect on lake elevation. Since lake stage follows changes in the river stage, changes in lake volume are not necessarily a function of the watershed inflows to the lake. These forced changes in lake volume can cause either the storage or the release of large volumes of water.

Outflow to the St. Johns River is an estimate of the total net water budget for the lake since it represents the overflow after all losses and volume changes have been taken into account. Discharge to the St. Johns River

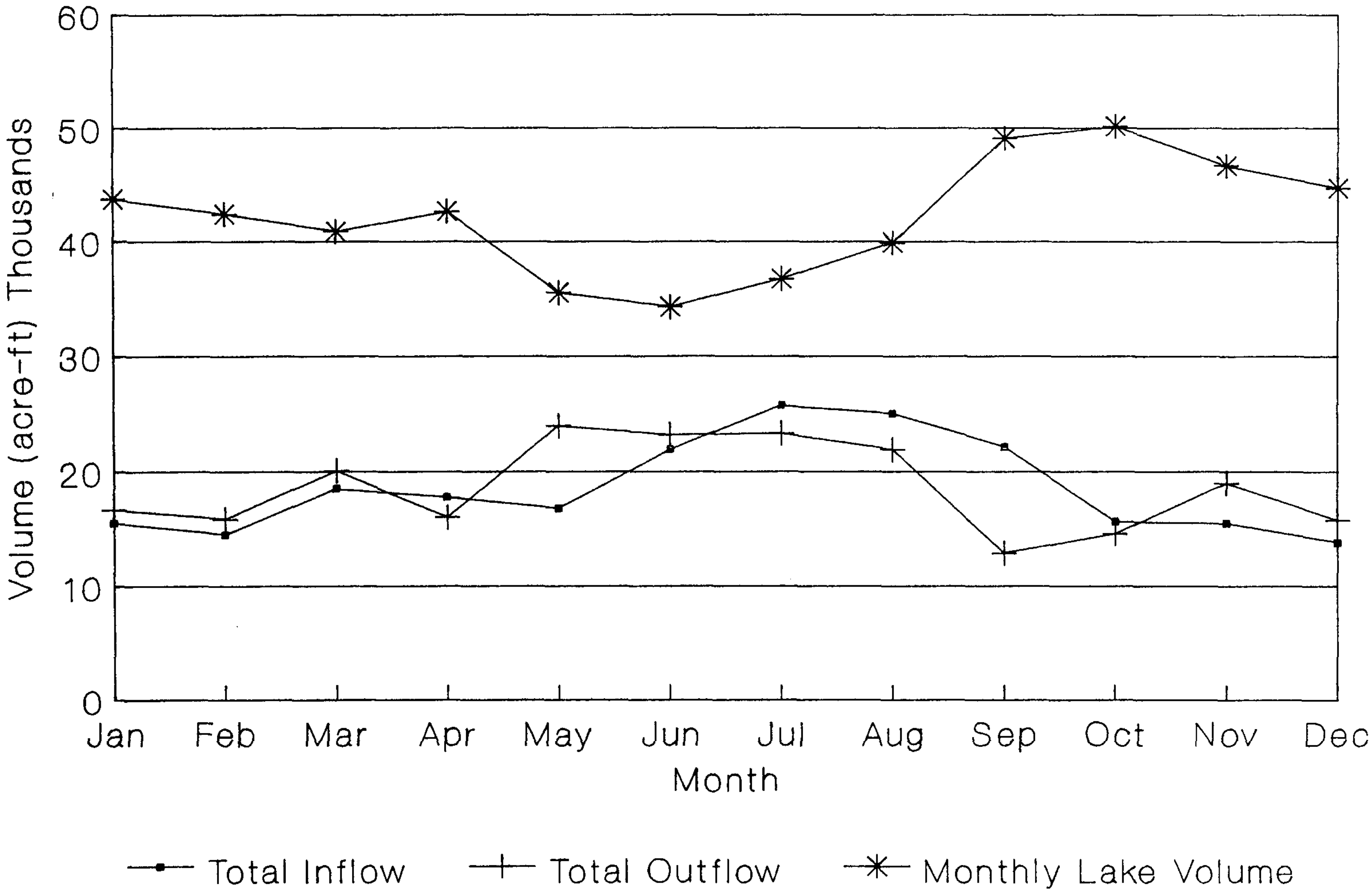

FIGURE 3.2-12. Lake Jessup Average Monthly Total Inflows, Total Outflows, and Average Volume, 1/80 to 12/90.

SOURCE: WAR 1991

averaged 177,807 acre-ft/year (241 cfs, 155.7 mgd) for the 1980 to 1990 period of record.

Water can also flow into Lake Jessup from the St. Johns River when inflows to the lake cannot supply the volume of water required to match the elevation of water in the St. Johns River at its confluence with Lake Jessup.

Total inflows to the lake averaged 222,859 acre-feet per year. The individual inflows could be separated into watershed inflows and direct inflows. The largest inputs to the lake were the watershed inflows of surface runoff (39.19 percent) and bank seepage from the shallow groundwater aquifer (35.44 percent). Other watershed inflows included septic tanks (1.02 percent) and WWTPs (4.06 percent). The watershed inflows combined accounted for 79.7 percent of total inflows.

Direct inflows accounted for 20.3 percent of the total inflow. Direct precipitation to the lake surface was the largest direct inflow (16.78 percent). The other direct inflows included springflow, diffuse leakage, and inflow from the St. Johns River. The inputs from upwelling Floridan aquifer water through springs and diffuse leakage through the lake bottom were due to the artesian conditions that exist under the lake. The watershed itself is divided roughly in half into areas of recharge and discharge which resulted in a net exchange of zero between the subbasins and the deep aquifer.

Watershed inflows were dominant due to the ratio of watershed area (90,006 acres) to Lake Jessup surface area (10,661 acres), which was 8.44 and the small magnitude of direct inflows such as springflow, upward leakage, and SJR inflow. Other Florida lakes have ratios ranging generally between 2 and 30 (Huber et al. 1982).

Hydraulic residence time for Lake Jessup was determined to average 87 days. This value was calculated as the ratio of average annual surface water outflow to the St. Johns River to the average volume of Lake Jessup. Other estimates of hydraulic residence time range from 99 days (Brezonik and Fox 1976) to 82 days (U.S. EPA 1977). Lakes Harney and Monroe are located near Lake Jessup and are similar in size and eutrophic state but have retention times on the order of 10 days (Brezonik and Fox 1976) since they are flow-through lakes associated with the St. Johns River. Lake Apopka, another large, hypereutrophic lake in the area, has residence time estimates ranging from 2 to 6 years (Stites 1992). The Lake Jessup residence time of 87 days allows ample time for waterborne nutrients to be assimilated by the biotic component of the lake which tends to retain nutrients within the lake system by incorporation into plant and animal biomass and settling of dead organisms into the sediments.

3.4 ESTIMATE OF ERROR

Site-specific data was not available for all components of the Lake Jessup water budget. Those components lacking data were estimated by the various methodologies described in Section 3.1. In general, where less data existed, more sweeping assumptions had to be made and less precise methodologies of estimation had to be used. It can be stated that the accuracy of an estimate was related to the accuracy of the available data. In each component of the water budget there is some inaccuracy. The following sections will place in perspective the possible error of each water budget component. Some components are small enough (< 5 percent of the total budget) that an error of a factor of two will not make a decided difference in the overall water budget. These components will not be discussed in great detail. Variables based on accurate measured data such as rainfall are assumed to be accurate presumably within approximately 5 percent. These variables will not be discussed in detail. Where accurate determination of error is not possible, error will be categorized as within a factor of 1.05 (+/- 5 percent), 1.20, 1.50, 2 (half or double), and 10 (+/- an order of magnitude). Refer to the corresponding subsections of Section 3.1 for methodology details.

3.4.1 <u>Springflow and Upward Leakage</u>

The total springflow was based on single measurements of the two Floridan aquifer springs that discharge to Lake Jessup (Rosenau et al. 1977). While springflow is typically comparatively constant, it could have varied substantially from 1980 to 1990. Since this inflow was only slightly more than 1 percent of the budget, the effect of error to the overall budget should not be significant. Other artesian inflows from unchecked flowing wells or springs in the lake bottom could not be considered due to lack of data.

Estimation of upward leakage was assumed to occur only for the area directly under Lake Jessup since the areas of upward leakage (discharge) and downward leakage (recharge) through the rest of the watershed were approximately equal (Tibbals 1990). LEAK was based on LEAKC, PSURF, LJSTG, and A_{LJ}. LJSTG and A_{LJ} were known fairly accurately (based on measured data). LEAKC, $2.5*10^{-6}$, could have varied from $1*10^{-6}$ to $5*10^{-6}$. Potentiometric surface of the Floridan aquifer actually ranged from approximately 40 feet NGVD to 15 feet NGVD from the west end of Lake Jessup to the east end. PSURF was chosen as the contour crossing the approximate middle of the lake (25 feet NGVD). This value could be off by approximately 10 feet more or less. Even with cumulative error taken into account, the total error would be less than a factor of about 4 which would keep this component within the range of 5 percent or less of the total budget.

3.4.2 <u>Direct Precipitation</u>

Rainfall that falls on the surface of Lake Jessup was based on rainfall (R) and A_{LJ}. R and A_{LJ} were both known fairly accurately (based on measured data). The error in the measurement of these values is not known but is probably within a factor of 1.05.

3.4.3 <u>Land Surface Runoff</u>

Land surface runoff (RO) was derived from the external inputs of rainfall and irrigation. The proportion of these inputs that discharges to surface waters was determined using subbasin hydrologic characteristics based on land use (Section 2.1.4, Table 3.1-1). RO is a function of R, AREA, C, IRR, IRRF. R and AREA were known from measured data. Values of C for subbasins were estimated according to land use (Section 2.1.4). C was also determined for subbasins GEESOLD (0.20) and HOWELL (0.26) using existing rainfall and discharge data (Section 2.1.3, Table 2.1.3-3). This was considered a more realistic method of estimation since it is based on actual data. The values of C determined by the land use method for GEESOLD and HOWELL were 0.311 and 0.481, respectively. This indicates that the land use method overestimated C by a factor of approximately 1.5 to 1.9, respectively. For the other less urbanized subbasins that factor is probably lower. The error may be due to the higher permeability soils of the Lake Jessup watershed compared to the study areas that were the source of the Dames & Moore data. Other inaccuracies arise in the categorization of land uses, the acreage attributed to land use types, and the precision of the land use data. Error in the C value does not affect the total inflows and outflows of the lake system, it determines the proportions of rainfall that goes to runoff and water entering groundwater through infiltration.

Irrigation water depth (IRR) is an external source of water to the water budget and was dependent on ET, R_{eff}, and IRR_{eff} (Section 2.1.4, Table 2.1.4-1). R_{eff} (0.717 inches/inch) Irr_{eff} (0.7 inches/inch) are derived from long-term data and are probably within a factor of 1.05. It is not possible to quantify the error of IRRF accurately but the extremes of 1 (SALTCRK) to 33 percent (GEESOLD) irrigated land for subbasins is probably unrealistically wide for this area. Most subbasin values of IRRF were within the range of 7 to 12 percent. An error factor of 2 is estimated for this variable, but for subbasins in the middle of the range the estimate is probably more accurate. Total volume of this external source of water is proportional to IRRF so it also had an estimated error factor of 2. As an external source, IRR affects the magnitude of total inflows to the system. IRR applies to only about 15 percent of the watershed area.

The overall error factor for surface runoff is estimated at approximately 1.20.

3.4.4 Shallow Groundwater Inflow

It was assumed that there was no net exchange (recharge or discharge) between the subbasins and the Floridan aquifer. For this study, all groundwater within the surface drainage area of Lake Jessup was assumed to enter the lake as bank seepage (Section 3.1.4). Bank seepage (SEEP) was estimated as the long-term average of infiltration, assuming that groundwater storage volume remains fairly constant over long periods of time. SEEP was equal to I_{avg} so the error in SEEP was determined by I. I was dependent on R, AREA, IRR, IRRF, ET, A_{LAKE}, A_{IMP}, EV, C_{PAN}, and RO. R, AREA, IRR, RO, and IRRF were discussed above. A_{LAKE}, EV, and C_{PAN} are not expected to be large sources of error since they were measured directly or derived from long-term data. A_{IMP} ranged from 1.4 percent (SALTCRK - rural) to 29 percent (HOWELL - urban) of the subbasin areas (Section 2.1.4). This range seems reasonable but it is not possible to quantify the possible error. The estimated error factor is 1.5 and it affects the water budget by controlling the amount of land that will lose water to the atmosphere by ET.

Average annual ET error was probably within a factor of 1.10. Individual years may have higher error since ET was held constant over time in the water budget model, but not in reality. ET was the major external sink of water from the watershed system although it was not accounted for explicitly in the water budget since it was not an outflow from the lake. A small change in ET loss (inches) would be reflected over most of the watershed area (not lakes or impervious surfaces) which would result in a large change in the overall budget.

The broadest assumption used in the water budget was the exchange with the Floridan aquifer, which was assumed to be zero (except directly under Lake Jessup). The actual net exchange with the Floridan aquifer within the entire watershed is not known but it is probably between 0 and 2 inches of recharge per year. A net recharge to the aquifer of 2 inches per year over the entire watershed would be an external loss of approximately 16,000 acre-feet per year, approximately 7 percent of total inflows, which would be removed from the bank seepage component.

While ET was estimated as closely as possible, the assumed recharge rate of 0 probably underestimates this loss from the system. Higher ET and recharge could reduce the groundwater seepage volume by a cumulative factor of up to 1.17 (11,570 acre-ft/year). This would increase the amount of St. Johns River water that was required to maintain lake volume by a similar amount.

3.4.5 Septic Tank (OSDS) Inflows

All septic tank discharge (ST) was assumed to contribute to groundwater inflow to Lake Jessup. ST was dependent on DCU and N_{ST}. DCU is not expected to be a significant source of error since it is based on large databases. N_{ST} was estimated using a fairly crude methodology due to a lack of applicable data (Section 2.1.5). The estimated error for individual subbasins is 2 since very little actual data was available for the analysis. The estimated error for the watershed is probably less than 1.5 since the total number of tanks in the county is less than 2 times the number attributed to the watershed. Septic tanks are an external source of water but accounted for only 1.02 percent of the total inflows to Lake Jessup.

3.4.6 Wastewater Treatment Plant Effluent

Wastewater treatment plant (WWTP) effluent (STP) discharged to land application systems or percolation ponds within the contributing drainage area was dependent on STP_O, the sum of the observed flows for all facilities within a subbasin (Section 2.1.6). Although observed flows are the most accurate data available, the value of STP_O was held constant over time and as such was subject to error as real WWTP flows fluctuated with time. Error for short periods of time could be a factor of 2 or more due to short-term fluctuations in WWTP use or shutdown. The error for the entire period of record may be as low as 1.2 since STP is a function of population, which remains fairly stable. STP is an external source for the water budget but accounted for only 4.06 percent of the total inflows.

3.4.7 Surface Evaporation

Evaporation (EV_{LJ}) from the water surface of Lake Jessup was dependent on EV, C_{PAN}, and A_{LJ}. All of these variables and constants were based on reliable data and assumed to be within an error factor of 1.05.

3.4.8 Surface Water Outflows

Surface water outflow (Lake Jessup discharge to the St. Johns River) was estimated using a mass balance approach which used the difference of all the other subbasin inflows and outflows. SJR_{OUT} was dependent on ARTES, PC_{LJ}, ST, STP, RO, SEEP, SJR_{IN}, DVOL, and EV_{LJ}. As such, the cumulative error from the other water budget components is contained in this component.

Typically, errors occur on both the high and low side of the unknown actual value, so cumulative errors from individual components may tend to cancel one another out to some degree. Since this component is the result of total inflows and total outflows, it is based primarily on rainfall, evaporation, and ET. Rainfall and evaporation are expected to be accurate. ET is expected to be within a factor of 1.10.

ET and exchange with the Floridan aquifer have the greatest potential to affect the total water budget. While ET was estimated as closely as possible, the assumed recharge rate of 0 probably underestimates this loss from the system. Higher ET and recharge could reduce the groundwater seepage volume by a cumulative factor of 1.17 (11,570 acre-ft/year). This would increase the amount of St. Johns River water that was required to maintain lake volume by a similar amount. The other significant external source or sink was irrigation water application which had an error factor of 2. But that only applied to approximately 15 percent of the watershed so the actual error would be approximately 1.15. The maximum possible cumulative error in the total water budget should be 1.32 (32 percent) or approximately 71,000 acre-ft/year, giving a range of approximately 152,000 to 294,000 acre-ft/year for total inflows or outflows.

4.0 NUTRIENT BUDGETS

4.0 NUTRIENT BUDGETS

Nitrogen (N) and phosphorus (P) budgets for Lake Jessup were determined through a spreadsheet-based modeling effort using the previously described water budget. The steady state spreadsheet model calculated monthly nutrient fluxes and storages of total nitrogen and total phosphorus which were then summarized in annual nutrient budgets. The term nutrient, as used in this report, generally refers to the N and P forms of total nitrogen (TN) and total phosphorus (TP). It may include inorganic nitrogen (IN) and ortho-phosphorus (OP) where appropriate.

4.1 METHODOLOGY

Inputs of N and P to Lake Jessup are attributable to the following major factors:

1. Springflow and upward leakage;
2. Land-use-related activities (e.g., application of fertilizers, OSDS and WWTP effluents, domestic animal fecal nutrients, natural decay of vegetation, etc.);
3. Bulk precipitation (wet and dry fallout); and
4. Naturally occurring nutrients on the land surface and within the soils or sediments.

The following equation illustrates the general methodology employed for the nutrient budget:

$$\text{FLOW VOLUME} * \text{CONCENTRATION} = \text{MASS LOADING} \qquad \text{eq. 4-1}$$

Nutrient mass loadings were determined by applying a concentration to each of the significant water budget inflows. The nutrient concentrations were derived from a variety of sources ranging from observed nutrient concentrations from monitoring data to multi-step calculations of concentrations based on physical and chemical characterizations of the watershed subbasins. The water budget was used to supply the volume of each subbasin, or direct input.

The significant nutrient inputs considered in this budget included the following:

1. Direct precipitation,
2. Land surface runoff,
3. Shallow groundwater seepage,
3. Septic tank (OSDS) inflow,
5. Wastewater treatment plant (WWTP) inflow,
6. St. Johns River inflow, and
7. Artesian inflows: upward leakage and springflow.

The water budget outflow of evaporation was not included in the nutrient budget since it does not remove nutrients from the lake system. Due to the artesian conditions surrounding the lake, no nutrients were exported through the bottom of the lake so the only outflows considered to export nutrients from Lake Jessup were:

1. St. Johns River outflow from Lake Jessup (TN and TP), and
2. Denitrification loss to the atmosphere (TN only).

The following nutrient pools and exchanges within the lake boundaries were also calculated:

1. Nutrient pool in Lake Jessup waters,
2. Nutrient pool in Lake Jessup sediments, and
3. Nutrient exchange between water and sediments.

Subbasin physical characteristics and most nutrient concentrations applied to the various flows and pools used to determine the nutrient budget, remained constant for the period of record (Table 4.1-1), except for lake water concentrations which change on a monthly basis (Section 2.1.7). The nutrient budget components are described in more detail in the following sections.

4.1.1 Direct Precipitation Loading

Nutrient loading from direct precipitation was determined using rainwater quality data for NH_3, NO_2, NO_3, organic N, total N, ortho-P, and total P

Table 4.1-1 Subbasin Characteristics and Nutrient Concentrations for the Different Components of the Nutrient Budget.

	Description		Subbasin								
			AIRPORT	BLACKHMK	EUREKA	GEESOLD	HOWELL	MARLBED	SALTCRK	SANFDAVE	SWEETCRK
AREA	Total Drainage Area	(acres)	8649	4047	964	27268	32153	1411	7046	5612	2857
AIMP	Total Impervious Area	(acres)	1237	93	30	4336	7880	23	99	786	166
ALAKE	Lake Surface Area	(acres)	87.1	0.0	0.0	1747.2	2515.0	0.0	123.4	317.7	19.3
NST	Number of Septic Tanks	- -	2437	800	800	3471	1738	800	1599	2068	1288
DCU	Septic Tank Factor	(gpd/lot)	117.0	117.0	117.0	117.0	117.0	117.0	117.0	117.0	117.0
ALJ	Lake Jessup Surface Area	(acres)	10661 FGFWFC Table at Avg. Lk. Stage 1.86 ft NGVD								
RAINTN	Rainfall Total N conc	(mg/l)	1.6								
RAININ	Rainfall Inorganic N conc	(mg/l)	1.09								
RAINTP	Rainfall Total P conc	(mg/l)	0.18								
RAINOP	Rainfall Ortho-P conc	(mg/l)	0.15								
Modeled Values:			Use observed values where possible								
RNFTN	Runoff Total N conc	(mg/l)	1.729	1.743	1.791	1.512	2.113	1.584	1.534	1.581	1.668
RNFIN	Runoff Inorg N conc	(mg/l)	0.298	0.301	0.309	0.261	0.364	0.273	0.265	0.273	0.288
RNFTP	Runoff Total P conc	(mg/l)	0.218	0.132	0.226	0.160	0.323	0.183	0.156	0.183	0.192
RNFOP	Runoff Ortho-P conc	(mg/l)	0.126	0.211	0.142	0.079	0.226	0.119	0.095	0.101	0.112
Observed Values:		0.1725	Avg Inorg N/Tot N ratio used to calculate Inorg N								
RNFTN	Runoff Total N conc	(mg/l)		8.860		1.340	1.600				
RNFIN	Runoff Inorg N conc	(mg/l)		7.190		0.530	0.500				
RNFTP	Runoff Total P conc	(mg/l)		1.296		0.147	0.207				
RNFOP	Runoff Ortho-P conc	(mg/l)		1.045		0.036	0.129				
STTN	Septic Tank Total N conc	(mg/l)	55.3	55.3	55.3	55.3	55.3	55.3	55.3	55.3	55.3
STIN	Septic Tank Inorg N conc	(mg/l)	39.3	39.3	39.3	39.3	39.3	39.3	39.3	39.3	39.3
STTP	Septic Tank Total P conc	(mg/l)	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0
STOP	Septic Tank Ortho-P conc	(mg/l)	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6
WWTPTN	WWTP effluent Total N conc	(mg/l)	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4
WWTPIN	WWTP effluent Inorg N conc	(mg/l)	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95
WWTPTP	WWTP effluent Total P conc	(mg/l)	9.31	9.31	9.31	9.31	9.31	9.31	9.31	9.31	9.31
WWTPOP	WWTP effluent Ortho-P conc	(mg/l)	7.83	7.83	7.83	7.83	7.83	7.83	7.83	7.83	7.83
SEEPTN	Shallow g-water Total N conc	(mg/l)	1.729	1.743	1.791	1.512	2.113	1.584	1.534	1.581	1.668
SEEPIN	Shallow g-water Inorg N conc	(mg/l)	0.298	0.301	0.309	0.261	0.364	0.273	0.265	0.273	0.288
SEEPTP	Shallow g-water Total P conc	(mg/l)	0.218	0.132	0.226	0.160	0.323	0.183	0.156	0.183	0.192
SEEPOP	Shallow g-water Ortho-P conc	(mg/l)	0.126	0.211	0.142	0.079	0.226	0.119	0.095	0.101	0.112
ARTESTN	Artesian Water Total N conc	(mg/l)	0.83								
ARTESIN	Artesian Water Inorg N conc	(mg/l)	0.54								
ARTESTP	Artesian Water Total P conc	(mg/l)	0.16								
ARTESOP	Artesian Water Ortho-P conc	(mg/l)	0.16								
	Averages:										
LJTN	Lake Jessup Total N conc	(mg/l)	3.14								
LJIN	Lake Jessup Inorg N conc	(mg/l)									
LJTP	Lake Jessup Total P conc	(mg/l)	0.28								
LJOP	Lake Jessup Ortho-P conc	(mg/l)									

Table 4.1-1 Subbasin Characteristics and Nutrient Concentrations for the Different Components of the Nutrient Budget.

Description			Subbasin								
			AIRPORT	BLACKHMK	EUREKA	GEESOLD	HOWELL	MARLBED	SALTCRK	SANFDAVE	SWEETCRK
SJRINTN	St. Johns River Total N conc	(mg/l)	1.53								
SJRININ	St. Johns River Inorg N conc	(mg/l)	0.21								
SJRINTP	St. Johns River Total P conc	(mg/l)	0.11								
SJRINOP	St. Johns River Ortho-P conc	(mg/l)	0.04								
		1.860 ft NGVD Avg Lake Jesup Stage									
		10661 Acres Surface Area at Avg									

Denitrification Estimates:	(1)	(2)
Reported rate (gN/sq ft/yr)	0.057	0.065
gN/acre/yr	2483	2833
gN/lake area/yr	26473601	30200321
tons N/lake area/yr	29.2	33.3
tons N/lake area/day	0.080	0.091

Notes:
DCU = Septic tank factor (gpd per lot, from Clements and Otis 1980)

(1) Boynton et al. (1980)
(2) Brezonik and Lee (1968)

Source: WAR 1991

presented by Irwin and Kirkland (1980). The average TN and TP concentrations for the rainfall station at Lake Hope at Maitland, Florida, were 1.6 mg/L and 0.18 mg/L, respectively (Table 4.1-1).

4.1.2 Land Surface Runoff Loading

Nutrient loading from surface runoff is dependent on the types of soils and land use within a subbasin and the surface area occupied by each type. Loadings attributable to diffuse land-use-related activities were estimated using a modification of the protocol used for the Urban Stormwater Analysis and Improvement Study for the Tampa Bay Watershed (Dames & Moore 1990). This method relates the physical properties of the watershed, including precipitation, land use, and soil hydrologic and hydraulic characteristics to a pollutant-loading rate. Average monthly constituent loadings were calculated as a weighted average based on the land use distribution within each subbasin (Section 2.1.4).

The loading concentrations determined by the above method were assumed constant over the time series using 1989 land use data. Surface runoff input concentrations of TN (RNFTN), TP (RNFTP), and OP (RNFOP) as a function of land use were determined (Table 2.1.4-2). RNFTN ranged from 1.512 mg/L (GEESOLD) to 1.791 mg/L (EUREKA). RNFTP ranged from 0.132 mg/L (BLACKHMK) to 0.323 mg/L (HOWELL) (Table 4.1-1). These concentrations were not used when runoff concentrations were available based on actual data (Section 2.1.7). Observed RNFTN ranged from 1.340 mg/L (GEESOLD) to 8.860 mg/L (BLACKHMK). Observed RNFTP ranged from 0.147 mg/L (GEESOLD) to 1.296 mg/L (BLACKHMK) (Table 4.1-1).

4.1.3 Shallow Groundwater Inflow Loading

Lateral inflow of groundwater (bank seepage) to the river also carries nutrients not derived from septic tanks or WWTPs. However, sufficient data do not exist to determine groundwater nutrient concentrations that have not been affected by septic tank or WWTP system effluents.

Concentrations of nutrients in lateral inflow for individual subbasins were assumed to be equivalent to the subbasin surface runoff concentrations of these parameters (Table 4.1-1). This assumption was used in an effort to weigh the loadings of this source according to land use. Also, no available data has been found to determine background concentrations of these shallow groundwater constituents specific to the study area. The phosphorus loading concentration may overestimate the actual background concentration of phosphorus forms, which generally are not mobile in soils.

4.1.4 Septic Tank Loading

Septic tank effluent loading was accounted for separately. Average concentrations of TN and TP in septic tank effluent were determined by Otis et al. (1975) to be 55.3 mg/L and 16.0 mg/L, respectively. Inorganic forms were also determined but not used in the nutrient budget (Table 4.1-1). For all septic tank effluent within the subbasins, all forms of nitrogen were assumed to be converted to mobile inorganic forms that are carried with the groundwater to the river.

Septic tank systems that are working properly were assumed to have no impact on groundwater phosphorus concentrations more than approximately 20 to 30 feet from the drainfield (Dudley and Stevenson 1973). Therefore, septic tank TP loading was not included in the phosphorus budget. The number of septic tanks per subbasin ranges from 800 to 2,437 (Table 4.1-1, Section 2.1.5).

4.1.5 Wastewater Treatment Plant Loading

WWTP effluent within the watershed is discharged to either land application systems or percolation ponds (Seminole County 1991). Both of these methods result in the introduction of the effluent to the groundwater where it migrates to the lake as bank seepage (lateral inflow). Average concentrations of TN and TP for aerobic treatment system effluent in the nutrient budget were 17.4 mg/L and 9.31 mg/L, respectively (Table 4.1-1, Section 2.1.6). All nitrogen was assumed to be converted to mobile inorganic forms that are carried with the groundwater to the lake.

TP from WWTPs was not included in the nutrient budget under the assumption that they will be removed by soil processes over the distances they would have to travel to reach Lake Jessup (Bicki et al. 1984).

4.1.6 St. Johns River Inflow

Nutrient loading from St. Johns River inflow was determined using USGS water quality data for the station St. Johns River at Deland, Florida, published in Water Resources Data for the 1985 through 1990 water years. The nitrogen and phosphorus data for that period was averaged to determine the nutrient concentration values used in the budget calculations. TN and TP averaged 1.53 mg/L and 0.11 mg/L, respectively. IN and OP concentrations averaged 0.21 mg/L and 0.04 mg/L, respectively but were not used in the nutrient budget (Table 4.1-1). River nutrient concentrations were assumed to remain constant over time.

4.1.7 Artesian Inflows

Nutrient loading from springflow and upward leakage was determined using water quality data for Sanlando Springs reported by Rosenau et al. (1977). Nitrogen and phosphorus concentrations were reported for a single sampling event in May 1972. TN and TP concentrations were 0.83 mg/L and 0.16 mg/L (Table 4.1-1). This data was considered representative of Upper Floridan aquifer water that enters Lake Jessup from springflow and upward leakage since Sanlando Springs is a Floridan aquifer spring and it is located adjacent to the study area. No complete data sets were available for springs within the watershed, and USGS water quality data for Floridan aquifer wells in the vicinity of Lake Jessup published in Water Resources Data for Florida does not include nutrient concentration data.

4.1.8 Nutrient Pool in Lake Waters

The total masses of TN and TP stored in Lake Jessup waters were calculated using the available time series of Lake Jessup water quality data obtained by the SJRWMD from the STORET database and the monthly Lake Jessup volume results of the water budget (Section 3.2). Nutrient concentration data was compiled for all Lake Jessup water quality stations (Section 2.1.7, Table 2.1.7-1) and sorted by date. The monthly average volume was multiplied by the nutrient concentrations for that month or the results for the nearest preceding sampling date. Where there were several months between consecutive sampling dates that had a large difference in concentration, some interpolation was performed for the middle months to provide a more realistic transition in loading rates between the two sampling dates.

Since nutrient concentrations could change independent of lake volume, so could the masses of TN and TP stored in lake waters. Changes in mass without change in volume are assumed to represent exchange with the sediment nutrient pool. An example would be if TN concentrations were halved, then the pool would be halved. The other half would be assumed to be deposited in the sediments. These nutrients were not exported to the St. Johns River since that was calculated separately based on the surface water outflow using, the same water quality data.

4.1.9 Surface Water Outflow

Nutrients from Lake Jessup waters are exported to the St. Johns River by surface water discharge. The nutrient export was calculated using the available time series of Lake Jessup water quality data obtained by the SJRWMD from the STORET database and the surface water discharge results of the water budget (Section 3.2). Data was compiled for all Lake Jessup stations (Section 2.1.7, Table 2.1.7-1) and sorted by date. The monthly surface outflow was multiplied by the nutrient concentration sampling results for that month or the results for the nearest preceding sampling date. Where there were several months between consecutive sampling dates that had a large difference in concentration, some interpolation was performed for the middle months to provide a more realistic transition in loading rates between the two sampling dates.

4.1.10 Nutrient Pools in Lake Sediments

TN and TP stored in Lake Jessup sediments was determined only for the muck sediments, which are quite thick and are the most likely to interact with the overlying waters. Muck depths were determined by Snyder et al. (1990) at 74 sites within Lake Jessup. The average depth for all sites was 1.39 meters (4.56 feet).

Physical and chemical characteristics of Lake Jessup sediment was calculated from data available in Brezonik and Fox (1976) and from SJRWMD unpublished data (Table 4.1.10-1). The SJRWMD data was obtained from two sampling locations (Figure 4.1.10-1), while the Brezonik and Fox data consisted of means and extremes from 18 unlabeled locations throughout the lake. Total Kjeldahl nitrogen (TKN) in sediments was assumed equal to TN. SJRWMD sediment TKN and TP averaged 15,000 ug/g and 485 ug/g, respectively. Brezonik and Fox TKN and TP averaged 1.77 percent (17,700 ug/g) and 5,052 ppm (5,052 ug/g).

The average values from the SJRWMD data were used to calculate the Lake Jessup TP sediment pool and the TN (TKN) pool as well, for consistency. The Brezonik

Table 4.1.10-1. Summary of Mean Sediment Physical and Chemical Characteristics for Lake Jessup.

Sediment Station Location	TKN (%)	Total P (ppm)	Carbon (%)	Water Content (%)	Leachable Ammonia (mg N/g)	Leachable Phosphate (ug P/g)	Exch Ammonia (mg N/g)	Exch Phosphate (ug P/g)	C/N Ratio (wt/wt)	N/P Ratio (wt/wt)
Organic Sediments(1)										
Average:	1.77	5052	20.4	92.0	0.47	50.5	0.55	49	11.1	3.5
Minimum:	0.29	2180	12.0	67.6	0.05	6	0.07	9	6.9	1.3
Maximum:	2.25	6820	29.2	95.2	0.99	1360	0.86	1210	17.4	5.2
Sandy Sediments(1)										
Average:	0.35	280		27.2	0.56	0.06	0.97	0.14		1.25

Sediment Station Location	TKN (ug/g)	Total P (ug/g)	Organic Carbon (ug/g)	Percent Solids (%)
West Lake Jessup(2)	13000	290	130000	10.9
East Lake Jessup(2)	17000	680	190000	7.2
	------	------	------	------
Average:	15000	485	160000	9.1

Nutrient Storage Calculation

Average Muck Depth	4.56	feet
Lake Jessup Area	10661	acre
Total Muck Volume	48618	acre-ft
Avg. Wet Density	1.045	
Total Muck Mass	69015669	tons
Total Solids (8%)	5521254	tons
Total N (TKN) Mass	82819	tons
Total P Mass	2678	tons

Calculation of Depth-Weighted Wet Bulk Density of Sediments

	Flocc. Muck	Firm Muck	Total Muck
Average Thickness (cm) (3)	18	121	139
Wet Bulk Density (g/cu cm) (4)	1.024	1.048	
Weighting Factor	18.432	126.808	
Weighted Avg Bulk Density (g/cu cm)	1.045		

Notes:
(1) Data from Brezonik and Fox (1976)
(2) Unpublished data from SJRWMD (1991)
(3) Data from Snyder et al. (1990)
(4) Data from Reddy and Graetz (1990)

Source: WAR 1991

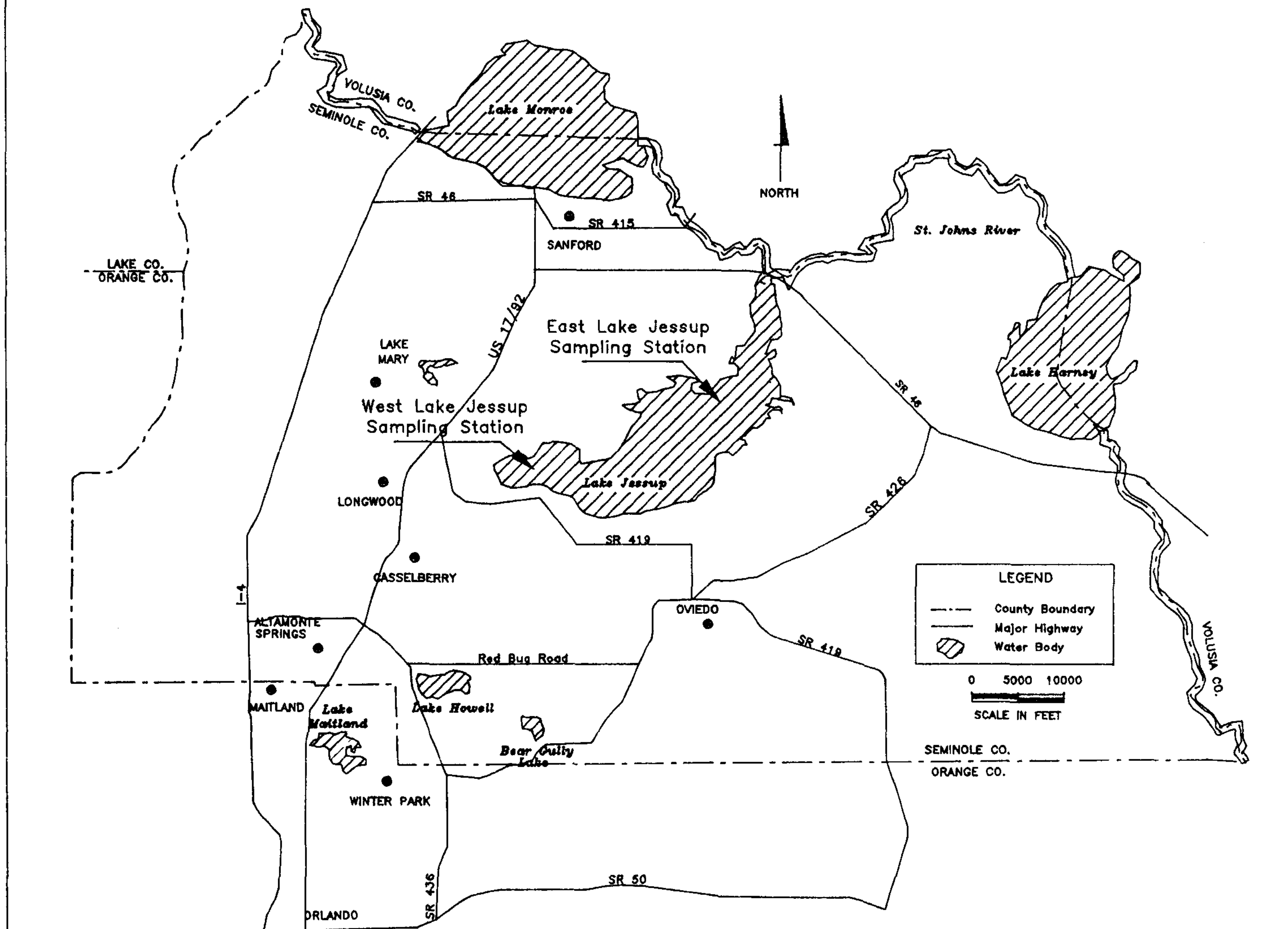

FIGURE 4.1.10-1. Lake Jessup Sediment Sampling Locations Compiled from the SJRWMD Water Quality Data Base.

SOURCE: SJRWMD 1991
WAR 1991

and Fox data was not used because the TP values were questionable. The average TKN values from the two data sources were approximately equal, but the average TP value from Brezonik and Fox was larger than the average TP value from SJRWMD data by approximately a factor of 10. The TP average for the SJRWMD data was in agreement with values presented by Brezonik and Fox (1976) for Lake Harney and Lake Monroe, which were in a similar state of eutrophication.

Volume of the muck sediments was determined using the lake area (10,661 acres) at average stage (1.86 feet NGVD), and the average muck depth of 4.56 feet. Total mass was calculated assuming muck wet bulk densities reported by Reddy and Graetz (1991) of 1.024 g/cm^3 for unconsolidated flocculent muck and 1.048 g/cm^3 for consolidated muck. The thickness-weighted (18 cm unconsolidated and 121 cm consolidated, Snyder et al. 1990) average wet bulk density was 1.045 g/cm^3. Total mass of muck solids was determined using the average water content of 92 percent (8 percent solids) reported by Brezonik and Fox (1976) instead of 9.05 percent solids (SJRWMD 1991b) because of the higher number of samples used. The sediment nutrient concentrations were then applied to the muck solids total mass to estimate the total mass of TN (TKN) and TP in the muck sediments. The total mass estimates of TN and TP (82,819 tons and 2,678 tons, respectively) were used as initial conditions (first month) for the sediment nutrient pool in the nutrient budget, and were augmented or depleted according to the calculations of the nutrient exchange between sediment and lake water.

4.1.11 Denitrification in Sediments

Lake sediments provide an ideal habitat for denitrifying flora (Panel On Nitrates 1978). Nitrogen from Lake Jessup sediments is likely lost to the atmosphere through denitrification, which is a biochemical process that reduces nitrate molecules to nitrogen gas. All of the requirements for denitrification are present in Lake Jessup sediments. Water and sediment quality (Sections 2.1.7 and 4.1.10) show high concentrations of nitrogen compounds used by the denitrifying bacteria as an energy source in conjunction with a carbon substrate which is also abundant in the organic muck bottom (Table 4.1.10-1). Anoxic conditions, which also are required for denitrification, are usually found several centimeters below the sediment surface (Panel on Nitrates 1978).

Estimates of denitrification rates in sediments have yielded results that differ by over two orders of magnitude. When applied to Lake Jessup sediments, the resulting rates of denitrification range from 15 tons/year to 10,725 tons/year (Table 4.1.11-1). By comparison, the estimated total TN loading to Lake Jessup is only approximately 800 tons/year. Estimates produced by using sediment cores under laboratory conditions produced the highest variability, and the highest values. This is due partly to the fact that some studies seek to determine the denitrifying capacity of the sediments, rather than estimate *in situ* conditions (Reddy and Graetz 1991; Sorensen 1978a). Also the effects on denitrification rates from removing and processing the sediment cores from the study area, as well as the measurement procedure may affect the rates (Reddy and Graetz 1991). The most applicable laboratory estimate of denitrification was determined by Reddy and Graetz using sediment cores from Lake Apopka, which is close to Lake Jessup in location, size, and trophic state. The estimated *in situ* rate was 0.024 ug/mL sediment per hour for the top 25 cm of sediment. This rate applied to Lake Jessup sediments results in denitrification losses of 2,501 tons N/year (Table 4.1.11-1) which is over three times the annual loading rate.

Denitrification can also be estimated by a mass balance approach using a nitrogen budget for a water body (Brezonik and Lee 1968). This method, while a less direct method of measurement, is less likely to produce results varying over orders of magnitude (unless denitrification is a very small part of the budget, which it is not). Due to the high variability in the available data, a conservative estimate of 0.065 $gN/ft^2/year$ (Brezonik and Lee 1968) was used which resulted in a lake-wide total of 33.3 tons N per year lost to the atmosphere.

4.1.12 <u>Nutrient Exchange with Lake Sediments</u>

N and P exchange with the sediments was not explicitly modeled, but determined using a mass balance approach based on the other components of the nutrient budget. The equation used to calculate nutrient flux to the sediments can be simplified as:

$$\text{Total N, P Sediments Flux} = \text{Total TN, TP Inflows} - \text{Total TN, TP Outflows} + \text{Change in Water TN, TP Pool} \qquad \text{eq. 4.1.12-1}$$

Table 4.1.11-1 Estimates of Denitrification Rates in Sediments.

Reference	Units	Value	Annual Lake Denitrific'n (ton N/year)	Daily Lake Denitrific'n (ton N/day)
1.	ug/ml/hr	0.03739	3897	10.67
2.	ug/ml/hr	0.024	2501	6.85
3.	ug/ml/hr	0.00117	15	0.04
4.	ug/ml/hr	0.00382	143	0.39
5.	ug/ml/hr	0.214375	10725	29.36
4.	mmole/m^2/dy	0.99	241	0.66
3.	mmole/m^2/dy	0.165	40	0.11
2.	mmole/m^2/dy	10.29	2501	6.85
6.	gN/ft^2/yr	0.057	29.2	0.080
7.	gN/ft^2/yr	0.065	33.3	0.091

References:
1. Reddy and Graetz, 1990. Lake Apopka sediments, 0-30 cm, depth weighted average of individual segments, enriched conditions.
2. Reddy and Graetz, 1990. Lake Apopka sediments, 0-25 cm, estimated in situ conditions.
3. Oren and Blackburn 1979. Kysing Fjord sediments, low-end estimat of areal rate for in situ conditions.
4. Sorensen 1978b. Randers Fjord sediments, 0-6 cm, in situ conditions.
5. Sorensen 1978a. Limfjorden sediments, 0-12 cm, enriched conditions
6. Boynton et al. 1980
7. Brezonik and Lee 1968

Source: WAR 1992

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1. Reddy and Graetz, 1990. Lake Apopka sediments, 0-30 cm, depth weighted average of individual segments, enriched conditions.
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5. Sorensen 1978a. Limfjorden sediments, 0-12 cm, enriched conditions
6. Boynton et al. 1980
7. Brezonik and Lee 1968

Source: WAR 1992

The nutrient pool for Lake Jessup muck sediment was assumed to fulfill the requirement of a source or a sink for nutrients left over from the difference between total nutrient inflows and outflows and changes in water nutrient pool. When outflows exceeded inflows, sediments were assumed to have been regenerated or resuspended from the sediments and exported. When inflows exceeded outflows, nutrients were assumed to have been deposited in the sediments. This approach was used because all other components of the nutrient budget were able to be quantified using existing data or modeling, which left nutrient exchange to either supply or accept the yearly (monthly) excess or deficient nutrients left over from the other calculations. This approach renders the results of this nutrient budget component somewhat unreliable since it was based on assumptions rather than actual data.

4.2 RESULTS - NUTRIENT BUDGET

The results of the monthly nutrient budget calculations for the period of record, January 1980 through December 1990, were summarized as annual nutrient budgets with averages and extremes for the annual nutrient budgets and monthly nutrient budgets (Appendix B). The annual values were either 12-month totals (for flow components), or averages (for pool components and percentages).

There were many more average annual loading components to Lake Jessup than export or outflow components (Figure 4.2-1). The TN loading components consisted of the subbasin loadings [surface runoff (206.02 tons/year), bank seepage (162.86 tons/year), and WWTPs plus septic tanks (332.81 tons/year)], artesian loading from springflow plus upward leakage (5.04 tons/year), direct precipitation (92.44 tons/year), inflow from the SJR (6.12 tons/year), and regeneration of nutrients from the sediments (90.60 tons/year). TN export components consisted of outflow to the SJR (859.24 tons/year) and denitrification (33.29 tons/year).

The TP budget did not have WWTP plus septic tank loading or export due to denitrification (Figure 4.2-1). The TP loading components consisted of the subbasin loadings [surface runoff (29.02 tons/year) and bank seepage (19.37 tons/year)], artesian loading from springflow plus upward leakage (0.97 tons/year), direct precipitation (10.40 tons/year), inflow from the SJR (0.44 tons/year), and regeneration of nutrients from the sediments

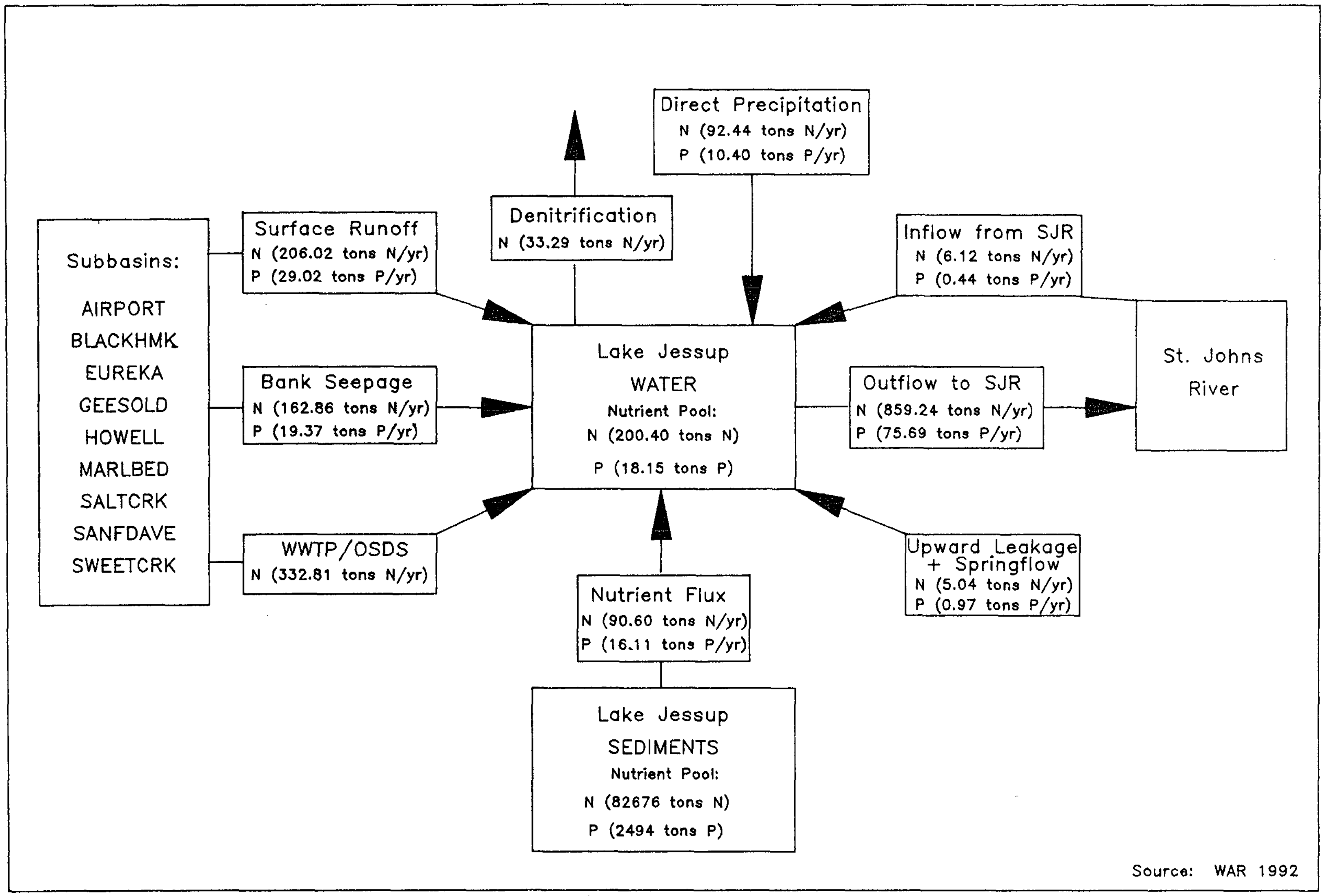

FIGURE 4.2-1. Schematic Diagram of Lake Jessup Nutrient Budget Components with Average Annual Fluxes (tons N,P/yr) and Pools (tons N,P). for 1980 through 1990.

(16.11 tons/year). The only TP export component was outflow to the SJR (75.69 tons/year).

The nutrient budget was organized by component, subbasin, and nutrient (N or P) (Appendix B). However, the TN budget and TP budget results will be presented separately by component in the following sections.

4.2.1 Total Nitrogen Loadings

Total TN annual loadings to Lake Jessup from the various contributing sources ranged from 733.12 tons to 881.31 tons, and averaged of 805.29 tons (Table 4.2-1, Figure 4.2.1-1). The highest loading occurred in 1983 as a result of high rainfall (62.85 inches) that year. The year with lowest loadings was 1990, apparently as a result of low rainfall that year. Since some of the sources such as WWTPs, septic tanks, and artesian inflows are fairly constant throughout the period of record, the annual total loadings generally vary according to the rainfall, which affects loading due to direct precipitation on the lake and surface runoff.

The average percent contribution to annual total TN loading from individual sources ranged from 24.18 percent to 0.66 percent (Table 4.2-1, Figure 4.2.1-1). WWTPs were the largest source of TN loading with an annual average contribution of 24.18 percent of the annual TN loadings. The combined contribution to annual TN loadings due to septic tanks plus WWPTs ranged from 38.99 percent to 46.85 percent and averaged 43.54 percent of the total TN loadings. The surface runoff loading averaged slightly less (23.47 percent) than the WWTP runoff contribution, and was the second largest single source. Runoff contribution ranged from 20.51 percent to 28.24 percent of the annual TN loadings. The monthly loadings from bank seepage, septic tanks, direct precipitation, St. Johns River (SJR) inflow, and artesian loadings averaged 21.33, 19.36, 10.30, 0.70, 0.66 percent of total loadings, respectively (Table 4.2-1, Figure 4.2.1-1).

The combined loading of septic tanks plus WWTPs was the largest TN source at 332.81 tons per year (Table 4.2-1, Figure 4.2.1-2). Their individual contributions averaged 147.98 and 184.82 tons TN per year, respectively. The numbers of septic tanks and WWTPs were assumed to remain constant through the period of record so their contributions remain constant with time. Septic

Table 4.2-1. Nitrogen Budget Summaries for Lake Jessup for the Years 1980 through 1990 with Period of Record Monthly and Annual Means and Extremes.

Year	Total Nitrogen Sources: Direct Rainfall (tons N)	Artesian Inflows (tons N)	Surface Runoff (tons N)	Bank Seepage (tons N)	Septic Tanks (tons N)	WWTPs (tons N)	Septic Tanks + WWTPs (tons N)	Inflow from SJ River (tons N)	Total Loading (tons N)
Annual Totals or Averages(1):									
1980	93.56	5.12	224.57	162.86	147.98	184.82	332.81	0.00	818.92
1981	82.88	5.14	188.11	162.86	147.98	184.82	332.81	0.00	771.80
1982	115.79	4.95	249.14	162.86	147.98	184.82	332.81	0.00	865.55
1983	121.47	4.96	259.21	162.86	147.98	184.82	332.81	0.00	881.31
1984	92.21	5.00	205.19	162.86	147.98	184.82	332.81	4.37	802.45
1985	85.56	5.00	189.62	162.86	147.98	184.82	332.81	18.85	794.70
1986	84.85	5.06	189.94	162.86	147.98	184.82	332.81	5.16	780.67
1987	89.35	5.02	201.66	162.86	147.98	184.82	332.81	18.24	809.95
1988	108.17	5.03	232.32	162.86	147.98	184.82	332.81	14.21	855.40
1989	72.23	5.09	164.83	162.86	147.98	184.82	332.81	6.52	744.34
1990	70.72	5.12	161.61	162.86	147.98	184.82	332.81	0.00	733.12
Annual and Monthly Means and Extremes:									
Annual Average:	92.44	5.04	206.02	162.86	147.98	184.82	332.81	6.12	805.29
Annual Minimum:	70.72	4.95	161.61	162.86	147.98	184.82	332.81	0.00	733.12
Annual Maximum:	121.47	5.14	259.21	162.86	147.98	184.82	332.81	18.85	881.31
Monthly Minimum:	0.19	0.38	2.47	13.57	11.45	14.30	25.74	0.00	44.56
Monthly Maximum:	29.18	0.44	60.48	13.57	12.56	15.69	28.25	18.85	131.91
Monthly Average:	7.70	0.42	17.17	13.57	12.33	15.40	27.73	0.51	67.11

Notes:
(1) Annual flows are sums of the monthly values, Annual storages are averages of the monthly values

Source: WAR 1991

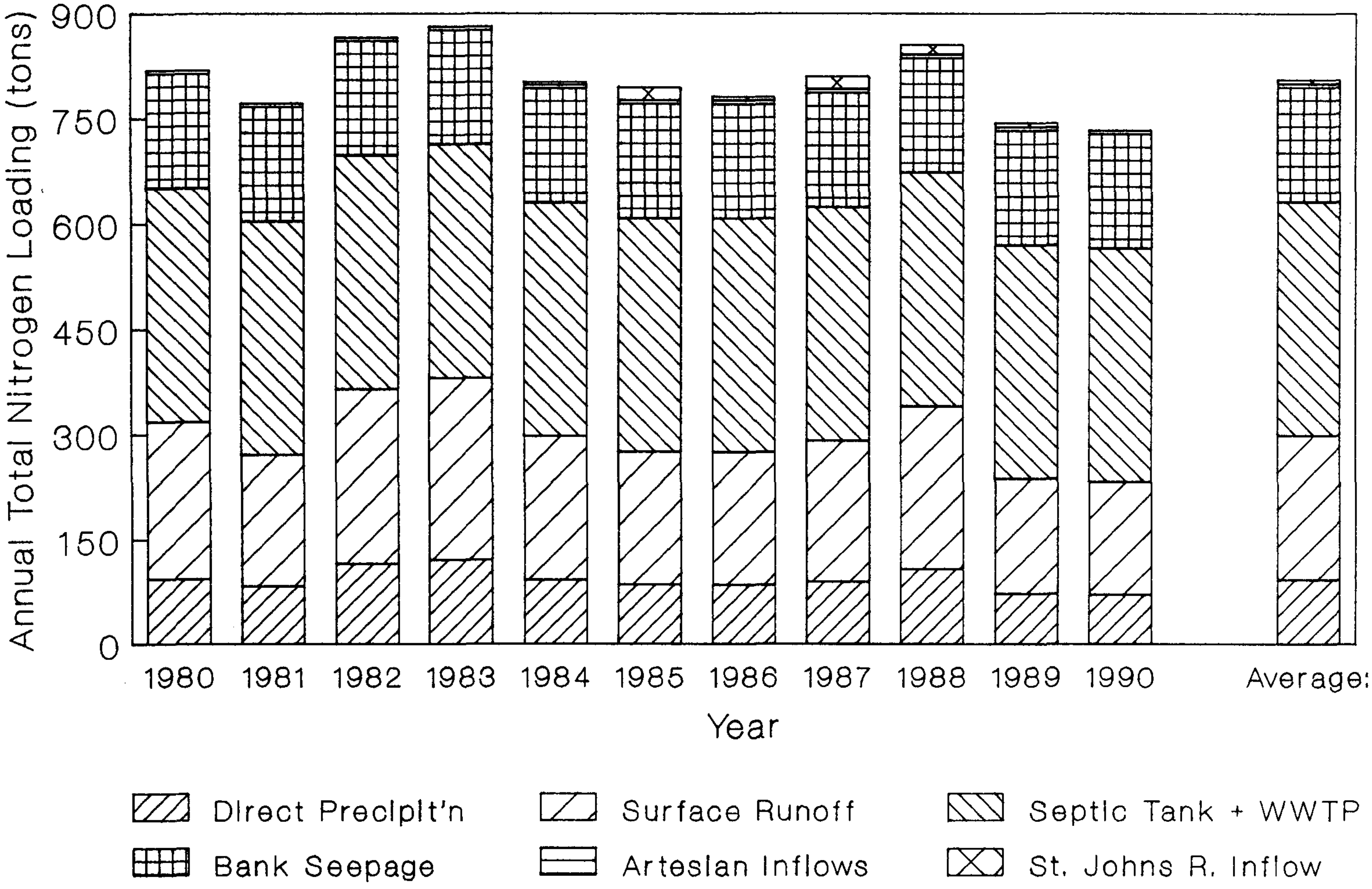

FIGURE 4.2.1-1. Relative Contribution of Total Nitrogen Sources to Annual Total Nitrogen Loadings to Lake Jessup.

SOURCE: WAR 1991

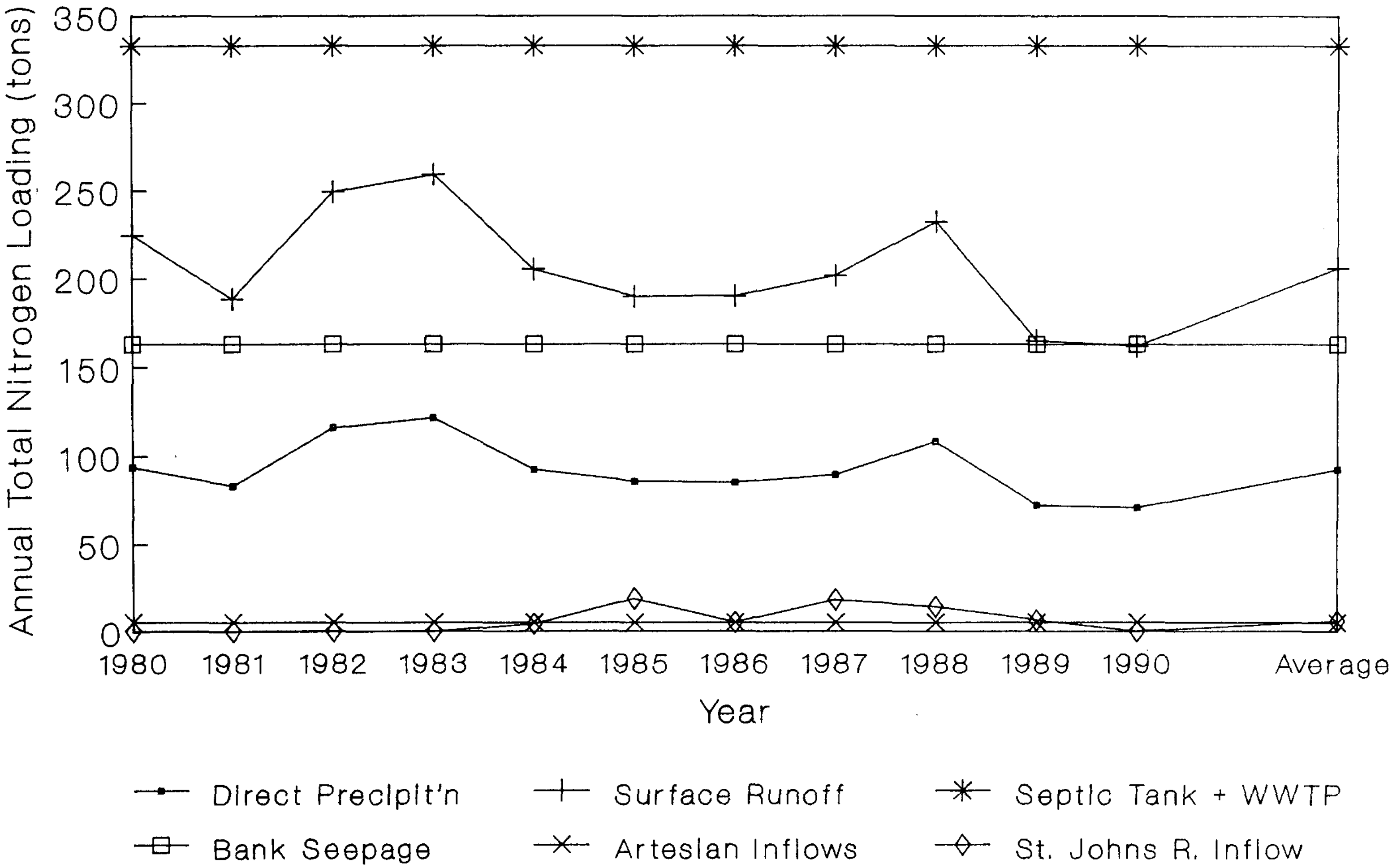

FIGURE 4.2.1-2. Lake Jessup Annual Total Loadings from Total Nitrogen Sources.

Source: WAR 1991

tank and WWTP loadings follow the same pathway as bank seepage but were accounted for separately. Bank seepage loading averaged 162.86 tons TN per year. The total of these three sources results in a total average loading to Lake Jessup through the groundwater pathway of 495.67 tons TN per year.

Nitrogen loading from surface runoff averaged 206.02 tons TN per year and ranged from 161.61 to 259.21 tons of TN loading to Lake Jessup. Direct precipitation loading averaged 92.44 tons TN per year with a range of 70.72 to 121.47 tons TN per year. These loadings fluctuated in response to changes in rainfall. The annual maximum and minimum occurred in 1983 and 1990, respectively, the same years as rainfall.

Upward leakage flow fluctuated slightly according to changes in lake water surface elevations, which were regulated by the water levels in the SJR. Springflow remained constant, so the fluctuation of the combined artesian inflows was minor. The contribution of TN loadings ranged from artesian water was 4.95 to 5.14 tons per year with an average annual loading of 5.04 tons.

SJR inflow to Lake Jessup occurred only when river water levels rose and there was not enough water input to the lake to bring lake water to the same level (Section 3.1.8). This occurred in scattered months in 1984 through 1989. The maximum annual loading from this source was 18.85 tons in 1985 with an average annual loading over the period of record of 6.12 tons per year.

4.2.2 Total Phosphorus Loadings

Total TP annual loadings to Lake Jessup from the various contributing sources ranged from 51.26 tons to 70.93 tons and averaged 60.20 tons (Table 4.2-2, Figure 4.2.2-1). As with TN, total loadings of TP varied with rainfall. The highest and lowest loadings occurred in 1983 and 1990, respectively. Surface runoff was the largest loading source of TP to Lake Jessup. This source averaged 40.78 percent to 50.12 percent of annual TP loadings with a mean annual average of 44.14 percent. Annual loadings due to bank seepage averaged from 30.00 percent to 42.79 percent and averaged 38.02 percent. The monthly loadings from direct precipitation, artesian inflows, and SJR inflow averaged 15.16, 1.91, and 0.77 percent of total inflows, respectively.

Table 4.2-2. Phosphorus Budget Summaries for Lake Jessup for the Years 1980 through 1990 with Period of Record Monthly and Annual Means and Extremes.

Year	Total Phosphorus Sources: Direct Rainfall (tons P)	Artesian Inflows (tons P)	Surface Runoff (tons P)	Bank Seepage (tons P)	Inflow from SJ River (tons P)	Total Loading (tons P)	Total Phosphorus Sources: Percentages of Total Loading: Direct Rainfall (%)	Artesian Inflows (%)	Surface Runoff (%)	Bank Seepage (%)	Inflow from SJ River (%)	Total Loading (%)
Annual Totals or Averages(1):												
1980	10.53	0.99	28.86	19.37	0.00	59.74	15.92%	1.89%	44.91%	37.29%	0.00%	100.00%
1981	9.32	0.99	26.71	19.37	0.00	56.40	14.14%	2.09%	43.07%	40.71%	0.00%	100.00%
1982	13.03	0.95	35.49	19.37	0.00	68.84	16.31%	1.76%	46.31%	35.62%	0.00%	100.00%
1983	13.67	0.96	36.94	19.37	0.00	70.93	18.31%	1.49%	50.21%	30.00%	0.00%	100.00%
1984	10.37	0.96	29.17	19.37	0.31	60.19	14.21%	2.02%	42.49%	40.54%	0.74%	100.00%
1985	9.63	0.96	26.97	19.37	1.36	58.29	14.25%	2.03%	41.95%	40.70%	1.07%	100.00%
1986	9.55	0.98	27.00	19.37	0.37	57.26	15.09%	1.91%	44.12%	38.11%	0.77%	100.00%
1987	10.05	0.97	28.64	19.37	1.31	60.34	14.57%	1.85%	43.42%	37.13%	3.03%	100.00%
1988	12.17	0.97	33.10	19.37	1.02	66.63	16.78%	1.63%	46.75%	32.78%	2.06%	100.00%
1989	8.13	0.98	23.41	19.37	0.47	52.35	13.43%	2.17%	40.78%	42.79%	0.84%	100.00%
1990	7.96	0.99	22.95	19.37	0.00	51.26	13.71%	2.16%	41.55%	42.58%	0.00%	100.00%
Annual and Monthly Means and Extremes:												
Annual Average:	10.40	0.97	29.02	19.37	0.44	60.20	15.16%	1.91%	44.14%	38.02%	0.77%	100.00%
Annual Minimum:	7.96	0.95	22.95	19.37	0.00	51.26	13.43%	1.49%	40.78%	30.00%	0.00%	100.00%
Annual Maximum:	13.67	0.99	36.94	19.37	1.36	70.93	18.31%	2.17%	50.21%	42.79%	3.03%	100.00%
Monthly Minimum:	0.02	0.07	0.34	1.61	0.00	2.05	1.06%	0.61%	15.51%	11.86%	0.00%	100.00%
Monthly Maximum:	3.28	0.09	8.62	1.61	1.36	13.60	24.13%	3.99%	63.39%	78.55%	36.38%	100.00%
Monthly Average:	0.87	0.08	2.42	1.61	0.04	5.02	15.16%	1.91%	44.14%	38.02%	0.77%	100.00%

Notes:
(1) Annual flows are sums of the monthly values, Annual storages are averages of the monthly values

Source: WAR 1991

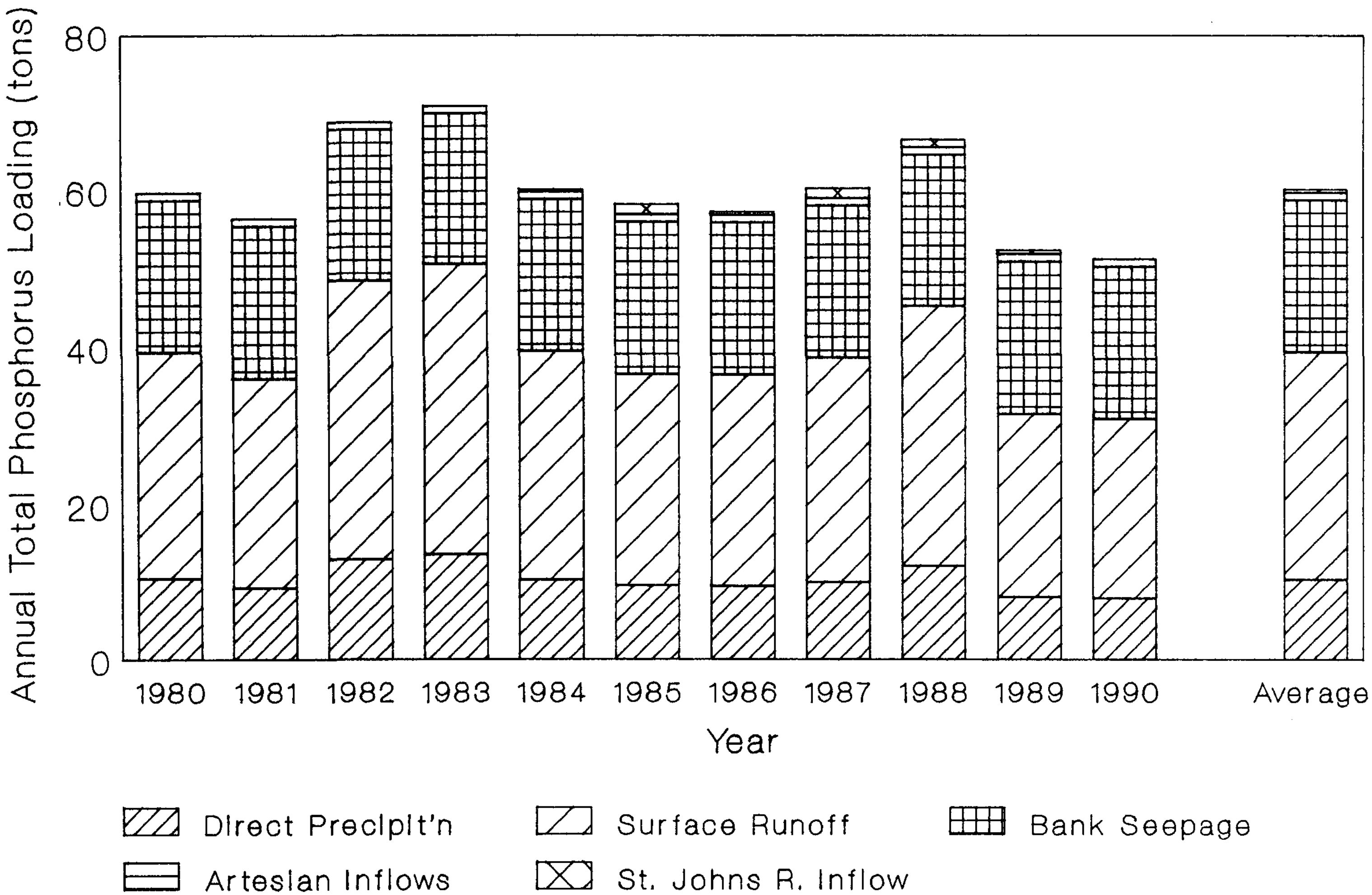

FIGURE 4.2.2-1. Relative Contribution of Total Phosphorus Sources to Annual Total Phosphorus Loadings into Lake Jessup.

Source: WAR 1991

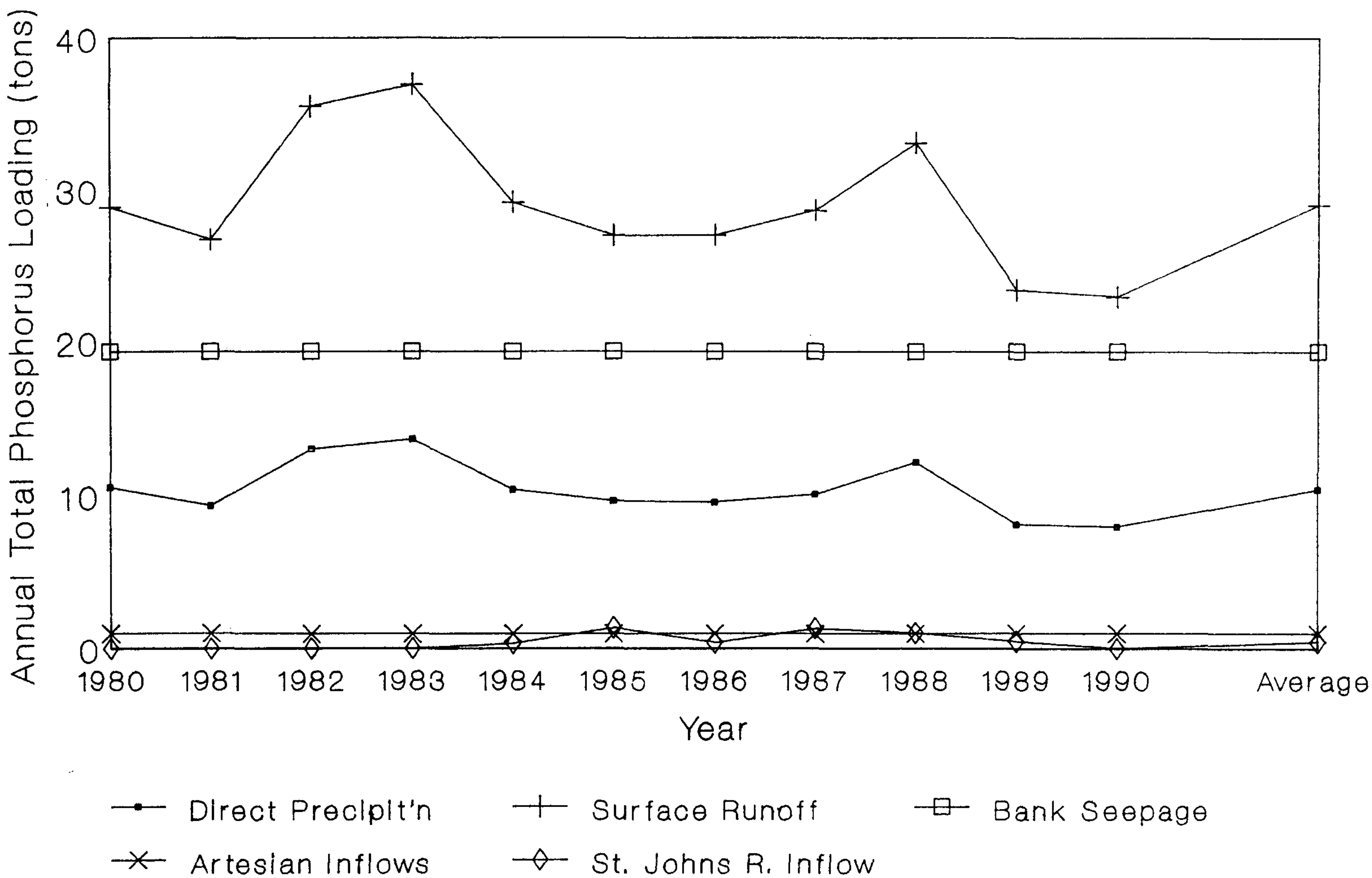

FIGURE 4.2.2-2. Lake Jessup Annual Total Loadings from Total Phosphorus Sources.

Source: WAR 1991

Figure 4.2.2-2 shows the annual total loadings from the various TP sources. The largest TP source was surface runoff which averaged 29.02 tons per year. This loading varied from 22.95 to 36.94 tons TP per year. Direct precipitation to Lake Jessup averaged 10.40 tons TP per year with a range of 7.96 to 13.67 tons TP per year. These two inputs fluctuated in response to changes in rainfall. The maximums occurred in 1983 and the minimums occurred in 1990 just as with rainfall.

Bank seepage remained constant at a total of 19.37 tons per year and was the second largest loading source. The TP loading from artesian water fluctuated very little, from 0.95 to 0.99 tons per year with an average annual loading of 0.97 ton. Upward leakage fluctuated according changes in lake water surface elevations, which were regulated by the water levels in the SJR. Springflow remained constant so the fluctuation of the combined artesian loading was minor.

SJR inflow to the lake occurred only when river water levels rose and there was not enough water input to the lake to bring lake water to the same level. This occurred in scattered months in 1984 through 1989. The maximum loading from this source was 1.36 tons in 1985 with an average annual loading over the period of record of 0.44 ton per year.

4.2.3 Lake Jessup Nutrient Pools and Exports

Lake Jessup water quality data were available starting in October 1983 so the preceding months in the nutrient budget used the period of record averages for Lake Jessup TN and TP concentrations (Figure 4.2.3-1, Table 2.1.7-1). The TN fluctuations do not seem to strongly display seasonal trends but TP did seem to decrease in winter months. The annual average TN concentrations (Table 4.2-3) show an increasing trend starting over the period of record with the lowest average year (1985) at 2.76 mg/L and ending in 1990 at an average of 4.97 mg/L, which was the maximum annual average. TP concentrations do not show any definite long-term trends. The range of annual average TP concentration was 0.21 to 0.44 mg/L with a long-term average of 0.32 mg/L. Monthly changes in Lake Jessup nutrient concentrations had a large effect on nutrient processes within the lake, which consist of nutrient pool in lake waters (Section 4.1.8), export to the SJR (Section 4.1.9), nutrient pool in the

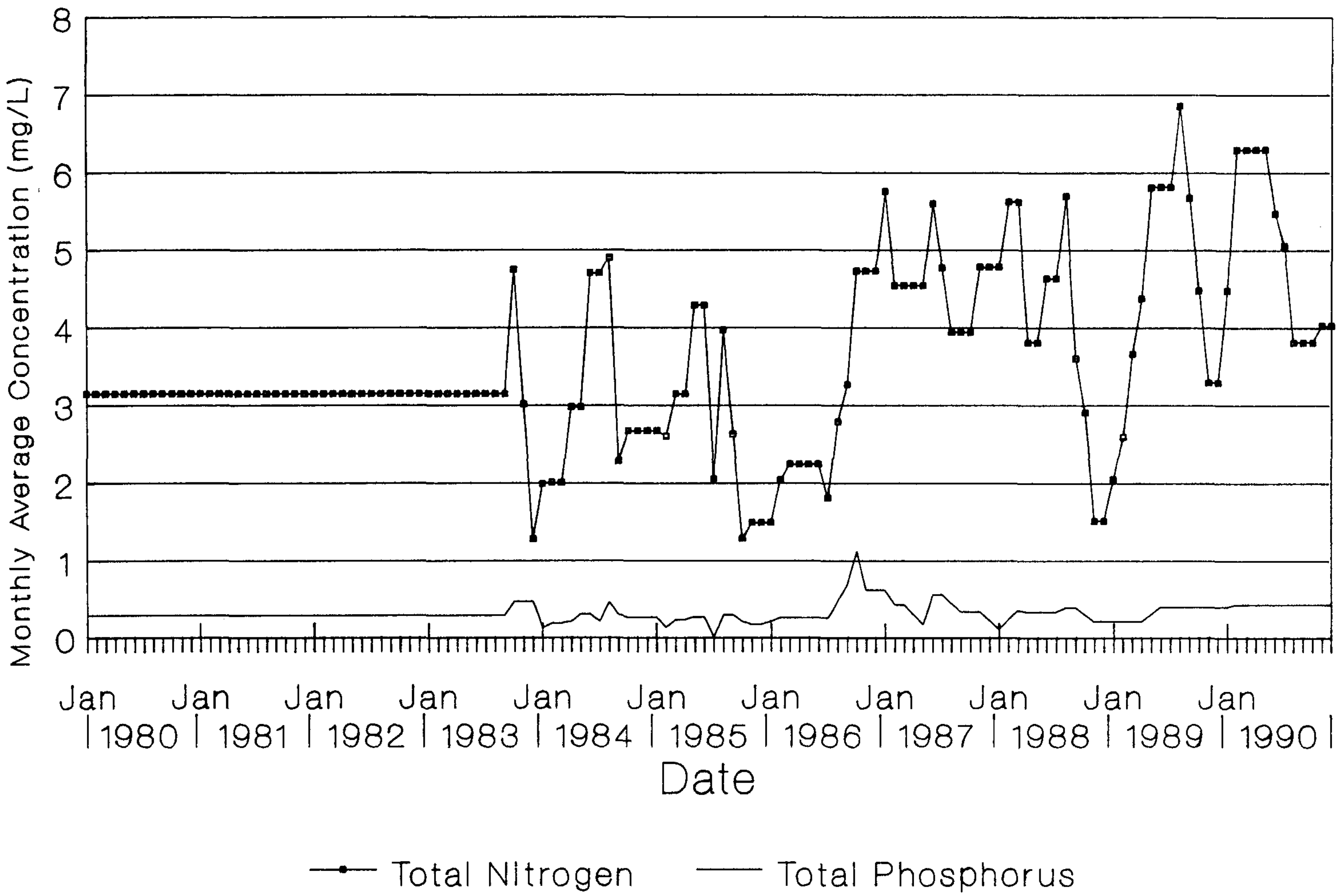

FIGURE 4.2.3-1. Lake Jessup Monthly Water Quality Values Used in Nutrient Budget Calculations.

SOURCE: SJRWMD 1991, WAR 1991

Table 4.2-3. Lake Jessup Water and Sediment Exchange Summaries for the Years 1980 through 1990 with Period of Record Monthly and Annual Means and Extremes.

Year	Lake Jessup Water Quality:		Lake Jessup Export to St. Johns River		Lk Jessup N Export		Lk Jessup Water Nutrient Pool:		Lk Jessup Sediment Nutrient Flux:		Lk Jessup Sediment Nutrient Pool:	
	Total Nitrogen Conc (mg/L)	Total Phosphorus Conc (mg/L)	Total Nitrogen (tons N)	Total Phosphorus (tons P)	Dinitrification to Atmos. (tons N)	Total Nitrogen Outflows (tons N)	Total Nitrogen (tons N)	Total Phosphorus (tons P)	Total Nitrogen (tons N)	Total Phosphorus (tons P)	Total Nitrogen (tons N)	Total Phosphorus (tons P)
Annual Totals or Averages(1):												
1980	3.15	0.28	764.12	68.89	33.29	797.41	150.03	13.53	41.44	-7.35	82844	2674
1981	3.15	0.28	713.48	64.33	33.29	746.77	140.22	12.64	42.68	-6.34	82901	2668
1982	3.15	0.28	864.86	77.97	33.29	898.15	223.95	20.19	-66.09	-12.16	82857	2657
1983	3.12	0.33	861.13	97.16	33.29	894.42	216.28	22.64	79.34	-39.72	82797	2640
1984	3.05	0.26	780.95	60.37	33.29	814.24	183.39	15.67	-99.83	12.51	82822	2627
1985	2.76	0.21	565.88	42.74	33.29	599.17	161.02	13.95	244.72	18.50	82886	2633
1986	2.88	0.44	671.81	99.53	33.29	705.10	159.37	24.51	-80.55	-64.29	83101	2619
1987	4.64	0.39	1036.36	86.43	33.29	1069.65	280.92	22.55	-393.44	-9.54	82761	2570
1988	4.01	0.30	1258.10	85.28	33.29	1291.39	237.79	17.01	-119.99	-12.44	82380	2560
1989	4.47	0.33	908.28	63.99	33.29	941.57	219.71	16.71	-310.05	-23.94	82222	2548
1990	4.97	0.43	1026.69	85.89	33.29	1059.98	231.77	20.21	-334.79	-32.43	81862	2515
Annual and Monthly Means and Extremes:												
Annual Average:	3.58	0.32	859.24	75.69	33.29	892.53	200.40	18.15	-90.60	-16.11	82676	2610
Annual Minimum:	2.76	0.21	565.88	42.74	33.29	599.17	140.22	12.64	-393.44	-64.29	81862	2515
Annual Maximum:	4.97	0.44	1258.10	99.53	33.29	1291.39	280.92	24.51	244.72	18.50	83101	2674
Monthly Minimum:	1.28	0.00	0.00	0.00	2.57	2.73	77.13	0.09	-172.85	-42.84	81786	2501
Monthly Maximum:	6.86	1.12	241.24	23.46	2.83	244.06	407.50	65.41	188.24	23.51	83213	2677
Monthly Average:	3.58	0.32	71.60	6.31	2.77	74.38	200.40	18.15	-7.55	-1.34	82676	2610

Notes:
(1) Annual flows are sums of the monthly values, Annual storages are averages of the monthly values

Source: WAR 1991

sediments (Section 4.1.10), and nutrient exchange with the sediments (Section 4.1.12).

The annual export of nutrients to the SJR (Figure 4.2.3-2) was dependent on the amount of water exported and the nutrient concentrations. Although 1990 was a below-average year for outflow volume to the SJR (Figure 3.2-7), it was an above-average year for export of both N and P due to the high concentrations of nutrients that year. TN export to the SJR ranged from 565.88 to 1,258.10 tons per year with an annual average of 859.24 tons TN (Table 4.2-3). The fluctuations reflect changes in both outflow volume (decrease from 1988 to 1989) and nutrient concentration (increase from 1989 to 1990). Denitrification export of nitrogen to the atmosphere remained constant at 33.29 tons per year (Figure 4.2.3-2). Annual total TN outflows ranged from 599.17 to 1,291.39 tons (Figure 4.2.3-3). Export to the SJR was the major contributor to the total export average of 892.53 tons TN per year.

Total TN export was roughly equal to total TN loading in the early period of record where lake TN concentration was at the long-term average (Figure 4.2.3-4). This was because total water inflows and outflows were generally fairly close (Figure 3.2-9) and loading concentrations were constant, as well as lake concentrations. When lake TN concentrations were lower than average (1985), TN loadings exceeded TN export. When lake TN concentrations increased to levels above the average, export exceeded loadings. The average annual total TN export of 892.53 tons exceeded the average annual total TN loading of 805.29 tons by 87.24 tons per year (Table 4.2-3) indicating that the lake is a net exporter of TN.

TP export from Lake Jessup occurred only through surface water outflow to the SJR. TP annual total export generally exceeded total loadings, except for 1985 which had low TP concentrations in Lake Jessup waters (Figure 4.2.3-5). The long-term average annual TP export of 75.69 tons exceeded the average annual loading of 60.20 tons by 15.49 tons per year (Table 4.2-3) indicating that the lake is a net exporter of TP.

The nutrient pool in Lake Jessup waters was a function of water volume and nutrient concentrations. Lake volume did not change drastically over the period of record, but nutrient concentrations fluctuated over approximately a

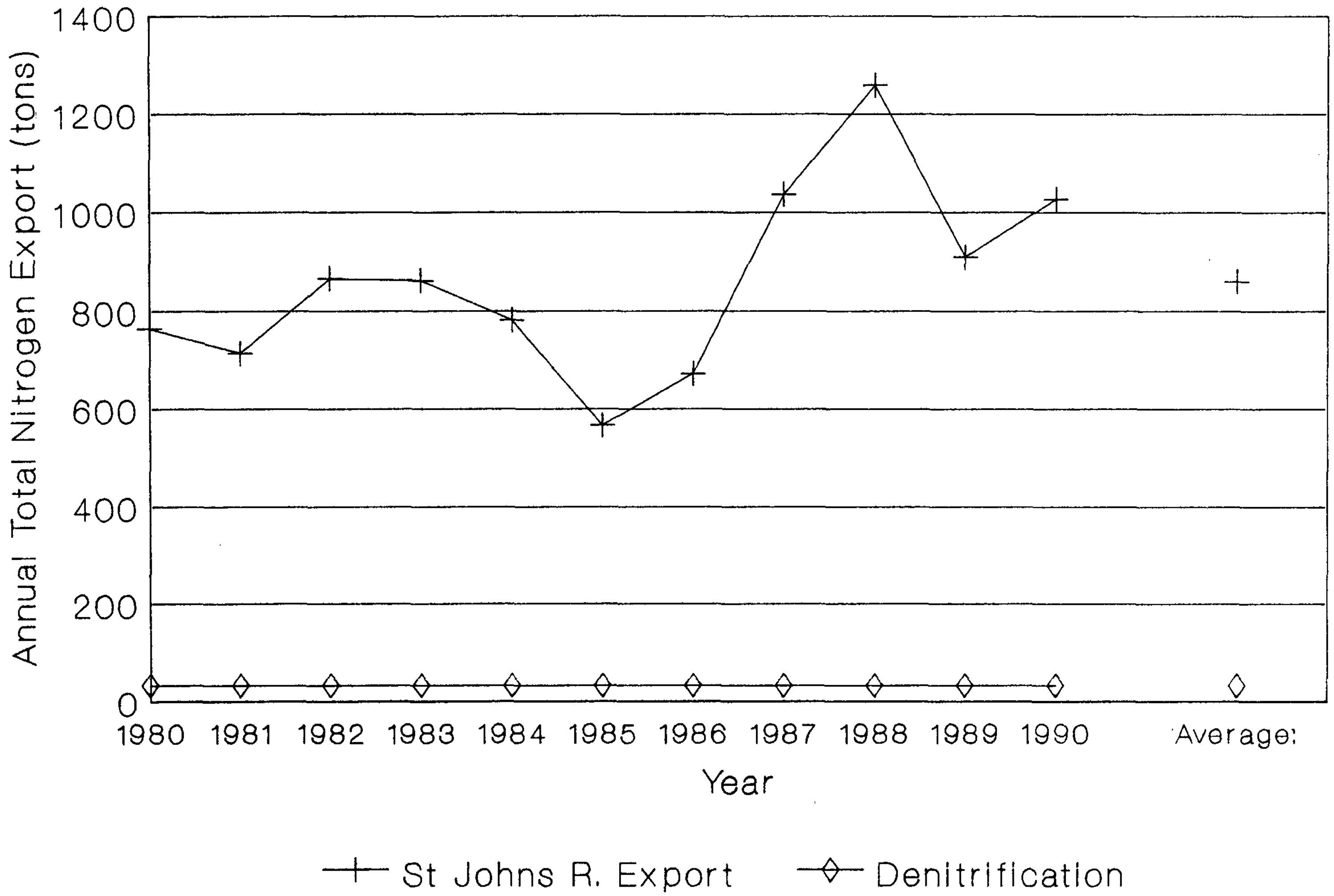

FIGURE 4.2.3-2. Annual Total Nitrogen Exports from Lake Jessup for Period of Record, 1/80 to 12/90.

Source: WAR 1991

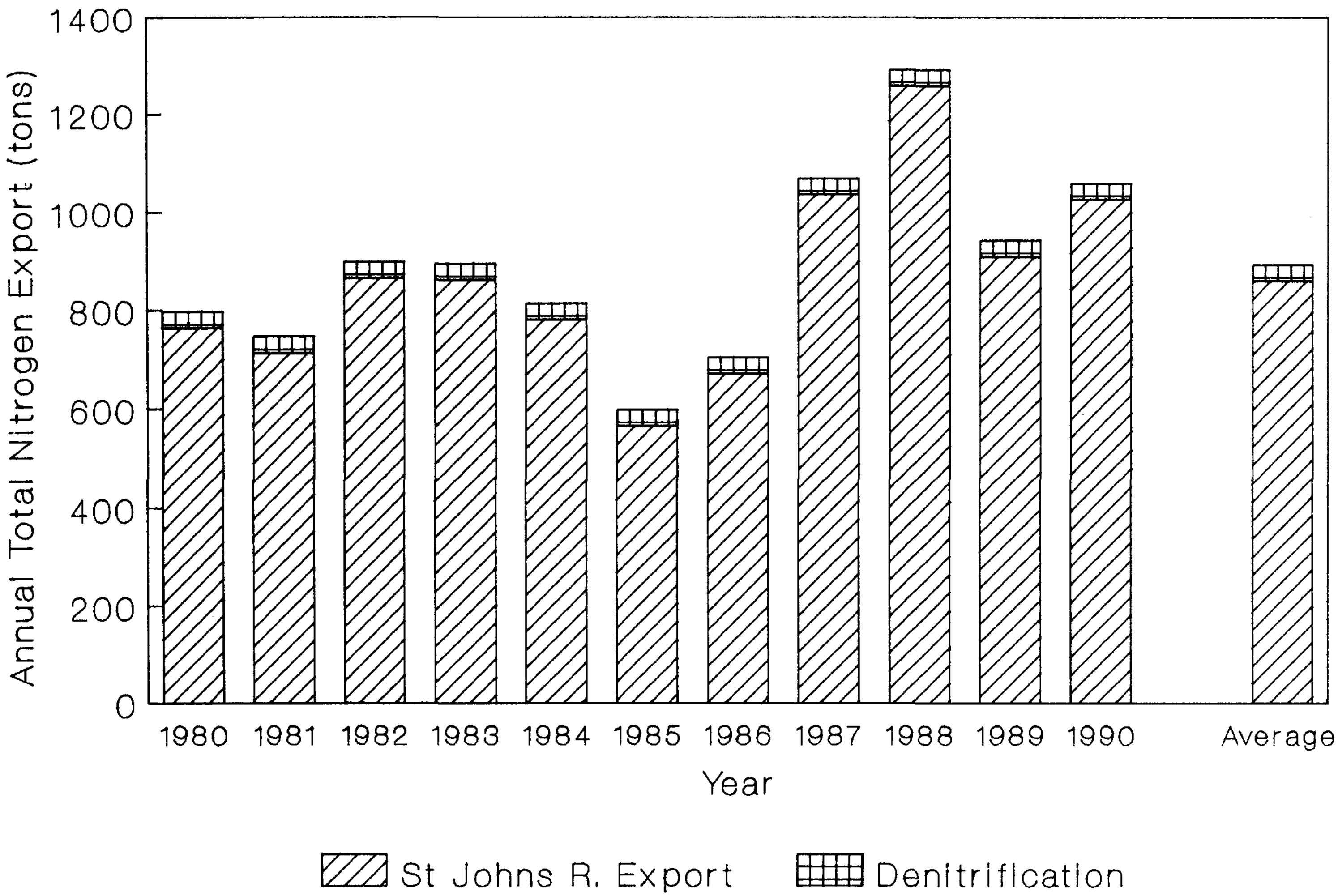

FIGURE 4.2.3-3. Relative Contribution of Total Nitrogen Exports to Annual Total Nitrogen Export.

Source: WAR 1991

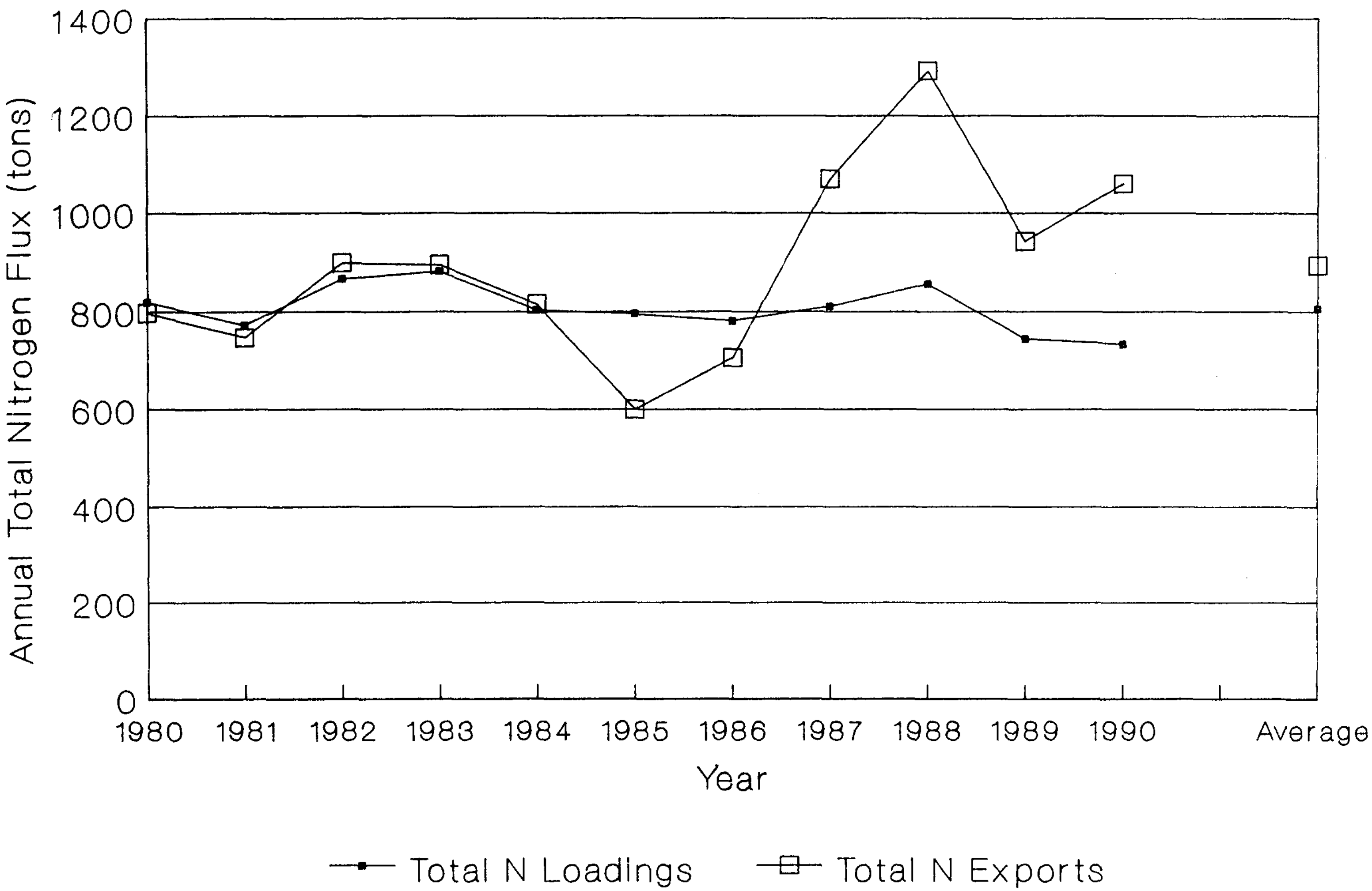

FIGURE 4.2.3.-4. Lake Jessup Annual Total Nitrogen Loadings and Exports for Period of Record, 1/80 to 12/90. Source: WAR 1991

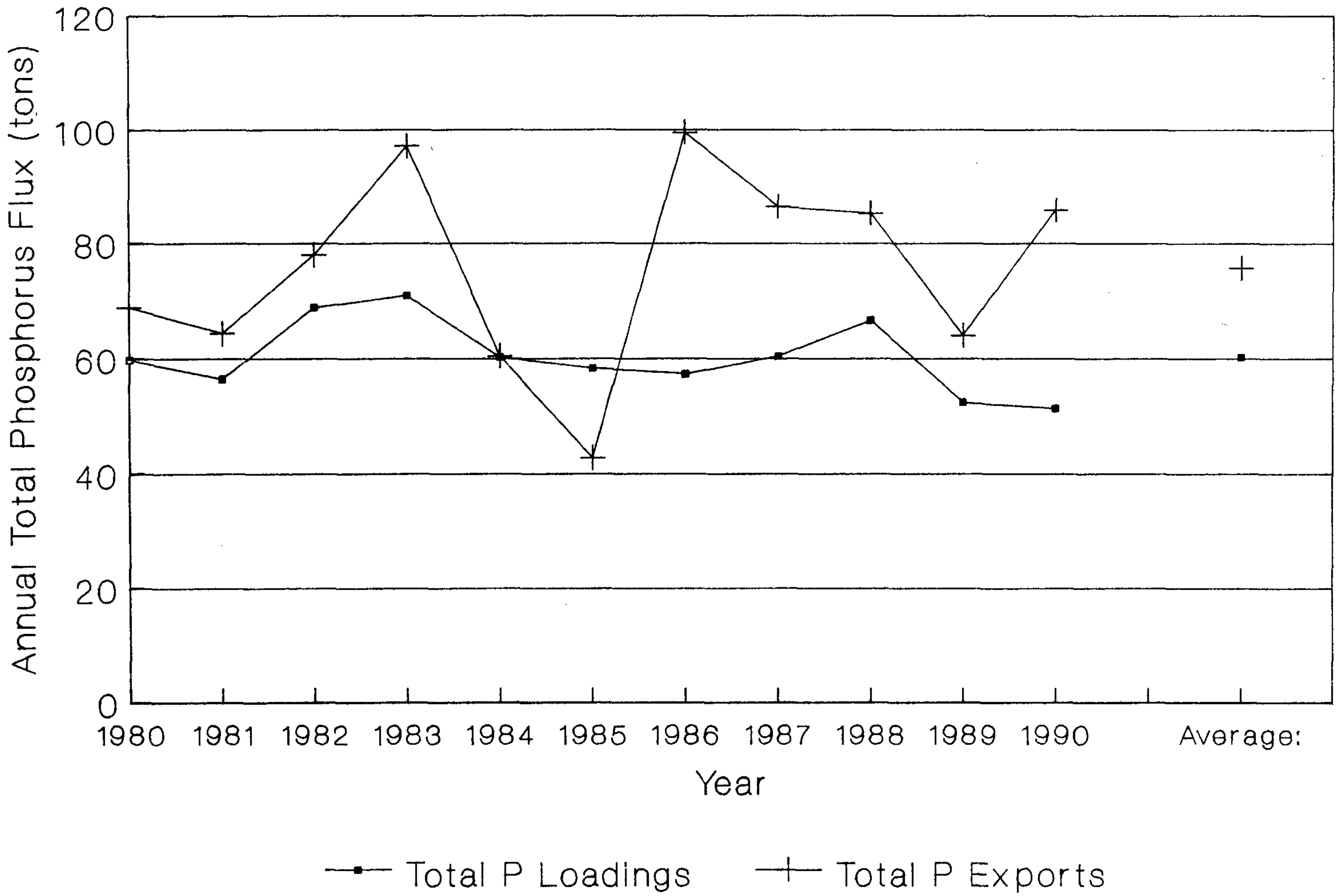

FIGURE 4.2.3-5. Lake Jessup Annual Total Phosphorus Loadings and Exports.

Source: WAR 1991

factor of 2 during the period of record. Annual average TN pool ranged from 140.22 tons to 280.92 tons and averaged 200.40 tons (Table 4.2-3). Annual average TP pool ranged from 12.64 tons to 24.51 tons and averaged 18.15 tons. Changes in the water nutrient pool forced by changes in nutrient concentrations constituted a flow of nutrients within the lake system, and this was not accounted for in the loadings or exports. This flow was assumed to take place as an exchange with the sediment nutrient pool. For example, when concentrations decreased, water nutrient pool decreased and nutrients were assumed to be transferred to the sediment nutrient pool.

The muck sediment nutrient pool for Lake Jessup fulfills the requirement of a source or a sink for TN and TP left over from the difference between total nutrient loadings and exports, and changes in the water nutrient pool. The initial sediment TN and TP pools were estimated previously (Section 4.1.12). When total export exceeded total loading, nutrients were assumed to have been regenerated (resuspended) and exported from the pool. When total loading exceeded total export, nutrients were assumed to have been deposited in the pool. The results of the nutrient budget calculations indicate an annual average regeneration of 90.60 tons of TN and 16.11 tons of TP per year from the sediments to Lake Jessup waters. TN annual average sediment flux ranged from 244.72 tons of deposition to 393.44 tons of regeneration. TP annual average sediment flux ranged from 18.5 tons of deposition to 64.29 tons of regeneration (Table 4.2-3).

The Lake Jessup sediment TN pool generally increased during the first half of the period of record, then decreased, with 1990 having the lowest content (Figure 4.2.3-6). The annual average sediment TN pool ranged from 78,295 tons to 79,534 tons, and averaged 79,109 tons TN (Table 4.2-3). The average annual TP pool steadily decreases through the period of record from the maximum of 2,558 tons in 1980 to the minimum of 2,399 tons in 1990 (Figure 4.2.3-7). The average annual sediment TP pool was 2,494 tons.

4.3 NUTRIENT BUDGET DISCUSSION

The nutrient budget calculations were based on a mixture of two data types: data from actual measurements of the Lake Jessup system and data estimated by separate modeling efforts. Data from actual sampling measurements were used whenever possible, such as Lake Jessup water quality, sediment quality,

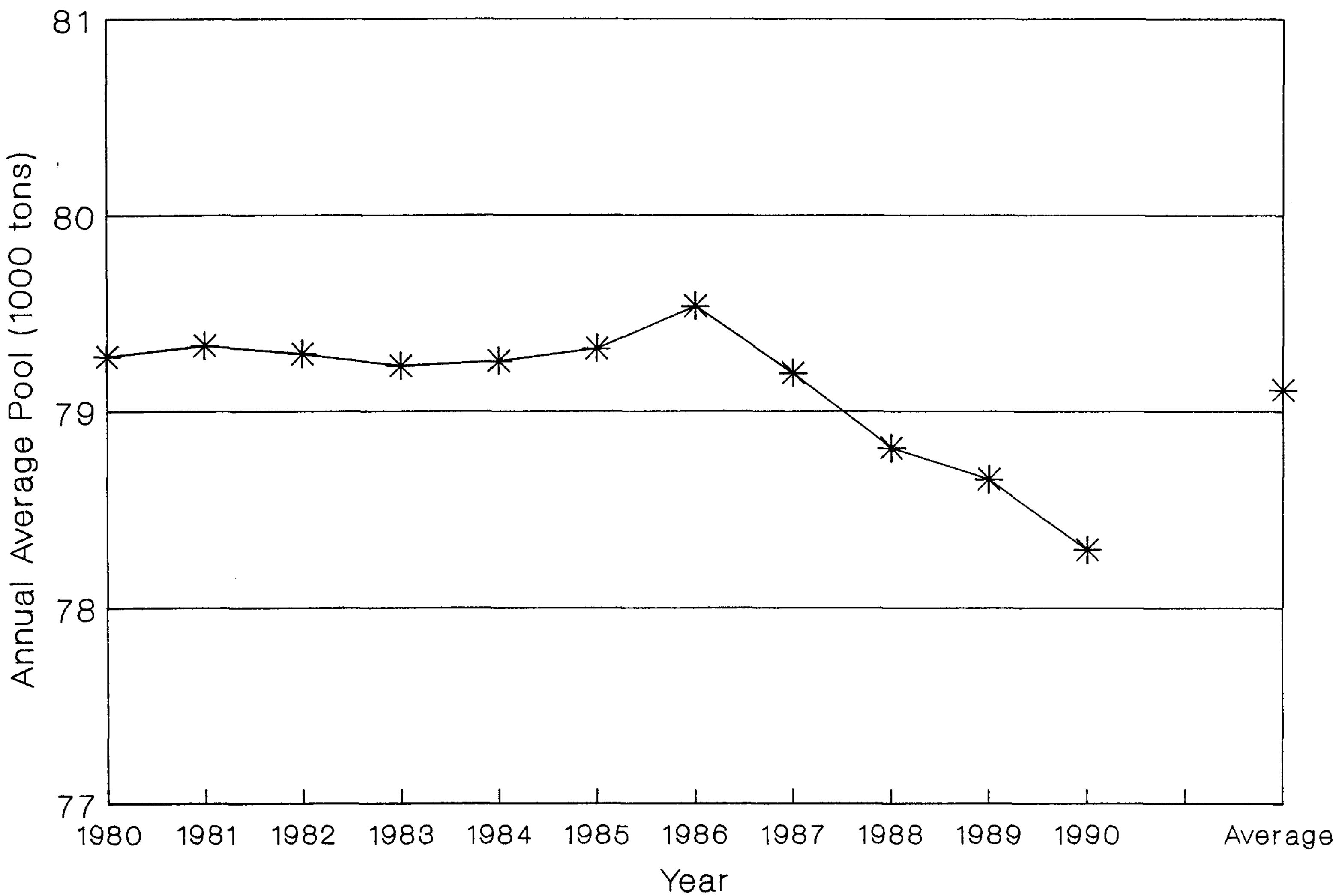

FIGURE 4.2.3-6. Annual Average Total Nitrogen in Lake Jessup Sediments.

Source: WAR 1991

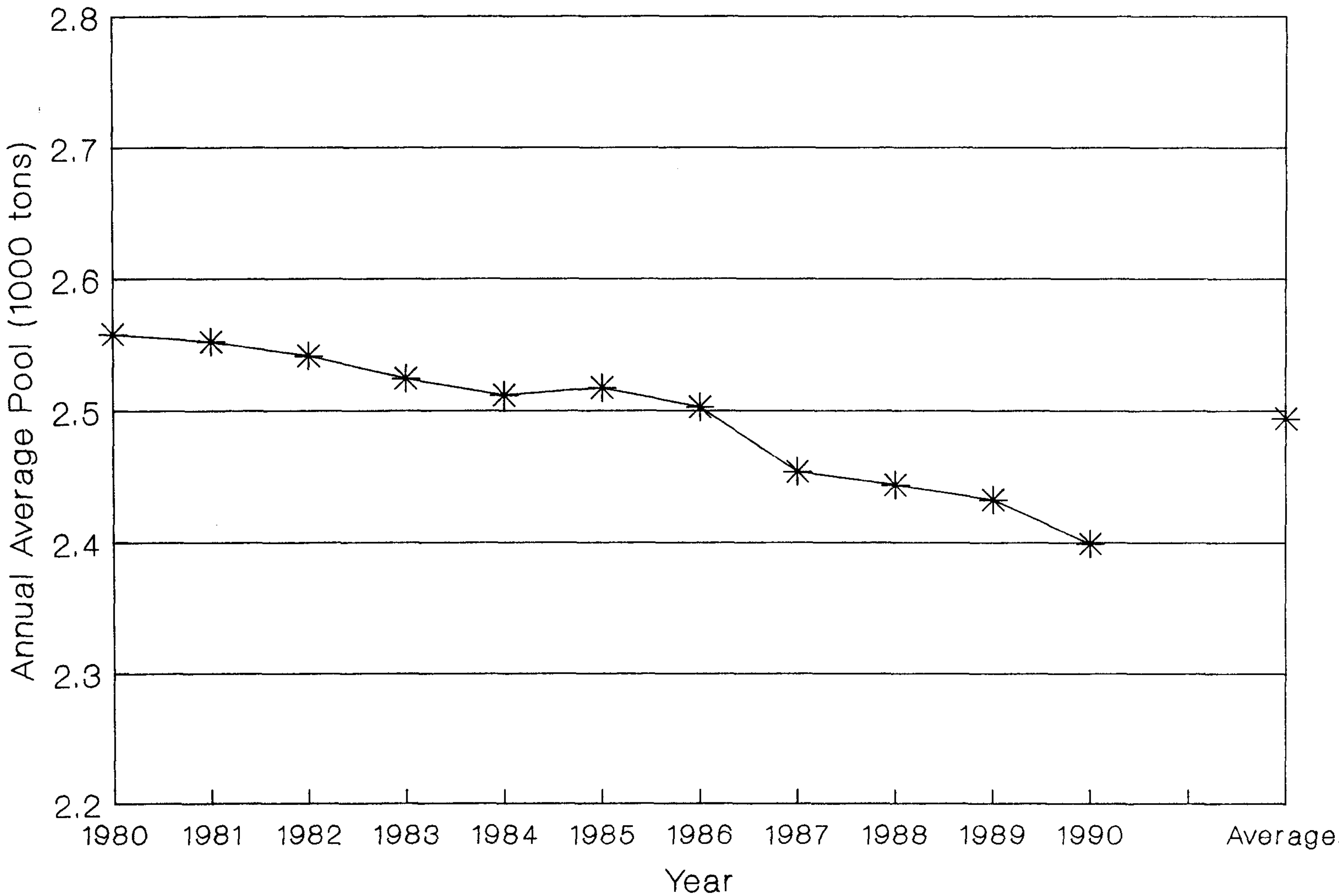

FIGURE 4.2.3-7. Annual Average Total Phosphorus in Lake Jessup Sediments.

Source: WAR 1991

sediment depths, and some tributary flow and water quality data. Data of the second type were used when actual data were not available, as in the case of most tributary runoff coefficients, runoff water quality data and bank seepage water quality data. The problems that arise from a lack of site-specific data can be illustrated by the disparity between the measured and the estimated nutrient concentrations for the BLACKHMK subbasin (Sweetwater Creek). The measured values for TN and TP were 8.86 and 1.30 mg/L, respectively. The values estimated by the Dames and Moore method were 1.74 and 0.13 mg/L, respectively. Clearly, if a similar case existed for all the tributaries that relied on estimated concentrations, the nutrient budget would greatly underestimate actual tributary runoff loadings.

Another major data deficiency was for bank seepage water quality. Site-specific water quality data could not be found for this input. This was the second largest hydrologic input, so it had the potential to be a large nutrient input. It was shown that septic tanks and WWTPs, which use the same hydrologic pathway (groundwater), are major nitrogen loading sources. It would be difficult to separate their contribution to nitrogen concentrations in groundwater measurements in the vicinity of Lake Jessup. The exact amount of phosphorus carried by seepage water also seems to be unknown. Although phosphorus is generally not mobile in soils, some is undoubtedly transported by this pathway. Perhaps the best approach would be to measure shallow groundwater nutrients at a number of points around the lake and assume that the water represented the combined input from shallow groundwater, septic tanks, and WWTP land application systems.

Actual data on septic tank numbers and distribution could greatly alter the results of the nutrient budget since they contribute so much nitrogen. WWTP concentration and measured treatment removal of nitrogen by percolation ponds would probably reduce the estimated contribution from WWTPs.

Tributary nutrient concentrations were determined by modeling. If the actual values were higher than the modeled values, it is possible that there would be a net flux of nutrients into the sediments, which is a more likely scenario. The reason nutrients were exported from the sediments in the nutrient budget was that there was a nutrient deficiency from the loadings that could not match the export based on measured water quality data.

The nutrient exchange between the sediment and water column was determined as the balance of all the other loadings and exports. The problem with this approach is that the error from all the other budget component computations is reflected in this final tally. Generally some estimates are high and others low so that combined, much of the individual errors cancel out. However, this leaves the reliability of the estimate of sediment exchange in some degree of doubt.

The results of the nutrient budget show the sediments as net exporters of TN (90.6 tons/year) and TP (16.11 tons/year). This condition seems unlikely, since lakes tend to accumulate nutrients by incorporation into plant and animal biomass and subsequent deposition into the sediments. However, it could also be speculated that the redirection of wastewater away from the lake has shifted the equilibrium of exchange in the direction of export from the sediments to the water column to some degree. Nutrients regenerated from the sediments could be incorporated into planktonic biomass and exported to the SJR by surface water outflow. Further study is required to determine the actual direction and magnitude of nutrient exchange between the sediments and water column.

Lake Jessup water quality data for 1983 to 1990 averaged 3.18 mg/L for TN and 0.284 mg/L for TP. By comparison, the median (50th percentile) values of TN and TP for Florida lakes have been estimated at 1.4 mg/L and 0.07 mg/L, respectively (Friedemann and Hand 1989). Lake Jessup ranks approximately at percentile 92 for TN and percentile 90 for TP. This means that Lake Jessup had higher nutrient concentrations than approximately 90 percent of the 466 Florida lake stations included in that study.

The water quality index for Lake Jessup was calculated by Hand et al. (1990) to be 60, which is the cutoff value between the fair and poor water quality categories. The median value for TN of 2.48 mg/L used in the calculation was somewhat lower than that the average determined in this study. The trophic state index of 82 for Lake Jessup (Hand et al. 1990) indicates poor trophic status (70 to 100).

The TN to TP ratios for Lake Jessup nutrient budget components were as follows:

Average Annual Loadings	= 13.38
Lake Jessup Water	= 11.04

Ratios less than 10 generally indicate nitrogen limitation, greater than 30 indicate phosphorus limitation, and between 10 and 30 indicate balanced nutrient composition (Hand et al. 1990). The values above indicate balanced nutrients for water entering Lake Jessup and within Lake Jessup. A previous report on Lake Jessup eutrophication (U.S. EPA 1977) gives an inorganic nitrogen (IN) to ortho-phosphorus (OP) ratio of approximately 1:1 which indicated that nitrogen was the limiting nutrient for primary producers in the lake. It was concluded that nitrogen control was the best method to control further lake eutrophication (U.S. EPA 1977). The value of the limiting nutrient concept applied to Lake Jessup is questionable since it is unlikely that primary production could be limited by either nutrient at the observed concentrations.

Retention times for water and nutrients within Lake Jessup water and sediments were calculated by the ratio of average volume or pool to average outflow. The results were:

Hydraulic Retention Time	(RT)	= 86.7 days
Water TN	RT	= 82.0 days
Water TP	RT	= 87.6 days
Sediment TN	RT	= 873 years
Sediment TP	RT	= 155 years
Combined TN	RT	= 80.7 years
Combined TP	RT	= 27.3 years

Hydraulic RT was slightly higher than previous estimates by the National Eutrophication Survey (U.S. EPA 1977) of 82 days and slightly lower than the estimate by Brezonik and Fox (1976) of 99 days. RT for water TN and TP are very similar because exports and volumes were calculated using the same water quality data. RT for TN in lake water is shorter than for TP because TN has an additional export via denitrification. The long RTs for nutrients in the sediments is due to the large volume of Lake Jessup muck sediments and high concentrations of nutrients. Due to the long RTs, nutrients entering the lake have time to interact with components of the nitrogen cycle of the lake such as biologic uptake, storage in plant or animal tissue, deposition in the sediments, and regeneration to the water column. Therefore, a separate calculation was performed combining the pools and outflows of the water column and the sediments to determine a combined retention time. This result may be the most realistic of the three estimates of nutrient retention times in the lake system.

Nutrient export rates for the Lake Jessup watershed were calculated as the average total loadings divided by the total area of all subbasins. Export rates averaged 20.1 kg TN/hectare (ha) per year for TN and 1.5 kg TP/ha per year. The TN export rate is roughly equivalent to the value proposed by Dames & Moore (1990) for multi-family residential land uses (19.82 kg TN/ha per year) which was exceeded only by the hi-density commercial land use rate of 32.18 kg/ha per year. Other land uses were generally between 2 and 10 kg/ha per year. The TP export rate compares closely to the recommended loading values for single-family (1.72 kg TP/ha per year), low-intensity commercial (1.412 kg TP/ha per year), and agricultural land uses (1.362 kg TP/ha per year). Recommended TP loading rates for various land uses ranged from 0.12 kg/ha per year for open land to 4.4 kg/ha per year for multi-family and 4.85 kg/ha per year for hi-intensity commercial (Dames & Moore 1990).

Nutrient loading rates to Lake Jessup were calculated by dividing the total loadings by the Lake Jessup surface area. Loading rates averaged 16.93 mg/m^2 per year for TN and 1.27 g/m^2 per year for TP. These values exceed the critical loading rates of 3.4 g/m^2 per year and 0.49 g/m^2 per year, respectively, developed by Shannon and Brezonik (1972) for north-central Florida lakes. Loading beyond the critical rate will cause or maintain a state of eutrophication. These results indicate that nutrient inputs to Lake Jessup must be decreased by a factor of 3 to 4 before any restoration methodology will be able to succeed.

The three easiest nutrient sources to control (surface runoff, septic tanks, and WWTPs) accounted for 67 percent of the TN inflow and 44 percent of the TP inflow. While it may not be possible to completely remove the nutrient input from these sources, it is possible to reduce the amounts of nutrients they release to receiving waters.

The use of stormwater retention/detention systems throughout the watershed would decrease the nutrient loading from this source by the mechanisms of settling/filtration and biological uptake by plants. Treatment efficiencies vary considerably depending on the system used and the loads it is subjected to. A review of the literature by Whalen and Cullum (1988) indicated that treatment efficiencies of roughly 30 to 50 percent for TKN (the major constituent of stormwater) could be expected from wet detention and up to 60 percent for a variety of wet retention systems. TP removal generally ranged from approximately 40 to 80 percent, with wet retention systems providing the highest treatment. Retention systems have longer holding times and remove nutrients primarily by vegetation uptake, degradation, and sediment binding. Wet detention systems rely on sedimentation, degradation, and vegetation uptake for nutrient removal. Wetland systems were also shown to be valuable assets in the treatment of stormwater, particularly in conjunction with detention systems.

WWTP percolation ponds were assumed to provide no treatment of TN in effluent, which probably led to an overestimate of WWTP input of TN. However, without some component of the treatment system specifically removing nitrogen from the effluent, WWTPs within the watershed will continue to contribute significant amounts of nitrogen to the lake through the groundwater pathway.

Reduction of septic tank effluent can only be accomplished through the systematic sewering of areas currently using septic tanks. Since this input was approximately 20 percent of the TN budget, this alternative should be investigated as part of any restoration effort.

The other nutrient inputs of direct precipitation, artesian upwelling through springs and diffuse leakage, bank seepage, and inflow from the St. Johns River account for less than one-third of the nitrogen budget and approximately 56 percent of the phosphorus budget. These inputs cannot be practically controlled, so efforts to restore Lake Jessup should focus on the inputs from stormwater, septic tanks, and wastewater treatment plants within the watershed.

4.4 ESTIMATE OF ERROR

Error in the nutrient budget was a result of error in the estimates of water budget components and the estimates of the nutrient concentrations. Since the error in the water budget components has already been discussed (Section 3.4), the following section will address the error in the determination of nutrient concentrations for the various loading sources and nutrient pools.

Site-specific nutrient data was not available for all components of the Lake Jessup water budget. Those components lacking data were estimated by the various methodologies described in Section 4.1. In general, where less data existed, more sweeping assumptions had to be made and less precise methodologies of estimation had to be used. The accuracy of an estimate was generally related to the accuracy of the available data. In each component of the nutrient budget there is some inaccuracy. The following sections will place in perspective the possible error of each nutrient budget concentration. Where accurate determination of error is not possible, error will be categorized as within a factor of 1.05 (+/- 5 percent), 1.20, 1.50, 2 (half or double), and 10 (an order of magnitude). Refer to the corresponding subsections of Section 4.1 for methodology details and Table 4.1-1 for nutrient concentration values.

4.4.1 Springflow and Upward Leakage

The nutrient concentrations for springflow and upward leakage were based on single measurements of Sanlando Springs, a Floridan aquifer spring located adjacent to the Lake Jessup (Rosenau et al. 1977). Springflow concentrations are typically comparatively constant, but they do vary with time and location. Other studies have shown an increase in TN concentrations in other Florida springs from the mid-1980s to 1990. Rainbow springs TN concentrations increased from less than 0.5 mg/L to over 1 mg/L between 1984 and 1990 (Nichols and Keesecker 1991). Artesian water quality in the Lake Jessup watershed could have varied substantially from 1980 to 1990. Since this inflow was less than 1 percent of the TN budget, and less than 2 percent of the TP budget, the effect of error to the overall budget should not be significant.

4.4.2 <u>Direct Precipitation</u>

Average rainfall quality (TN=1.6 mg/L, TP=0.18 mg/L) for a station at the edge of the watershed was presented by Irwin and Kirkland (1981). TN values ranged from 0.19 mg/L to 6.8 mg/L. TP values ranged from 0.01 mg/L to 0.89 mg/L. These extremes vary approximately by a factor of 10. The average values for all stations were 1.1 mg/L (TN), and 0.10 mg/L. The average values used were within a factor of 2 of the mean for all stations.

4.4.3 <u>Land Surface Runoff</u>

Runoff (from rainfall and irrigation) concentrations of TN (RNFTN) and TP (RNFTP) were determined either by modeling (Section 2.1.4) or by existing water quality data for tributaries (Section 2.1.7). TN concentrations for subbasins estimated according to land use (Section 2.1.4) ranged from 1.51 mg/L (GEESOLD) to 2.11 mg/L (EUREKA), a fairly narrow range. RNFTN was also determined from existing water quality data for subbasins GEESOLD (1.34 mg/L), HOWELL (1.60 mg/L), and BLACKHMK (8.86 mg/L). The modeled values were generally within a factor of 1.2 except for BLACKHMK (1.74 mg/L) which underestimated the measured value by a factor of 5. The measured value for BLACKHMK (Sweetwater Creek) was based on data from the early 1970s when other loading sources may have been contributing to tributary nutrients and may not be applicable. RNFTN error is estimated at a factor of 1.5.

TP concentrations for subbasins estimated according to land use (Section 2.1.4) ranged from 0.132 mg/L (BLACKHMK) to 0.323 mg/L (HOWELL). RNFTP was also determined from existing water quality data for subbasins GEESOLD (0.147 mg/L) , HOWELL (0.207 mg/L), and BLACKHMK (1.296 mg/L). The modeled values were generally within a factor of 1.5 except for BLACKHMK (1.296 mg/L) which underestimated the measured value by a factor of 10. The measured value for BLACKHMK (Sweetwater Creek) was based on data from the early 1970s when other loading sources may have been contributing to tributary nutrients and may not be applicable. RNFTP error is estimated at a factor of 1.5.

Since runoff is one of the largest loading sources (23.47 percent), error in RNFTN and RNFTP could affect the total loadings by a factor of approximately 1.125.

4.4.4 Shallow Groundwater Inflow

Shallow groundwater nutrient concentrations, SEEPTN and SEEPTP, were assumed to be equal to RNFTN and RNFTP determined by the subbasin land use distribution (Section 2.1.4). These values have the same variation among subbasins as described for RNFTN (1.512 mg/L to 2.11 mg/L) and RNFTP (0.132 mg/L to 0.323) (Section 4.4.3). SEEPTN can range from <0.001 mg/L to 7.58 mg/L in an area the size of the Lake Jessup watershed (Ambient Groundwater Quality Monitoring Program 1990). An accurate representative value for SEEPTN is not known, nor is data available to aid in that determination. One problem is that many studies concentrate on areas that are enriched by some anthropogenic sources. In these areas TN concentrations can reach 180 mg/L (Ayers Associates 1991). The potential error for SEEPTN is extremely high but since un-enriched background levels were desired, the error factor is estimated at 10.

SEEPTP can range over orders of magnitude, from 0.01 mg/L to almost 40 mg/L (Ambient Groundwater Quality Monitoring Program 1990, Ayres Associates 1991). The potential error is quite large and the true values for individual subbasins probably have a very broad range but without any applicable data, it is not possible to quantify the possible error. The estimated error factor is 10 due to the extreme range of possible concentrations.

Since bank seepage was a major source of TN (21 percent) and TP (38 percent), this error could drastically alter the total loadings to the lake.

4.4.5 Septic Tank (OSDS) Inflows

Septic tank loading of TN was assumed to contribute all of the nitrogen in septic tank effluent to Lake Jessup. It is possible that soil biogeochemical processes (such as denitrification and plant uptake) reduce the quantity of TN that reaches the lake, probably not more than 25 percent. The estimate of TN in septic tank effluent STTN (55.3 mg/L) was subject to some error but this estimate was based on actual data and as such is probably within a factor of 1.10. The cumulative estimated error for this source is probably less than 1.5. Septic tanks accounted for 19.36 percent of the total loadings to Lake Jessup so the error to the total loadings could be a factor of approximately 1.1.

4.4.6 Wastewater Treatment Plant Effluent

WWTP effluent TN concentration error is subject to approximately the same error as STTN but is even more likely to overestimate the loading from this source since WWTP effluent is treated more thoroughly. The error for the may be as low as 1.5, but is probably closer to 2. WWTP loading was the largest source in the nutrient budget (24.18 percent) but is likely 50 to 70 percent of the estimated loading, and could be less depending on the amount of advanced wastewater treatment used throughout the watershed.

4.4.7 Denitrification

Section 4.1.11 described various estimates of denitrification rates from literature. These values ranged over several orders of magnitude. The larger values produced annual exports larger than all loadings combined. The possible error is therefore quite large. Denitrification is apparently not one of the largest components of the Lake Jessup nitrogen budget or there would not be any nitrogen in the water column and sediments. The error factor is estimated to lie between 3 and 5.

4.4.8 St. Johns River Loading

TN and TP concentrations for the St. Johns River were estimated using a long-term average of a fairly complete data set. The values used (1.53 mg/L and 0.11 mg/L, respectively) are accurate for long term loadings, but in reality, water quality ranged from 1.00 mg/L to 2.66 mg/L for TN and from 0.06 mg/L to 0.21 for TP. The maximum possible error factor of approximately 3 is not applicable since annual loadings were desired. The estimated error factor assuming annual average concentrations is approximately 1.2. The SJR was a minor loading source so this small error factor is almost insignificant to the overall TN and TP budgets.

4.4.9 Lake Jessup Nutrient Concentrations

Lake Jessup TN and TP concentrations (LJTN and LJTP) were used to determine export to the SJR and the pool of nutrients in Lake Jessup waters. These variables were based on observed data from six different stations so there is still the possibility of error from spatial heterogeneity as well as inaccuracy from the temporal gaps in the data of up to 7 months (Section 2.1.7). Sufficient data does not exist to determine spatial water quality heterogeneity within Lake Jessup. Sampling frequency typically ranged from 4 to 6 dates/year which should have picked up most major shifts in water quality. LJTN averaged 3.18 mg/L and ranged from 1.28 mg/L to 6.86 mg/L. The average is approximately within a factor of two of either extreme. It is possible that for any data point may be in error by a factor of two, particularly extremely high or low values. The overall error factor of the individual values is probably somewhat less, perhaps 1.5. The error of the long term mean is estimated at 1.2.

LJTP ranged from 0 to 1.12 mg/L. A more reliable minimum is probably 0.10 mg/L since the data from the 0 mg/L sampling date is the only data in this range. No other values drop below 0.1 mg/L but approach it. This indicates a range of over a factor of 10 with the mean within a factor of 3 of the minimum and a factor of 4 of the maximum. The overall error factor of individual values is estimated at approximately 2 and the error of the long-term mean is estimated at approximately 1.4

The components of the nutrient budget affected by error in lake water quality would be SJR export of TN and TP and sediment flux of TN and TP.

4.4.10 <u>Lake Jessup Sediment Nutrient Concentrations</u>

Lake Jessup sediment TN (TKN) and TP concentrations from SJRWMD were used to determine the pool of nutrients in Lake Jessup sediment. These values were based on single datums from two different stations so there is the possibility of error sampling procedure and from spatial and temporal heterogeneity. Sediment data presented by Brezonik and Fox (1976) indicate a factor of approximately 1.3 between the averages and maximums for both TP and TN. Minimums were outside the range of typical values. Sediment pool concentration needed only to be approximate since the content of nutrients in the sediments did not affect any fluxes of nutrients or the overall nutrient budget.

The overall nutrient budget error is primarily due to large possible error in nutrient concentrations for the major contributors. The nutrient budget methodology used is assumed to be accurate enough to determine which components are major contributors. The largest sources of potential error based on percent contribution and estimated error are: WWTP TN loading, septic tank TN loading, bank seepage TP and TN loading, and surface runoff TP and TN loading. Other sources were either minor contributors (approximately 5 percent or less, artesian TN and TP, SJR inflow TN and TP) or were based on fairly accurate data (direct precipitation TN and TP).

The largest potential sources of error in the nutrient budget are those for which accurate data does not exist. As a result, these components were estimated by accepted methodologies which extrapolate on limited data or rely entirely on unrelated data (such as RNFTN and RNFTP using land use data). WWTP and septic tank TN loadings assumed that all nitrogen in effluent reached the lake. It is likely that this overestimates the true case but the extent is unknown. Bank seepage loading may be overestimated or underestimated, by an unknown, and possibly large extent. Runoff loadings could be underestimated or underestimated, but probably not by a large extent.

It is unlikely that total TN and TP loading are in error by a factor of 5. Since WWTP and septic tanks (almost half of TN) probably overestimate, the total TN loading could be less by a factor of 2. Total TN loading due to seepage may be greatly underestimated which could result in increased TN loading by a factor of 2.

Total TP loading error is predominantly due to seepage loading. Changes in seepage TP concentration by an order of magnitude could affect the total loadings by a factor of 3 to 5.

5.0 CONCLUSIONS

5.0 CONCLUSIONS

Previous studies have indicated that Lake Jessup has poor water quality and is considered hypereutrophic (U.S. EPA 1977, Brezonik and Fox 1976, and Hand et al. 1990). The determination of an accurate nutrient budget for Lake Jessup is encumbered by the complex and poorly measured hydrology, and poorly measured (or unmeasured) nutrient concentrations for the hydrologic inputs.

Major deficiencies in existing data that compromise the accuracy of the hydrologic budget include:

- Measured regional evapotranspiration,
- Modeled or measured groundwater seepage into Lake Jessup,
- Modeled or measured recharge to the Floridan aquifer within the Lake Jessup watershed,
- Modeled or measured upward leakage through the bottom of Lake Jessup,
- Accurate accounting of the irrigation water applied within the Lake Jessup watershed, and
- Flow measurements of exchange between Lake Jessup and the St. Johns River.

Major deficiencies in existing data that compromise the accuracy of the nutrient budget include:

- Accurate hydrologic budget,
- Regularly measured water quality for all major tributaries,
- Shallow groundwater quality near Lake Jessup,
- Accurate estimate of number and location of septic tanks within the watershed and the capacity of watershed soils to remove TN and TP from septic tank effluent,
- Accurate estimate of the capacity of watershed soils to remove TN and TP from WWTP effluent, and
- Accurate estimate of denitrification from *in situ* Lake Jessup sediments.

Annual nutrient loadings to Lake Jessup estimated from the results of the nutrient budget were 16.93 g/m^2 for TN and 1.27 g/m^2 for TP. These values exceed the critical annual loading rates of 3.4 g/m^2 for TN and 0.49 g/m^2 for TP developed for north central Florida lakes by Shannon and Brezonik (1972). Loading beyond the critical rates will cause or maintain a state of eutrophication.

The estimated average hydraulic retention time of Lake Jessup waters of 87 days gives ample time for nutrients to be assimilated by the biologic component of the lake and stored in plant and animal biomass, and ultimately in the sediments. This process tends to retain nutrients within the lake system.

Total hydrologic inflows to Lake Jessup averaged 222,859 acre-ft/year. The largest hydrologic inflow was surface runoff (95,117 acre-ft/year). This inflow was made up primarily of discharge from subbasins containing Howell Creek (34,309 acre-ft/year) and Gee and Soldier Creeks (25,399 acre-ft/year). The other major inflows were bank seepage (68,060 acre-ft/year) and direct precipitation (42,490 acre-ft/year).

Total nitrogen (TN) loadings to Lake Jessup averaged 805 tons/year. The largest sources of TN were surface runoff (206 tons/year), WWTP discharge to land application systems (185 tons), bank seepage (163 tons/year), septic tanks (145 tons/year), and direct precipitation (92 tons/year).

Total phosphorus (TP) loadings to Lake Jessup averaged 60 tons/year. The largest sources of TP were surface runoff (29 tons/year), bank seepage (19 tons/year), and direct precipitation (10 tons/year).

The water budget estimate for Lake Jessup discharge to the St. Johns River was 177,807 acre-ft/year. This discharge was estimated to carry 859.24 tons TN/year and 75.69 tons TP/year.

The nutrient budget was subject to more error than the hydrologic budget due to the extreme variability in water quality estimates for the major contributors of TN and TP. Total loadings could be overestimated or underestimated by factors of 2 for TN and from 3 to 5 for TP.

Since all WWTP effluent has been routed to land application systems or outside of the watershed, all loadings are essentially from nonpoint sources. Some of these cannot be practically controlled. Nutrients in rainwater were a major source of nutrients but obviously cannot be reduced. Nutrient sources that can be controlled include surface runoff, septic tanks, and WWTP effluent. These inputs accounted for 67 percent of the TN loadings and 44 percent of the TP loadings. Control measures required would include watershed-wide use of stormwater treatment systems, tertiary treatment of sewage effluent discharged within the watershed, and systematic sewerage of all areas presently on septic tanks. While this would not remove all nutrients attributed to these sources, these procedures should be considered as major considerations in any restoration effort.

6.0 REFERENCES

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Ambient Ground-Water Quality Monitoring Program (AGWQMP). 1990. Ground-Water Quality Sampling Results from Wells in the Southwest Florida Water Management District: Northern Region (Section 1). Southwest Florida Water Management District, Brooksville, Florida.

Ayres Associates. 1991. Evaluation of Nutrient Loading Potential from Wastewater Sources in the Crystal River/Kings Bay Watershed. Ayres Associates, Tampa, Florida.

Barraclough, J.T. 1962. Ground-Water Resources of Seminole County, Florida. Report of Investigations no. 27. U.S. Geological Survey, Tallahassee, Florida.

Bartel, R.L. and J.D. Barksdale, 1985. Hydrogeologic Assessment of Solid Waste Landfills in Northwest Florida. Water Resources Special Report 85-1. Northwest Florida Water Management District, Havana, Florida.

Beaven, T.R. and B.F. McPherson. 1978a. Stormwater Runoff Data for a Highway Area, Broward County, Florida (Open-File Report 78-612). U.S. Geological Survey, Tallahassee, Florida.

Beaven, T.R. and B.F. McPherson. 1978b. Urban Stormwater Runoff Data for a Residential Area, Pompano Beach, Florida (Open-File Report 78-324). U.S. Geological Survey, Tallahassee, Florida.

Bicki, T.J. et al. 1984. Impact of On-site Sewage Disposal Systems on Surface and Ground Water Quality, Report to Florida Department of Health and Rehabilitative Services. Institute of Food and Agricultural Sciences (FAS), University of Florida, Gainesville, Florida.

Bowie, G.L. et al. 1985. Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling (Second Edition). Tetra Tech, Inc., Lafayette, California.

Boynton, W.R., W.M. Kemp, and C.G. Osborne. 1980. Nutrient Fluxes Across the Sediment Water Interface in the Turbid Zone of a Coastal Plain Estuary. In: V.S. Kennedy (ed.), Estuarine Perspectives. Academic Press, New York.

Brezonik, P.L. and J.L. Fox. 1976. Analysis of Eutrophication and Water Quality in the Middle St. Johns River Basin. Department of Environmental Engineering Sciences, University of Florida, Gainesville, Florida.

Brezonik, P.L. and G.F. Lee. 1968. Denitrification as a Nitrogen Sink in Lake Mendota, Wisconsin. Environmental Science Technology 2: 120-125.

Brown, L.C. and T.O. Barnwell, Jr. 1987. The Enhanced Stream Water Quality Models QUAL2E and QUAL2EU-UNCAS: Documentation and User Manual. U.S. Environmental Protection Agency (U.S. EPA), Athens, Georgia.

Calhoun, F.G. et al. 1974. Characterization Data for Selected Florida Soils. Soil Conservation Service Soil Science Research Report Number 74-1. University of Florida, Gainesville, Florida.

Carlisle, V.W. et al. 1978. Characterization Data for Selected Florida Soil. Soil conservation Service Soil Science Research Report Number 78-1. University of Florida, Gainesville, Florida.

Clements, E.V., and R.J. Otis. 1980. Design Manual - On-site Wastewater Treatment and Disposal Systems. U.S. Environment Protection Agency Report No. 625/1-80-012. In: Bicki et al., 1984.

Climatic Data Center. 1987. Local Climatological Data, Annual Summary With Comparative Data, Pensacola, Florida. National Oceanic and Atmospheric Administration, Asheville, North Carolina.

Dames and Moore. 1990. Urban Stormwater Analysis and Improvement Study for the Tampa Bay Watershed. Southwest Florida Water Management District, Brooksville, Florida.

Dudley, J.G., and P.A. Stephenson. 1973. Nutrient enrichment of groundwater from septic tank disposal systems. Upper Great Lakes Regional Commission, University of Wisconsin, Madison, Wisconsin.

EarthInfo, Inc. 1990. Data retrieved from CD-ROM Database. EarthInfo, Boulder, Colorado.

Edgerton, E.S., P.L. Brezonik, and C.D. Hendry. 1979. Atmospheric Deposition of Acidity and Sulfur in Florida (Presented Paper). University of Florida, Dept. of Environmental Engineering Sciences, Gainesville, Florida.

Florida Department of Environmental Regulations (FDER). 1992. Personal Communication. Domestic Wastewater Permitting Section. Orlando, Florida.

Friedemann, M. and J. Hand. 1989. Typical Water Quality Values for Florida's Lakes, Streams and Estuaries. Standards and Monitoring Section, Bureau of Surface Water Management, Florida Department of Environmental Regulation, Tallahassee, Florida.

German, E.R. 1989. Quantity and Quality of Stormwater Runoff Recharged to the Floridan Aquifer System Through Two Drainage Wells in the Orlando, Florida, Area. U.S. Geological Survey, Denver, Colorado.

Hand, J., V. Tauxe, M. Friedemann, and L. Smith. 1990. 1990 Florida Water Quality Assessment, 305(b) Technical Appendix. Florida Department of Environmental Regulation, Tallahassee, Florida.

Hansel, M.J., and R.E. Machmeier. 1980. On-site Wastewater Treatment on Problem Soils. J. Water Poll. Control Fed. 52:548-558.

Hardee, J., R.A. Miller and H.C. Mattraw, Jr. 1979a. Stormwater-Runoff Data for a Multi-family Residential Area, Dada County, Florida (Open-File Report 79-1295). U.S. Geological Survey, Tallahassee, Florida.

Hardee, J., R.A. Miller and H.C. Mattraw, Jr. 1979b. Stormwater-Runoff Data for a Multi-family Residential Area, Dade County, Florida Open-File Report 79-1295). U.S. Geological Survey, Tallahassee, Florida.

Heath, R.C. and C.S. Conover. 1981. Hydrologic Almanac of Florida. U.S. Department of the Interior Geological Survey Open-File Report 81-1107.

Hem, John D. 1989. Study and Interpretation of the Chemical Characteristics of Natural Water (Third Edition). USGS Water-Supply Paper 2254. U.S. Government Printing Office, Washington, D.C.

Huber, W.C., P.L. Brezonik, J.P. Heaney, R.E. Dickinson, S.D. Preston, D.S. Dwornik, and M.A. DeMaio. 1982. A Classification of Florida Lakes. Department of Environmental Engineering Sciences, University of Florida, Gainesville, Florida.

Huber, W.C. 1990. Personal communication. Expert witness testimony in Case Number CI-87-2677, Ninth Judicial Circuit Court for Orange County, Florida. Department of Environmental Engineering Sciences, University of Florida, Gainesville, Florida.

Irwin, G.A. and R.T. Kirkland. 1980. Chemical and Physical Characteristics of Precipitation at Selected Sites in Florida. U.S. Geological Survey (USGS) Water Resources Investigations 80-81. USGS, Tallahassee, Florida.

Keller, A. 1992. Personal Communication. SWFWMD, Palatka, Florida.

Knowles, R. 1979. Denitrification, Acetylene Reduction, and Methane Metabolism in Lake Sediment Exposed to Acetylene. Applied and Environmental Microbiology 38(3):486-493.

Lichtler, W.F., W. Anderson, and B.F. Joyner. 1968. Water Resources of Orange County, Florida. Report of Investigations No. 50. U.S. Geological Survey, Tallahassee, Florida.

MacVicar, T.K., T. VanLent, and A. Castro. 1984. South Florida Water Management Model Documentation Report. Technical Publication 84-3. Resource Planning Department, South Florida Water Management District. West Palm Beach, Florida.

Mycyk, R.T., L.D. Fayard, W.L. Fletcher, and J.K. Ogle. 1986a. Water Resources Data for Florida, 1985, Volume 3B, Southwest Florida Groundwater. U.S. Geological Survey, Tallahassee, Florida.

Mycyk, R.T., L.D. Fayard, W.L. Fletcher, and J.K. Ogle. 1986b. Water Resources Data for Florida, 1985, Volume 3A, Southwest Florida Groundwater. U.S. Geological Survey, Tallahassee, Florida.

National Oceanic and Atmospheric Administration (NOAA). 1986. Climatological Data, Annual Summary, Florida, Volume 90.

Nichols, J.C., and D.H. Keesecker. 1991. Diagnostic Studies of the Rainbow River. Water and Air Research, Inc., Gainesville, Florida.

Oren, A. and T.H. Blackburn. 1979. Estimation of sediment Denitrification Rates at *In Situ* Nitrate Concentrations. Applied and Environmental Microbiology 37(1):174-176.

Otis, R.J. et al. 1975. The Performance of Single Household Treatment Units. J. Environmental Engineering Division of the American Society of Civil Engineers 102:175-189. In: Bicki et al., 1984.

Panel on Nitrates, National Research Council. 1978. Nitrates: An Environmental Assessment. National Academy of Sciences, Washington, DC.

Plumb, R.H. 1981. Procedures for Handling and Chemical Analysis of Sediment and Water Samples. Environmental Laboratory, Waterways Experiment Station, Vicksburg, Mississippi.

Rao, P.S.C. et al. 1982. User's Guide for Estimating Nonpoint Source Model Parameters for Selected Pesticides and Phosphorus. U.S. Environmental Protection Agency (U.S. EPA), Athens, Georgia.

Reddy, K.R. and D.A. Graetz. 1991. Internal Nutrient Budget for Lake Apopka. Final Report, Project No. 15-150-01-SWIM. Institute of Food and Agricultural Sciences (IFAS), University of Florida, Gainesville, Florida. Special Publication SJ 91-SP6.

Rosenau, Jack G., et al. 1977. Springs of Florida Bulletin No. 31 (Revised). U.S. Geological Survey, Tallahassee, Florida.

Seminole County. 1989. Unpublished Data. Sanford, Florida.

Seminole County. 1990. Seminole County Real Features Base Map. Traffic Zones. Sanford, Florida.

Seminole County. 1991. Sanitary Sewer Element. Seminole County 1991 Comprehensive Plan. Seminole County Planning Office, Sanford, Florida.

Shannon, E.E. and P.L. Brezonik. 1972. Eutrophication Analysis: A Multivariate Approach. Journal of Sanitary Engineering Division, American Society of Civil Engineers 98:37-57.

Shellentrayer, G.W. and G.W. Hurt. 1990. Soil Survey of Seminole County, Florida. U.S. Department of Agriculture, Soil Conservation Service, Gainesville, Florida.

Shermyen, A.H. et al. 1990. 1990 Florida Statistical Abstract, Twenty-fourth Edition. Bureau of Economic and Business Research, College of Business Administration, University of Florida. The University Presses of Florida, Gainesville, Florida.

Shiffer, D.M. 1989a. Effects of Highway-Runoff Detention Methods on Water Quality of the Surfical Aquifer System in Central Florida. U.S. Geological Survey, Tallahassee, Florida.

Shiffer, D.M. 1989b. Effects of Highway-Runoff Detention Methods on the Quality of Water and Bed Sediments of Two Wetlands in Central Florida. U.S. Geological Survey, Tallahassee, Florida.

Snyder, L.E. et al. 1990. Top Level Predator Sport Fish Investigations on the Lower St. Johns River. St. Johns Fishery Resources, Lower St. Johns Project, Study XI. Florida Game and Freshwater Fish Commission, Tallahassee, Florida.

Soil Conservation Service (SCS). 1972. National Engineering Handbook, Section 4: Hydrology. U.S. Department of Agriculture, Engineering Division, Washington, D.C.

Soil Conservation Service (SCS). 1991. Gee and Soldier Creeks Flood Plain Management Study, Seminole County, Florida. SCS, Gainesville, Florida.

Sompongse, D. 1982. The Role of Wetland Soils in Nitrogen and Phosphorus Removal from Agricultural Drainage Water. Ph.D. Dissertation, University of Florida, Gainesville, Florida.

Sorensen, J. 1978a. Denitrification Rates in a Marine Sediment as Measured by the Acetylene Inhibition Technique. Applied and Environmental Microbiology 36(1):139-143.

Sorensen, J. 1978b. Capacity for Denitrification and Reduction of Nitrate to Ammonia in a Coastal Marine Sediment. Applied and Environmental Microbiology 35(2):301-305.

Southwest Florida Water Management District (SWFWMD). 1975. Agricultural Consumptive Use Explained. Hydroscope. SWFWMD, Brooksville, Florida.

Spechler, R.M., L.C. Marray. L.A. Bradner, and G.F. Phelps. 1991. Potentiometric Surface of the Upper Floridan Aquifer in the St. Johns River Water Management District and Vicinity, September 1990. USGS Open-File Report 91-190. U.S. Department of the Interior, U.S. Geological Survey, Denver, Colorado.

St. Johns River Water Management District (SJRWMD). 1987. Seminole County Wetlands Map. Water Resources department, SJRWMD, Palatka, Florida.

St. Johns River Water Management District (SJRWMD). 1991. Water Quality and Sediment Quality Data Retrieved from the STORET Database SJRWMD, Palatka, Florida.

Stites, D. 1992. Personal Communication. SJRWMD, Palatka, Florida.

Suphunvorranop, T. and D.A. Clapp. 1984. Howell Branch Basin Surface Water Management Study, Phase I, Volume I. Department of Water Resources, St. Johns River Water Management District, Palatka, Florida. Project Number 20 200 05.

Tarver, D.P. et al. 1986. Aquatic and Wetland Plants of Florida, Third Edition. Bureau of Aquatic Plant Research and Control, Florida DNR, Tallahassee, Florida.

Thomann, R.V. 1972. Systems Analysis and Water Quality Management. McGraw-Hill, New York, New York.

Tibbals, C.H. 1990. Hydrology of the Floridian Aquifer System in East-Central Florida. Regional Aquifer-System Analysis. U.S. Geological Survey Professional Paper 1403-E. United States Government Printing Office, Washington, D.C.

U.S. Environmental Protection Agency (U.S. EPA) National Eutrophication Survey. 1977. Report on Lake Jessup, Seminole County, Florida. Working Paper No. 260. U.S. EPA, Washington, D.C.

U.S. Geological Survey (USGS). 1956. Orlando East (7.5-minute series topographic map).

U.S. Geological Survey (USGS). 1959. Forest City (7.5-minute series topographic map).

U.S. Geological Survey (USGS). 1965a. Osteen (7.5-minute series topographic map).

U.S. Geological Survey (USGS). 1965b. Sanford (7.5-minute series topographic map).

U.S. Geological Survey (USGS). 1965c. Sanford South West (7.5-minute series topographic map).

U.S. Geological Survey (USGS). 1970a. Oviedo (7.5-minute series topographic map).

U.S. Geological Survey (USGS). 1970b. Oviedo South West (7.5-minute series topographic map).

U.S. Geological Survey (USGS). 1980a. Casselberry (7.5-minute series topographic map).

U.S. Geological Survey (USGS). 1980b. Orlando West (7.5-minute series topographic map).

U.S. Geological Survey (USGS). 1984. Water Resources Data - Florida - Water Year 1983 Volume 1A., Northeast Florida. USGS, Altamonte Springs, Florida.

U.S. Geological Survey (USGS). 1985. Water Resources Data - Florida - Water Year 1984 Volume 1A., Northeast Florida. USGS, Altamonte Springs, Florida.

U.S. Geological Survey (USGS). 1986. Water Resources Data - Florida - Water Year 1985, Volume 4. Northwest Florida. USGS, Altamonte Springs, Florida.

U.S. Geological Survey (USGS). 1988. Water Resources Division Data. Date Processed: 12-02-88. USGS, Tallahassee, Florida.

U.S. Geological Survey (USGS). 1989. Water Resources Data - Florida - Water Year 1988 Volume 1A., Northeast Florida. USGS, Altamonte Springs, Florida.

U.S. Geological Survey (USGS). 1990a. Water Resources Data - Florida - Water Year 1988 Volume 1A., Northeast Florida. USGS, Altamonte Springs, Florida.

U.S. Geological Survey (USGS). 1990b. Unpublished Water Quality Data from the WATSTORE Database. USGS, Orlando, Florida.

U.S. Geological Survey (USGS). 1991. Water Resources Data - Florida Water Year 1988 Volume 1A., Northeast Florida. USGS, Altamonte Springs, Florida.

U.S. Geological Survey (USGS). 1991. Unpublished Water Quality Data from the WATSTORE Database. USGS, Orlando, Florida.

Water and Air Research (WAR). 1991. Analysis Results. Gainesville, Florida.

Water and Air Research (WAR). 1992. Analysis Results. Gainesville, Florida.

Whalen, P.J. and M.G. Cullum. 1988. An Assessment of Urban Land Use/Stormwater Runoff Quality Relationships and Treatment Efficiencies of Selected Stormwater Management Systems. Technical Publication 88-9. South Florida Water Management District, West Palm Beach, Florida

White, W.A. 1970. The Geomorphology of the Florida Peninsula (Geological Bulletin No. 51). Florida Department of Natural Resources, Tallahassee, Florida.

APPENDICES

APPENDIX A

Lake Jessup Water Budget Results for the Years 1980 Through 1990, With Averages and Extremes for Years and Months

Appendix A. Inputs and Outputs to the Lake Jessup Annual Water Budget from Artesian Sources and Meteorological Sources and Sinks for the Years 1980 through 1990 with Monthly and Annual Means and Extremes.

Year	Artesian:			Meteorological:				Lk Jessup Surface:		Subbasin AIRPORT:			
	Average Daily Springflow (cfs)	SPFLOW Spring-flow (acre-ft)	LEAK Upward Leakage (acre-ft)	R Sanford Rainfall (inches)	IRR Calculated Irrigation Demand (inches)	EV Lisbon Pan Evaporation (inches)	ET Evapo-transpiration (inches)	PCLJ Direct Precip-itation (acre-ft)	EVLJ Surface Evapor-ation (acre-ft)	RO Surface Runoff (acre-ft)	I Infil-tration (acre-ft)	SEEP Bank Seepage Inflow (acre-ft)	ST Septic Tank Inflows (acre-ft)
Annual Totals or Averages (1)													
1980	3.1	2,217	2,317	48.41	16.32	59.88	34.31	43,008	46,017	9,582	(1,600)	2,643	320
1981	3.1	2,217	2,339	42.88	30.67	59.63	34.31	38,095	45,811	10,592	477	2,643	320
1982	3.1	2,217	2,166	59.91	17.22	54.38	34.31	53,225	41,749	14,393	8,333	2,643	320
1983	3.1	2,217	2,176	62.85	14.03	56.00	34.31	55,837	43,101	15,035	9,645	2,643	320
1984	3.1	2,217	2,218	47.71	26.43	60.81	34.31	42,386	46,655	11,663	2,675	2,643	320
1985	3.1	2,217	2,214	44.27	23.07	59.20	34.31	39,330	45,388	10,799	907	2,643	320
1986	3.1	2,217	2,267	43.90	26.44	57.77	34.31	39,001	44,430	10,765	845	2,643	320
1987	3.1	2,217	2,231	46.23	30.92	56.58	34.31	41,071	43,542	11,385	2,129	2,643	320
1988	3.1	2,217	2,240	55.97	15.27	58.24	34.31	49,724	44,793	13,433	6,334	2,643	320
1989	3.1	2,217	2,295	37.37	28.40	61.69	34.31	33,200	47,583	9,257	(2,284)	2,643	320
1990	3.1	2,217	2,318	36.59	28.22	63.45	34.31	32,507	48,703	9,070	(2,678)	2,643	320
Annual and Monthly Means and Extremes													
Annual Average:	3.06	2,217	2,253	47.83	23.36	58.88	34.31	42,490	45,252	11,452	2,253	2,643	320
Annual Minimum:	3.06	2,217	2,166	36.59	14.03	54.38	34.31	32,507	41,749	9,070	(2,678)	2,643	320
Annual Maximum:	3.06	2,217	2,339	62.85	30.92	63.45	34.31	55,837	48,703	15,035	9,645	2,643	320
Monthly Minimum:	3.06	158	158	0.10	0.00	1.37	1.78	89	1,060	85	(1,624)	220	25
Monthly Maximum:	3.06	204	204	15.10	6.48	8.88	3.69	13,415	7,323	3,559	5,062	220	27
Monthly Average:	3.06	186	188	3.99	1.95	4.91	2.86	3,541	3,771	970	220	220	27

Notes:
(1) Annual flows are sums of the monthly values, Annual storages are averages of the monthly values

Source: WAR 1991

Appendix A.

Year	Subbasin: BLACKHMK STP WWTP Inflows (acre-ft)	Net Subbasin Inflow (acre-ft)	RO Surface Runoff (acre-ft)	I Infil-tration (acre-ft)	SEEP Bank Seepage Inflow (acre-ft)	ST Septic Tank Inflows (acre-ft)	STP WWTP Inflows (acre-ft)	Subbasin: EUREKA Net Subbasin Inflow (acre-ft)	RO Surface Runoff (acre-ft)	I Infil-tration (acre-ft)	SEEP Bank Seepage Inflow (acre-ft)	ST Septic Tank Inflows (acre-ft)	STP WWTP Inflows (acre-ft)
Annual Totals or Averages (1)													
1980	0	14,631	4,152	1,353	1,363	105	0	5,620	1,044	316	327	105	0
1981	0	13,554	3,797	270	1,363	105	0	5,265	961	81	327	105	0
1982	0	17,356	5,117	4,293	1,363	105	0	6,584	1,285	1,007	327	105	0
1983	0	17,998	5,338	4,968	1,363	105	0	6,806	1,339	1,161	327	105	0
1984	0	14,626	4,168	1,402	1,363	105	0	5,636	1,052	340	327	105	0
1985	0	13,762	3,857	453	1,363	105	0	5,325	973	114	327	105	0
1986	0	13,728	3,851	434	1,363	105	0	5,318	973	114	327	105	0
1987	0	14,348	4,078	1,127	1,363	105	0	5,545	1,032	281	327	105	0
1988	0	16,396	4,774	3,249	1,363	105	0	6,242	1,199	759	327	105	0
1989	0	12,220	3,321	(1,180)	1,363	105	0	4,789	842	(262)	327	105	0
1990	0	12,033	3,255	(1,382)	1,363	105	0	4,723	825	(310)	327	105	0
Annual and Monthly Means and Extremes													
Annual Average:	0	14,605	4,155	1,363	1,363	105	0	5,623	1,048	327	327	105	0
Annual Minimum:	0	12,033	3,255	(1,382)	1,363	105	0	4,723	825	(310)	327	105	0
Annual Maximum:	0	17,998	5,338	4,968	1,363	105	0	6,806	1,339	1,161	327	105	0
Monthly Minimum:	0	332	37	(827)	114	8	0	159	11	(188)	27	8	0
Monthly Maximum:	0	3,806	1,258	2,638	114	9	0	1,380	314	616	27	9	0
Monthly Average:	0	1,217	346	114	114	9	0	469	87	27	27	9	0

Notes:
(1) Annual flows

Source: WAR 1991

Appendix A.

Year	Net Subbasin Inflow (acre-ft)	Subbasin: GEESOLD RO Surface Runoff (acre-ft)	I Infil-tration (acre-ft)	SEEP Bank Seepage Inflow (acre-ft)	ST Septic Tank Inflows (acre-ft)	STP WWTP Inflows (acre-ft)	Net Subbasin Inflow (acre-ft)	Subbasin: HOWELL RO Surface Runoff (acre-ft)	I Infil-tration (acre-ft)	SEEP Bank Seepage Inflow (acre-ft)	ST Septic Tank Inflows (acre-ft)	STP WWTP Inflows (acre-ft)	Net Subbasin Inflow (acre-ft)
Annual Totals or Averages (1)													
1980	1,476	24,608	29,439	32,701	455	6,915	64,680	34,412	25,789	25,951	228	897	61,488
1981	1,394	24,233	27,987	32,701	455	6,915	64,305	31,395	17,172	25,951	228	897	58,471
1982	1,717	30,008	51,546	32,701	455	6,915	70,080	42,419	49,800	25,951	228	897	69,495
1983	1,771	30,874	54,758	32,701	455	6,915	70,946	44,273	54,808	25,951	228	897	71,349
1984	1,485	25,807	34,087	32,701	455	6,915	65,879	34,498	25,886	25,951	228	897	61,574
1985	1,405	23,728	26,053	32,701	455	6,915	63,800	31,928	18,803	25,951	228	897	59,004
1986	1,405	24,064	27,541	32,701	455	6,915	64,136	31,862	18,839	25,951	228	897	58,938
1987	1,464	25,803	34,584	32,701	455	6,915	65,876	33,727	24,405	25,951	228	897	60,803
1988	1,631	27,911	42,737	32,701	455	6,915	67,984	39,583	40,935	25,951	228	897	66,659
1989	1,274	21,370	16,346	32,701	455	6,915	61,442	27,455	5,434	25,951	228	897	54,531
1990	1,257	20,986	14,638	32,701	455	6,915	61,058	26,905	3,590	25,951	228	897	53,981
Annual and Monthly Means and Extremes													
Annual Average:	1,480	25,399	32,701	32,701	455	6,915	65,471	34,405	25,951	25,951	228	897	61,481
Annual Minimum:	1,257	20,986	14,638	32,701	455	6,915	61,058	26,905	3,590	25,951	228	897	53,981
Annual Maximum:	1,771	30,874	54,758	32,701	455	6,915	70,946	44,273	54,808	25,951	228	897	71,349
Monthly Minimum:	47	628	(2,161)	2,725	35	535	3,979	288	(5,317)	2,163	18	69	2,546
Monthly Maximum:	350	6,911	20,057	2,725	39	587	10,262	10,447	22,085	2,163	19	76	12,705
Monthly Average:	123	2,117	2,725	2,725	38	576	5,456	2,867	2,163	2,163	19	75	5,123

Notes:
(1) Annual flows

Source: WAR 1991

Appendix A.

Year	Subbasin: MARLBED						Subbasin: SALTCRK						Subbasin:
	RO Surface Runoff (acre-ft)	I Infil-tration (acre-ft)	SEEP Bank Seepage Inflow (acre-ft)	ST Septic Tank Inflows (acre-ft)	STP WWTP Inflows (acre-ft)	Net Subbasin Inflow (acre-ft)	RO Surface Runoff (acre-ft)	I Infil-tration (acre-ft)	SEEP Bank Seepage Inflow (acre-ft)	ST Septic Tank Inflows (acre-ft)	STP WWTP Inflows (acre-ft)	Net Subbasin Inflow (acre-ft)	RO Surface Runoff (acre-ft)
Annual Totals or Averages (1)													
1980	1,351	578	594	105	0	2,049	6,333	2,145	1,921	210	0	8,463	7,255
1981	1,243	217	594	105	0	1,942	5,631	(311)	1,921	210	0	7,761	6,706
1982	1,663	1,629	594	105	0	2,362	7,833	7,453	1,921	210	0	9,963	8,927
1983	1,733	1,864	594	105	0	2,432	8,212	8,765	1,921	210	0	10,342	9,295
1984	1,361	613	594	105	0	2,060	6,255	1,866	1,921	210	0	8,385	7,329
1985	1,259	269	594	105	0	1,958	5,802	293	1,921	210	0	7,932	6,775
1986	1,259	268	594	105	0	1,957	5,758	151	1,921	210	0	7,889	6,780
1987	1,334	523	594	105	0	2,033	6,068	1,247	1,921	210	0	8,198	7,193
1988	1,551	1,253	594	105	0	2,250	7,317	5,608	1,921	210	0	9,447	8,326
1989	1,088	(305)	594	105	0	1,787	4,910	(2,859)	1,921	210	0	7,040	5,874
1990	1,067	(377)	594	105	0	1,766	4,808	(3,230)	1,921	210	0	6,938	5,758
Annual and Monthly Means and Extremes													
Annual Average:	1,355	594	594	105	0	2,054	6,266	1,921	1,921	210	0	8,396	7,293
Annual Minimum:	1,067	(377)	594	105	0	1,766	4,808	(3,230)	1,921	210	0	6,938	5,758
Annual Maximum:	1,733	1,864	594	105	0	2,432	8,212	8,765	1,921	210	0	10,342	9,295
Monthly Minimum:	14	(278)	49	8	0	72	18	(1,690)	160	16	0	196	81
Monthly Maximum:	406	949	49	9	0	465	1,968	4,768	160	18	0	2,146	2,175
Monthly Average:	113	49	49	9	0	171	522	160	160	17	0	700	608

Notes:
(1) Annual flows

Source: WAR 1991

Appendix A.

Year	SANFDAVE					Subbasin: SWEETCRK							
	I Infil-tration (acre-ft)	SEEP Bank Seepage Inflow (acre-ft)	ST Septic Tank Inflows (acre-ft)	STP WWTP Inflows (acre-ft)	Net Subbasin Inflow (acre-ft)	RO Surface Runoff (acre-ft)	I Infil-tration (acre-ft)	SEEP Bank Seepage Inflow (acre-ft)	ST Septic Tank Inflows (acre-ft)	STP WWTP Inflows (acre-ft)	Net Subbasin Inflow (acre-ft)	ARTES SPFLOW plus LEAK (acre-ft)	PCLJ Direct Precip-itation (acre-ft)
Annual Totals or Averages (1)													
1980	2,036	2,144	271	0	9,670	3,568	447	416	169	0	4,153	4,534	43,008
1981	810	2,144	271	0	9,122	3,226	(338)	416	169	0	3,810	4,556	38,095
1982	5,920	2,144	271	0	11,342	4,404	2,368	416	169	0	4,989	4,383	53,225
1983	6,707	2,144	271	0	11,710	4,604	2,824	416	169	0	5,189	4,393	55,837
1984	2,183	2,144	271	0	9,744	3,558	422	416	169	0	4,143	4,434	42,386
1985	978	2,144	271	0	9,190	3,296	(176)	416	169	0	3,880	4,431	39,330
1986	1,017	2,144	271	0	9,195	3,282	(205)	416	169	0	3,867	4,484	39,001
1987	1,972	2,144	271	0	9,608	3,469	223	416	169	0	4,054	4,448	41,071
1988	4,479	2,144	271	0	10,741	4,111	1,692	416	169	0	4,696	4,457	49,724
1989	(1,114)	2,144	271	0	8,289	2,818	(1,275)	416	169	0	3,402	4,512	33,200
1990	(1,407)	2,144	271	0	8,173	2,761	(1,408)	416	169	0	3,345	4,535	32,507
Annual and Monthly Means and Extremes													
Annual Average:	2,144	2,144	271	0	9,708	3,554	416	416	169	0	4,139	4,470	42,490
Annual Minimum:	(1,407)	2,144	271	0	8,173	2,761	(1,408)	416	169	0	3,345	4,383	32,507
Annual Maximum:	6,707	2,144	271	0	11,710	4,604	2,824	416	169	0	5,189	4,556	55,837
Monthly Minimum:	(995)	179	21	0	283	23	(606)	35	13	0	72	336	89
Monthly Maximum:	3,353	179	23	0	2,377	1,093	1,683	35	14	0	1,142	392	13,415
Monthly Average:	179	179	23	0	809	296	35	35	14	0	345	372	3,541

Notes:
(1) Annual flows

Source: WAR 1991

Appendix A.

Year	Inflow Volumes:								Outflow Volumes:					
	RO Surface Runoff (acre-ft)	I Infil-tration (acre-ft)	SEEP Bank Seepage Inflow (acre-ft)	ST Septic Tank Inflows (acre-ft)	STP WWTP Inflows (acre-ft)	ST + STP Septic Tk and WWTP Effluent (acre-ft)	SJRIN Inflow from SJ River (acre-ft)	Total Inflows to Lake (acre-ft)	EVLJ Surface Evapor-ation (acre-ft)	SJROUT Discharge to SJ River (acre-ft)	Total Outflows from Lake (acre-ft)	Surface Discharge to SJ River (cfs)	ARTES SPFLOW plus LEAK	PCLJ Direct Precip-itation
Annual Totals or Averages (1)														
1980	94,390	64,794	68,060	1,968	7,812	9,780	0	219,771	46,017	178,409	224,426	245	2.33%	17.68%
1981	87,785	46,365	68,060	1,968	7,812	9,780	0	208,276	45,811	166,585	212,396	230	2.54%	15.67%
1982	116,048	132,350	68,060	1,968	7,812	9,780	0	251,495	41,749	201,929	243,677	279	2.16%	18.23%
1983	120,703	145,500	68,060	1,968	7,812	9,780	0	258,772	43,101	210,379	253,480	290	1.85%	20.48%
1984	95,691	69,474	68,060	1,968	7,812	9,780	2,099	222,450	46,655	175,115	221,770	240	2.45%	15.71%
1985	88,417	47,693	68,060	1,968	7,812	9,780	9,060	219,077	45,388	161,705	207,093	211	2.47%	15.60%
1986	88,594	49,004	68,060	1,968	7,812	9,780	2,478	212,397	44,430	183,339	227,770	248	2.34%	16.62%
1987	94,089	66,491	68,060	1,968	7,812	9,780	8,770	226,219	43,542	162,544	206,086	211	2.23%	16.15%
1988	108,205	107,046	68,060	1,968	7,812	9,780	6,829	247,055	44,793	220,492	265,285	294	1.99%	18.64%
1989	76,935	12,501	68,060	1,968	7,812	9,780	3,136	195,622	47,583	146,832	194,415	198	2.62%	14.74%
1990	75,435	7,437	68,060	1,968	7,812	9,780	0	190,317	48,703	148,553	197,257	205	2.63%	15.12%
Annual and Monthly Means and Extremes														
Annual Average:	95,117	68,060	68,060	1,968	7,812	9,780	2,943	222,859	45,252	177,807	223,059	241	2.33%	16.78%
Annual Minimum:	75,435	7,437	68,060	1,968	7,812	9,780	0	190,317	41,749	146,832	194,415	198	1.85%	14.74%
Annual Maximum:	120,703	145,500	68,060	1,968	7,812	9,780	9,060	258,772	48,703	220,492	265,285	294	2.63%	20.48%
Monthly Minimum:	1,186	(13,686)	5,672	152	604	756	0	8,152	1,060	0	1,361	(152)	0.79%	1.00%
Monthly Maximum:	28,131	61,211	5,672	167	663	830	9,060	48,430	7,323	37,733	43,443	614	4.64%	27.70%
Monthly Average:	7,926	5,672	5,672	164	651	815	245	18,572	3,771	14,817	18,588	241	2.33%	16.78%

Notes:
(1) Annual flows

Source: WAR 1991

Appendix A.

Year	Inflow Percentages: RO Surface Runoff	SEEP Bank Seepage Inflow	ST Septic Tank Inflows	STP WWTP Inflows	SJRIN Inflow from SJ River	Total Inflows to Lake	Outflow Percentages: EVLJ Surface Evapor-ation	SJROUT Discharge to SJ River	Total Outflows from Lake
Annual Totals or Averages (1)									
1980	39.93%	35.04%	1.01%	4.01%	0.00%	100.00%	20.61%	79.39%	100.00%
1981	38.39%	37.94%	1.10%	4.36%	0.00%	100.00%	29.06%	70.94%	100.00%
1982	41.42%	33.39%	0.96%	3.83%	0.00%	100.00%	18.62%	81.38%	100.00%
1983	44.92%	28.62%	0.83%	3.29%	0.00%	100.00%	17.70%	82.30%	100.00%
1984	37.72%	37.51%	1.09%	4.31%	1.22%	100.00%	31.24%	68.76%	100.00%
1985	36.89%	37.82%	1.09%	4.33%	1.79%	100.00%	31.16%	68.84%	100.00%
1986	39.04%	35.63%	1.03%	4.07%	1.27%	100.00%	26.27%	73.73%	100.00%
1987	38.49%	34.11%	0.99%	3.92%	4.12%	100.00%	28.16%	71.84%	100.00%
1988	41.41%	30.55%	0.88%	3.49%	3.05%	100.00%	22.52%	77.48%	100.00%
1989	36.00%	39.56%	1.15%	4.55%	1.39%	100.00%	30.02%	69.98%	100.00%
1990	36.87%	39.70%	1.14%	4.54%	0.00%	100.00%	27.43%	72.57%	100.00%
Annual and Monthly Means and Extremes									
Annual Average:	39.19%	35.44%	1.02%	4.06%	1.17%	100.00%	25.71%	74.29%	100.00%
Annual Minimum:	36.00%	28.62%	0.83%	3.29%	0.00%	100.00%	17.70%	68.76%	100.00%
Annual Maximum:	44.92%	39.70%	1.15%	4.55%	4.12%	100.00%	31.24%	82.30%	100.00%
Monthly Minimum:	11.13%	11.71%	0.34%	1.37%	0.00%	100.00%	3.83%	0.00%	100.00%
Monthly Maximum:	58.09%	69.57%	2.05%	8.13%	49.40%	100.00%	100.00%	96.17%	100.00%
Monthly Average:	39.19%	35.44%	1.02%	4.06%	1.17%	100.00%	25.71%	74.29%	100.00%

Notes:
(1) Annual flows

Source: WAR 1991

APPENDIX B

Lake Jessup Nutrient Budget Results for the Years 1980 Through 1990
With Averages and Extremes for Years and Months

Appendix B. Nitrogen and Phosphorus Budgets Summaries for Lake Jessup for the Years 1980 through 1990 with Period of Record Monthly and Annual Means and Extremes.

Year	Direct Rainfall: Total Nitrogen (tons N)	Direct Rainfall: Total Phosphorus (tons P)	Artesian Inflows: Total Nitrogen (tons N)	Artesian Inflows: Total Phosphorus (tons P)	Surface Runoff Loading: Total Nitrogen: Subbasin AIRPORT (tons N)	Subbasin BLACKHMK (tons N)	Subbasin EUREKA (tons N)	Subbasin GEESOLD (tons N)	Subbasin HOWELL (tons N)	Subbasin MARLBED (tons N)	Subbasin SALTCRK (tons N)	Subbasin SANFDAVE (tons N)	Subbasin SWEETCRK (tons N)	Total Tributary Loading (tons N)
Annual Totals or Averages (1)														
1980	93.56	10.53	5.12	0.99	27.43	50.02	2.54	44.83	74.86	2.91	0.87	15.60	8.09	224.57
1981	82.88	9.32	5.14	0.99	24.90	45.74	2.34	44.15	68.30	2.68	0.87	14.42	7.32	188.11
1982	115.79	13.03	4.95	0.95	33.84	61.64	3.13	54.67	92.28	3.58	0.87	19.19	9.99	249.14
1983	121.47	13.67	4.96	0.96	35.35	64.31	3.26	56.25	96.32	3.73	0.87	19.98	10.44	259.21
1984	92.21	10.37	5.00	0.96	27.42	50.21	2.56	47.02	75.05	2.93	0.87	15.75	8.07	205.19
1985	85.56	9.63	5.00	0.96	25.39	46.46	2.37	43.23	69.46	2.71	0.87	14.56	7.47	189.62
1986	84.85	9.55	5.06	0.98	25.31	46.39	2.37	43.84	69.32	2.71	0.87	14.57	7.44	189.94
1987	89.35	10.05	5.02	0.97	26.77	49.13	2.51	47.01	73.37	2.87	0.87	15.46	7.87	201.66
1988	108.17	12.17	5.03	0.97	31.58	57.51	2.92	50.85	86.11	3.34	0.87	17.90	9.32	232.32
1989	72.23	8.13	5.09	0.98	21.76	40.01	2.05	38.94	59.73	2.34	0.87	12.63	6.39	164.83
1990	70.72	7.96	5.12	0.99	21.32	39.21	2.01	38.24	58.53	2.30	0.87	12.38	6.26	161.61
Annual and Monthly Means and Extremes														
Annual Average:	92.44	10.40	5.04	0.97	27.37	50.06	2.55	46.28	74.85	2.92	0.87	15.68	8.06	206.02
Annual Minimum:	70.72	7.96	4.95	0.95	21.32	39.21	2.01	38.24	58.53	2.30	0.87	12.38	6.26	161.61
Annual Maximum:	121.47	13.67	5.14	0.99	35.35	64.31	3.26	56.25	96.32	3.73	0.87	19.98	10.44	259.21
Monthly Minimum:	0.19	0.02	0.38	0.07	0.20	0.44	0.03	1.15	0.63	0.03	0.07	0.18	0.05	2.47
Monthly Maximum:	29.18	3.28	0.44	0.09	8.37	15.15	0.76	12.59	22.73	0.88	0.07	4.68	2.48	60.48
Monthly Average:	7.70	0.87	0.42	0.08	2.28	4.17	0.21	3.86	6.24	0.24	0.07	1.31	0.67	17.17

Notes:
(1) Annual flows are sums of the monthly values, Annual storages are averages of the monthly values

Source: WAR 1991

Appendix B.

Year	Surface Runoff Loading: Total Phosphorus: Subbasin AIRPORT (tons P)	Subbasin BLACKHMK (tons P)	Subbasin EUREKA (tons P)	Subbasin GEESOLD (tons P)	Subbasin HOWELL (tons P)	Subbasin MARLBED (tons P)	Subbasin SALTCRK (tons P)	Subbasin SANFDAVE (tons P)	Subbasin SWEETCRK (tons P)	Total Tributary Loading (tons P)	Septic Tank Loading: Total Nitrogen: Subbasin AIRPORT (tons N)	Subbasin BLACKHMK (tons N)	Subbasin EUREKA (tons N)	Subbasin GEESOLD (tons N)
Annual Totals or Averages (1)														
1980	3.459	7.317	0.321	4.918	9.685	0.336	0.088	1.805	0.932	28.861	24.04	7.89	7.89	34.24
1981	3.139	6.691	0.295	4.844	8.836	0.309	0.088	1.669	0.842	26.714	24.04	7.89	7.89	34.24
1982	4.266	9.016	0.395	5.998	11.939	0.414	0.088	2.221	1.150	35.487	24.04	7.89	7.89	34.24
1983	4.457	9.406	0.411	6.171	12.461	0.431	0.088	2.313	1.202	36.940	24.04	7.89	7.89	34.24
1984	3.457	7.345	0.323	5.158	9.710	0.339	0.088	1.824	0.929	29.172	24.04	7.89	7.89	34.24
1985	3.201	6.797	0.299	4.743	8.986	0.313	0.088	1.686	0.860	26.973	24.04	7.89	7.89	34.24
1986	3.191	6.786	0.299	4.810	8.968	0.313	0.088	1.687	0.857	26.998	24.04	7.89	7.89	34.24
1987	3.375	7.186	0.317	5.157	9.493	0.332	0.088	1.790	0.906	28.643	24.04	7.89	7.89	34.24
1988	3.982	8.413	0.368	5.579	11.141	0.386	0.088	2.072	1.073	33.101	24.04	7.89	7.89	34.24
1989	2.744	5.853	0.259	4.271	7.727	0.271	0.088	1.461	0.736	23.410	24.04	7.89	7.89	34.24
1990	2.689	5.736	0.254	4.194	7.573	0.265	0.088	1.433	0.721	22.952	24.04	7.89	7.89	34.24
Annual and Monthly Means and Extremes														
Annual Average:	3.451	7.322	0.322	5.077	9.683	0.337	0.088	1.815	0.928	29.023	24.04	7.89	7.89	34.24
Annual Minimum:	2.689	5.736	0.254	4.194	7.573	0.265	0.088	1.433	0.721	22.952	24.04	7.89	7.89	34.24
Annual Maximum:	4.457	9.406	0.411	6.171	12.461	0.431	0.088	2.313	1.202	36.940	24.04	7.89	7.89	34.24
Monthly Minimum:	0.025	0.065	0.003	0.126	0.081	0.003	0.007	0.020	0.006	0.337	1.86	0.61	0.61	2.65
Monthly Maximum:	1.055	2.216	0.096	1.381	2.940	0.101	0.007	0.541	0.285	8.624	2.04	0.67	0.67	2.91
Monthly Average:	0.288	0.610	0.027	0.423	0.807	0.028	0.007	0.151	0.077	2.419	2.00	0.66	0.66	2.85

Notes:
(1) Annual flow

Source: WAR 1991

Appendix B.

Year	Subbasin HOWELL (tons N)	Subbasin MARLBED (tons N)	Subbasin SALTCRK (tons N)	Subbasin SANFDAVE (tons N)	Subbasin SWEETCRK (tons N)	Total Septic Tank Loading (tons N)	WWTP Loading: Total Nitrogen: Subbasin GEESOLD (tons N)	Subbasin HOWELL (tons N)	Total WWTP Loading (tons N)	Bank Seepage Loading: Total Nitrogen: Subbasin AIRPORT (tons N)	Subbasin BLACKHMK (tons N)	Subbasin EUREKA (tons N)	Subbasin GEESOLD (tons N)	Subbasin HOWELL (tons N)
Annual Totals or Averages (1)														
1980	17.15	7.89	15.77	20.40	12.71	147.98	163.61	21.22	184.82	6.21	3.23	0.80	67.23	74.56
1981	17.15	7.89	15.77	20.40	12.71	147.98	163.61	21.22	184.82	6.21	3.23	0.80	67.23	74.56
1982	17.15	7.89	15.77	20.40	12.71	147.98	163.61	21.22	184.82	6.21	3.23	0.80	67.23	74.56
1983	17.15	7.89	15.77	20.40	12.71	147.98	163.61	21.22	184.82	6.21	3.23	0.80	67.23	74.56
1984	17.15	7.89	15.77	20.40	12.71	147.98	163.61	21.22	184.82	6.21	3.23	0.80	67.23	74.56
1985	17.15	7.89	15.77	20.40	12.71	147.98	163.61	21.22	184.82	6.21	3.23	0.80	67.23	74.56
1986	17.15	7.89	15.77	20.40	12.71	147.98	163.61	21.22	184.82	6.21	3.23	0.80	67.23	74.56
1987	17.15	7.89	15.77	20.40	12.71	147.98	163.61	21.22	184.82	6.21	3.23	0.80	67.23	74.56
1988	17.15	7.89	15.77	20.40	12.71	147.98	163.61	21.22	184.82	6.21	3.23	0.80	67.23	74.56
1989	17.15	7.89	15.77	20.40	12.71	147.98	163.61	21.22	184.82	6.21	3.23	0.80	67.23	74.56
1990	17.15	7.89	15.77	20.40	12.71	147.98	163.61	21.22	184.82	6.21	3.23	0.80	67.23	74.56
Annual and Monthly Means and Extremes														
Annual Average:	17.15	7.89	15.77	20.40	12.71	147.98	163.61	21.22	184.82	6.21	3.23	0.80	67.23	74.56
Annual Minimum:	17.15	7.89	15.77	20.40	12.71	147.98	163.61	21.22	184.82	6.21	3.23	0.80	67.23	74.56
Annual Maximum:	17.15	7.89	15.77	20.40	12.71	147.98	163.61	21.22	184.82	6.21	3.23	0.80	67.23	74.56
Monthly Minimum:	1.33	0.61	1.22	1.58	0.98	11.45	12.65	1.64	14.30	0.52	0.27	0.07	5.60	6.21
Monthly Maximum:	1.46	0.67	1.34	1.73	1.08	12.56	13.89	1.80	15.69	0.52	0.27	0.07	5.60	6.21
Monthly Average:	1.43	0.66	1.31	1.70	1.06	12.33	13.63	1.77	15.40	0.52	0.27	0.07	5.60	6.21

Notes:
(1) Annual flow

Source: WAR 1991

Appendix B.

Year	Subbasin MARLBED (tons N)	Subbasin SALTCRK (tons N)	Subbasin SANFDAVE (tons N)	Subbasin SWEETCRK (tons N)	Total Bank Seepage Loading (tons N)	Bank Seepage Loading: Total Phosphorus: Subbasin AIRPORT (tons P)	Subbasin BLACKHMK (tons P)	Subbasin EUREKA (tons P)	Subbasin GEESOLD (tons P)	Subbasin HOWELL (tons P)	Subbasin MARLBED (tons P)	Subbasin SALTCRK (tons P)	Subbasin SANFDAVE (tons P)	Subbasin SWEETCRK (tons P)
Annual Totals or Averages (1)														
1980	1.28	4.01	4.61	0.94	162.86	0.783	0.245	0.101	5.646	11.397	0.148	0.407	0.533	0.109
1981	1.28	4.01	4.61	0.94	162.86	0.783	0.245	0.101	5.646	11.397	0.148	0.407	0.533	0.109
1982	1.28	4.01	4.61	0.94	162.86	0.783	0.245	0.101	5.646	11.397	0.148	0.407	0.533	0.109
1983	1.28	4.01	4.61	0.94	162.86	0.783	0.245	0.101	5.646	11.397	0.148	0.407	0.533	0.109
1984	1.28	4.01	4.61	0.94	162.86	0.783	0.245	0.101	5.646	11.397	0.148	0.407	0.533	0.109
1985	1.28	4.01	4.61	0.94	162.86	0.783	0.245	0.101	5.646	11.397	0.148	0.407	0.533	0.109
1986	1.28	4.01	4.61	0.94	162.86	0.783	0.245	0.101	5.646	11.397	0.148	0.407	0.533	0.109
1987	1.28	4.01	4.61	0.94	162.86	0.783	0.245	0.101	5.646	11.397	0.148	0.407	0.533	0.109
1988	1.28	4.01	4.61	0.94	162.86	0.783	0.245	0.101	5.646	11.397	0.148	0.407	0.533	0.109
1989	1.28	4.01	4.61	0.94	162.86	0.783	0.245	0.101	5.646	11.397	0.148	0.407	0.533	0.109
1990	1.28	4.01	4.61	0.94	162.86	0.783	0.245	0.101	5.646	11.397	0.148	0.407	0.533	0.109
Annual and Monthly Means and Extremes														
Annual Average:	1.28	4.01	4.61	0.94	162.86	0.783	0.245	0.101	5.646	11.397	0.148	0.407	0.533	0.109
Annual Minimum:	1.28	4.01	4.61	0.94	162.86	0.783	0.245	0.101	5.646	11.397	0.148	0.407	0.533	0.109
Annual Maximum:	1.28	4.01	4.61	0.94	162.86	0.783	0.245	0.101	5.646	11.397	0.148	0.407	0.533	0.109
Monthly Minimum:	0.11	0.33	0.38	0.08	13.57	0.065	0.020	0.008	0.470	0.950	0.012	0.034	0.044	0.009
Monthly Maximum:	0.11	0.33	0.38	0.08	13.57	0.065	0.020	0.008	0.470	0.950	0.012	0.034	0.044	0.009
Monthly Average:	0.11	0.33	0.38	0.08	13.57	0.065	0.020	0.008	0.470	0.950	0.012	0.034	0.044	0.009

Notes:
(1) Annual flow

Source: WAR 1991

Appendix B.

Year	Total Bank Seepage Loading (tons P)	Total Nitrogen Sources: Direct Rainfall (tons N)	Artesian Inflows (tons N)	Surface Runoff (tons N)	Bank Seepage (tons N)	Septic Tanks (tons N)	WWTPs (tons N)	Septic Tanks + WWTPs (tons N)	Inflow from SJ River (tons N)	Total Loading (tons N)	Total Nitrogen Sources: Percentages of Total Loading: Direct Rainfall (%)	Artesian Inflows (%)	Surface Runoff (%)	Bank Seepage (%)
Annual Totals or Averages (1)														
1980	19.368	93.56	5.12	224.57	162.86	147.98	184.82	332.81	0.00	818.92	10.49%	0.65%	25.50%	20.84%
1981	19.368	82.88	5.14	188.11	162.86	147.98	184.82	332.81	0.00	771.80	9.49%	0.70%	22.23%	22.20%
1982	19.368	115.79	4.95	249.14	162.86	147.98	184.82	332.81	0.00	865.55	11.78%	0.62%	25.86%	20.30%
1983	19.368	121.47	4.96	259.21	162.86	147.98	184.82	332.81	0.00	881.31	13.13%	0.58%	28.24%	19.07%
1984	19.368	92.21	5.00	205.19	162.86	147.98	184.82	332.81	4.37	802.45	9.72%	0.67%	22.33%	21.90%
1985	19.368	85.56	5.00	189.62	162.86	147.98	184.82	332.81	18.85	794.70	9.47%	0.68%	21.57%	22.01%
1986	19.368	84.85	5.06	189.94	162.86	147.98	184.82	332.81	5.16	780.67	9.96%	0.67%	22.72%	21.70%
1987	19.368	89.35	5.02	201.66	162.86	147.98	184.82	332.81	18.24	809.95	9.91%	0.65%	22.89%	21.09%
1988	19.368	108.17	5.03	232.32	162.86	147.98	184.82	332.81	14.21	855.40	11.83%	0.61%	25.69%	19.79%
1989	19.368	72.23	5.09	164.83	162.86	147.98	184.82	332.81	6.52	744.34	8.76%	0.71%	20.51%	22.74%
1990	19.368	70.72	5.12	161.61	162.86	147.98	184.82	332.81	0.00	733.12	8.81%	0.72%	20.65%	22.98%
Annual and Monthly Means and Extremes														
Annual Average:	19.368	92.44	5.04	206.02	162.86	147.98	184.82	332.81	6.12	805.29	10.30%	0.66%	23.47%	21.33%
Annual Minimum:	19.368	70.72	4.95	161.61	162.86	147.98	184.82	332.81	0.00	733.12	8.76%	0.58%	20.51%	19.07%
Annual Maximum:	19.368	121.47	5.14	259.21	162.86	147.98	184.82	332.81	18.85	881.31	13.13%	0.72%	28.24%	22.98%
Monthly Minimum:	1.614	0.19	0.38	2.47	13.57	11.45	14.30	25.74	0.00	44.56	0.43%	0.33%	5.50%	10.29%
Monthly Maximum:	1.614	29.18	0.44	60.48	13.57	12.56	15.69	28.25	18.85	131.91	22.12%	0.96%	45.85%	30.46%
Monthly Average:	1.614	7.70	0.42	17.17	13.57	12.33	15.40	27.73	0.51	67.11	10.30%	0.66%	23.47%	21.33%

Notes:
(1) Annual flow

Source: WAR 1991

Appendix B.

Year	Septic Tanks (%)	WWTPs (%)	Septic Tanks + WWTPs (%)	Inflow from SJ River (%)	Total Loading (%)	Total Phosphorus Sources: Direct Rainfall (tons P)	Artesian Inflows (tons P)	Surface Runoff (tons P)	Bank Seepage (tons P)	Inflow from SJ River (tons P)	Total Loading (tons P)	Total Phosphorus Sources: Percentages of Total Loading: Direct Rainfall (%)	Artesian Inflows (%)	Surface Runoff (%)
Annual Totals or Averages (1)														
1980	18.91%	23.61%	45.52%	0.00%	100.00%	10.53	0.99	28.86	19.37	0.00	59.74	15.92%	1.89%	44.91%
1981	20.18%	25.21%	45.39%	0.00%	100.00%	9.32	0.99	26.71	19.37	0.00	56.40	14.14%	2.09%	43.07%
1982	18.43%	23.02%	41.45%	0.00%	100.00%	13.03	0.95	35.49	19.37	0.00	68.84	16.31%	1.76%	46.31%
1983	17.34%	21.65%	38.99%	0.00%	100.00%	13.67	0.96	36.94	19.37	0.00	70.93	18.31%	1.49%	50.21%
1984	19.90%	24.86%	44.76%	0.63%	100.00%	10.37	0.96	29.17	19.37	0.31	60.19	14.21%	2.02%	42.49%
1985	19.98%	24.95%	44.93%	1.35%	100.00%	9.63	0.96	26.97	19.37	1.36	58.29	14.25%	2.03%	41.95%
1986	19.67%	24.57%	44.24%	0.70%	100.00%	9.55	0.98	27.00	19.37	0.37	57.26	15.09%	1.91%	44.12%
1987	19.16%	23.93%	43.09%	2.37%	100.00%	10.05	0.97	28.64	19.37	1.31	60.34	14.57%	1.85%	43.42%
1988	17.92%	22.38%	40.29%	1.79%	100.00%	12.17	0.97	33.10	19.37	1.02	66.63	16.78%	1.63%	46.75%
1989	20.66%	25.81%	46.47%	0.81%	100.00%	8.13	0.98	23.41	19.37	0.47	52.35	13.43%	2.17%	40.78%
1990	20.83%	26.02%	46.85%	0.00%	100.00%	7.96	0.99	22.95	19.37	0.00	51.26	13.71%	2.16%	41.55%
Annual and Monthly Means and Extremes														
Annual Average:	19.36%	24.18%	43.54%	0.70%	100.00%	10.40	0.97	29.02	19.37	0.44	60.20	15.16%	1.91%	44.14%
Annual Minimum:	17.34%	21.65%	38.99%	0.00%	100.00%	7.96	0.95	22.95	19.37	0.00	51.26	13.43%	1.49%	40.78%
Annual Maximum:	20.83%	26.02%	46.85%	2.37%	100.00%	13.67	0.99	36.94	19.37	1.36	70.93	18.31%	2.17%	50.21%
Monthly Minimum:	9.52%	11.89%	21.41%	0.00%	100.00%	0.02	0.07	0.34	1.61	0.00	2.05	1.06%	0.61%	15.51%
Monthly Maximum:	27.97%	34.93%	62.90%	28.48%	100.00%	3.28	0.09	8.62	1.61	1.36	13.60	24.13%	3.99%	63.39%
Monthly Average:	19.36%	24.18%	43.54%	0.70%	100.00%	0.87	0.08	2.42	1.61	0.04	5.02	15.16%	1.91%	44.14%

Notes:
(1) Annual flow

Source: WAR 1991

Appendix B.

Year	Bank Seepage (%)	Inflow from SJ River (%)	Total Loading (%)	Lake Jessup Water Quality: Total Nitrogen Conc (mg/L)	Total Phosphorus Conc (mg/L)	Lake Jessup Export to St. Johns River Total Nitrogen (tons N)	Total Phosphorus (tons P)	Lake Jessup Dinitrification to Atmos. (tons N)	N Export: Total Nitrogen Outflows (tons N)	Lake Jesup Water Nutrient Pool: Total Nitrogen (tons N)	Total Phosphorus (tons P)	Lake Jessup Sediment Nutrient Flux Total Nitrogen (tons N)	Total Phosphorus (tons P)
Annual Totals or Averages (1)													
1980	37.29%	0.00%	100.00%	3.15	0.28	764.12	68.89	33.29	797.41	150.03	13.53	41.44	-7.35
1981	40.71%	0.00%	100.00%	3.15	0.28	713.48	64.33	33.29	746.77	140.22	12.64	42.68	-6.34
1982	35.62%	0.00%	100.00%	3.15	0.28	864.86	77.97	33.29	898.15	223.95	20.19	-66.09	-12.16
1983	30.00%	0.00%	100.00%	3.12	0.33	861.13	97.16	33.29	894.42	216.28	22.64	79.34	-39.72
1984	40.54%	0.74%	100.00%	3.05	0.26	780.95	60.37	33.29	814.24	183.39	15.67	-99.83	12.51
1985	40.70%	1.07%	100.00%	2.76	0.21	565.88	42.74	33.29	599.17	161.02	13.95	244.72	18.50
1986	38.11%	0.77%	100.00%	2.88	0.44	671.81	99.53	33.29	705.10	159.37	24.51	-80.55	-64.29
1987	37.13%	3.03%	100.00%	4.64	0.39	1036.36	86.43	33.29	1069.65	280.92	22.55	-393.44	-9.54
1988	32.78%	2.06%	100.00%	4.01	0.30	1258.10	85.28	33.29	1291.39	237.79	17.01	-119.99	-12.44
1989	42.79%	0.84%	100.00%	4.47	0.33	908.28	63.99	33.29	941.57	219.71	16.71	-310.05	-23.94
1990	42.58%	0.00%	100.00%	4.97	0.43	1026.69	85.89	33.29	1059.98	231.77	20.21	-334.79	-32.43
Annual and Monthly Means and Extremes													
Annual Average:	38.02%	0.77%	100.00%	3.58	0.32	859.24	75.69	33.29	892.53	200.40	18.15	-90.60	-16.11
Annual Minimum:	30.00%	0.00%	100.00%	2.76	0.21	565.88	42.74	33.29	599.17	140.22	12.64	-393.44	-64.29
Annual Maximum:	42.79%	3.03%	100.00%	4.97	0.44	1258.10	99.53	33.29	1291.39	280.92	24.51	244.72	18.50
Monthly Minimum:	11.86%	0.00%	100.00%	1.28	0.00	0.00	0.00	2.57	2.73	77.13	0.09	-172.85	-42.84
Monthly Maximum:	78.55%	36.38%	100.00%	6.86	1.12	241.24	23.46	2.83	244.06	407.50	65.41	188.24	23.51
Monthly Average:	38.02%	0.77%	100.00%	3.58	0.32	71.60	6.31	2.77	74.38	200.40	18.15	-7.55	-1.34

Notes:
(1) Annual flow

Source: WAR 1991

Appendix B.

Year	Lake Jessup Sediment Nutrient Pool: Total Nitrogen (tons N)	Total Phosphorus (tons P)
Annual Totals or Averages (1)		
1980	82844	2674
1981	82901	2668
1982	82857	2657
1983	82797	2640
1984	82822	2627
1985	82886	2633
1986	83101	2619
1987	82761	2570
1988	82380	2560
1989	82222	2548
1990	81862	2515
Annual and Monthly Means and Extremes		
Annual Average:	82676	2610
Annual Minimum:	81862	2515
Annual Maximum:	83101	2674
Monthly Minimum:	81786	2501
Monthly Maximum:	83213	2677
Monthly Average:	82676	2610

Notes:
(1) Annual flow

Source: WAR 1991