DRE-45

LAKE OKEECHOBEE - KISSIMMEE BASIN
PROPOSALS FOR MANAGEMENT ACTIONS

CENTRAL AND SOUTHERN FLORIDA FLOOD
CONTROL DISTRICT

MARCH 20, 1975

INTRODUCTION:

In November, 1972, at the request of the Governor and Cabinet, the Governing Board of the Central and Southern Florida Flood Control District held a public hearing on the Kissimmee River Basin at West Palm Beach. The Board reported its findings of fact and recommendations to the Governor and Cabinet on December 12, 1972.

Its first three recommendations, which were adopted by the Governor and Cabinet, are listed below:

> "1. A program should be immediately initiated to correct existing pollution sources in the Kissimmee Basin. Adequate restrictions should be placed on any new facilities which will discharge into the waters of the basin.
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> "2. A program should be initiated to plan and control all land and water use activities in the basin. Particular emphasis should be given to treatment of agricultural and urban runoff, sewage effluent, and industrial discharges. Acceleration of land and water use planning and control within the State plan is mandatory.
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> "3. It is essential to implement the first two (2) recommendations above, before or concurrent with, further restoration of the Kissimmee marshes, beyond that recommended by the Flood Control District staff. A study should be initiated to determine if additional restoration will be needed and to what extent. In this connection, it is recommended that an inter-disciplinary team be established to assist in making such determinations. In conjunction with the study, and as a part of it, there should be an extensive monitoring program of water quality in the Kissimmee Basin and Lake Okeechobee to determine the effectiveness of pollution control at the source and land and water use regulations."

Recommendation No. 3 consists of two parts. The first part concerns the seasonal reflooding of additional areas of flood-plain upstream of four of the five water level control structures in C-38. This portion of the recommendation based on staff studies and recommendations had been adopted by the Board as a District program several months prior to the public hearing.

The second part of Recommendation No. 3 proposed that no further action be taken beyond the seasonal reflooding of a larger portion of the original river flood plain until additional information and knowledge was obtained to substantiate the need for such action. In the opinion of the staff sufficient data and information is now at hand to permit affirmative management actions to be taken which are both rational and supportable.

Certain of these data, in retrospect, was available when the U. S. Geological Survey had completed its study of Lake Okeechobee. That data has, however, been confirmed by the District's studies and, as a result, additional credibility has thereby been developed. In regard to the Kissimmee Basin only limited data has heretofore been available on which to base sound judgments, and the issue here was clouded by opinions, speculation and misuse and misinterpretation of the limited data available. The only soundly-based and documented management proposal was that adopted by the District Governing Board for the seasonal reflooding of an additional 10,000 acres of river floodplain, based on the District's own studies. As with Lake Okeechobee, there is now sufficient data, and understanding of that data, available to proceed with the implementation of management proposals.

SEASONAL REFLOODING OF THE FLOOD PLAIN:

Ecological studies in the marshes of the Kissimmee River have been conducted by the District since 1970. Among the several types of studies, one set involved the experimental manipulation of water levels in the impoundment pools upstream of two of the water level control structures in C-38. As a result of these studies two firm conclusions were reached:

(a) The marshes of the existing impoundments are too shallow; and

(b) The lack of water level fluctuation in the impoundments is detrimental to the marsh ecology.

These particular studies have been reported in the District's Technical Publication No. 74-2, dated March, 1974.

The management action proposed consists of the following:

1. Institution of a seasonal regulation schedule for the pools upstream of Structures 65B, 65C, 65D and 65E calling for a rise to an elevation 2 feet above the present controlled pool stage by mid-October and a drawdown to an elevation 1 foot below controlled stage in mid-May; and

2. Obtaining the right to seasonally reflood the additional 10,000± acres of marsh involved by acquisition or other suitable means.

Raising water levels two feet above present control stage in each impoundment will not only expand the total size of each impoundment; the fluctuating water schedule will also be an attempt to reproduce natural conditions of high and low water periods.

The rising waters flooding the expanded pool marshes will allow survival and growth of the small marsh fishes and other forage organisms necessary for the sport fishery and bird feeding. The falling water levels will concentrate these forage organisms for the enhancement of the fishery and bird feeding opportunity. The drying portion of the fluctuating water cycle will also promote growth of many plant species such as millet and beak-rush of value to waterfowl.

The implementation of this proposal will require raising the elevations of the tops of the spillway structure gates 2 feet. This can be readily accomplished in place by District forces at negligible cost. If acquisition of the additional marsh area is required, special legislation would be needed to permit its acquisition by the District.

Under this proposal the higher stages which would result during the wet season from mid-July to mid-August would have negligible effect on the Upper Basin. If a major storm should occur, the "excess" storage in C-38 and the impoundment pools could be removed in less than 10 hours. A 10-hour delay in discharge from the Upper Basin while this stored water is removed would result in about a 1 inch rise in stage in the Kissimmee-Hatchineha-Cypress group of lakes.

LAKE OKEECHOBEE:

The staff believes that in regard to Lake Okeechobee the time has come to begin to move out of the study phase and into the action phase. However, there must be assurance that action is not taken just for the sake of action. There must be assurance that the action is reasonable in that it conforms with both the needs and the facts. The staff is of the opinion that the need is to reduce the nutrient load which is entering Lake Okeechobee and that the facts are that the principal potentially manageable sources of nutrient loads can be, and have been, identified as: (a) the Taylor Creek/Nubbin Slough

drainage area, (b) the north-central portion of the Everglades Agricultural Area, and (c) the areas in the lower Kissimmee Basin tributary to C-38 pools S-65D and S-65E and below. The affirmative management actions proposed herein are keyed to those facts.

Management actions can address the need only by: (a) reducing nutrient concentrations, (b) reducing inflow volumes, or (c) some combination of reduced concentration and reduced flows. Programs for action can only be of (a) project-type scope, (b) on-the-farm land and water management scope, or (c) some combination of both. The management actions proposed will be considered in these terms.

Taylor Creek/Nubbin Slough Area: the intensified land use in this area together with the configuration of the water-handling system do not make this area susceptible to a project-type approach for either reducing nutrient concentrations or reducing inflow volumes. The approach recommended here is for the introduction and implementation of "on-the-farm" land and water management techniques designed to reduce nutrient concentrations.

This approach was used several years ago in this same area with the active participation and cooperation of the University of Florida Agricultural Extension Service and the SCS, USDA, in the installation of anaerobic lagoons for the handling of dairy barn wastes. The approach was successful in terms of obtaining the cooperation of the operators, although apparently unsuccessful in terms of reduction of pollutant loads.

The staff is not aware of precisely all the on-the-farm measures which might be taken, but among them would be:

1. Re-working of existing drainage systems to provide greater run-off retention.

2. Measures to ensure proper operation and functioning of lagoon systems.

3. Greater dispersion of individual dairy herds.

4. Return of liquid wastes to the land for fertilization of forage crops.

The approach here will require the direct involvement of the University of Florida Agricultural Extension Service and USDA to develop a management plan and to provide education, the USDA to provide funding, and the individual operators in furnishing input to the program and cooperation in its implementation.

North-Central Portion of the Everglades Agricultural Area: the type of agriculture practiced in this area, the water-control needs of that agriculture, and the land values associated with it indicate a project-type approach for this area. Such an approach would be directed principally toward: (a) reducing inflow volumes to Lake Okeechobee, and (b) providing for maximum re-use within the area of runoff water generated on the area.

The proposal here consists of:

1. Removing the "humps" from the Miami and North New River Canals thus permitting a portion of the average annual runoff of 250,000 A.F., to be redirected to the Conservation Areas; and

2. Dedicating the approximately 42 sq.mi. "Holey Land", between the Miami and North New River Canals, to the purpose of storing a portion of the re-directed runoff from the agricultural lands to the north.

The "Holey Land" is State-owned and it is now clear that its use by private interests will not be allowed. The agreement on the part of the State to purchase the Rotenberger Tract for use as a game management area should now make it possible to commit the "Holey Land" to some other beneficial use related to removing a portion of the nutrient load entering the Lake from the Agricultural Area.

The "hump removal" element of this proposal is already an authorized part of the C&SF Project for the purpose of Lake regulation. All that is required here is to give it a higher priority status in the funding schedule for the Project. The support of the Governor and Cabinet, and the Legislature, should ensure that this work attains high priority status.

Although quantitative studies have not yet been made it is estimated that "hump removal" would make it possible to re-direct as much as 70% of the average annual runoff from this area away from the Lake. This would be at the cost of somewhat higher pumping heads for the agricultural interests located near the Lake.

Assuming a "Holey Land" retention area design which would permit by the end of the rainy season the accumulation of 3 to 3.5 feet of runoff water over and above rainfall on the area, about half of the re-directed runoff could be placed into that area. Some 30%-40% of the entire Agricultural Area's average dry season supplemental water demand could be met from this storage, thus providing for an internal re-cycling of this enriched water. Since the same total volume of water will be handled under this proposal as is now being handled, pumping costs (both monetary and energetic) to the District will not be increased.

In addition to the enhancement of its bird feeding values which will result from the introduction of water on an annual basis, additions to this basic proposal can be made which would make the area into a rather excellent sports fishery area.

Once a commitment of this area to this purpose is obtained from the State, the required enlarged levee system, distribution canals and pumping stations can be designed and built within a 3-4 year period.

Downstream Reach of the Lower Kissimmee Valley: land use in this area is similar to that in the Taylor Creek/Nubbin Slough area. Therefore, the same approach (in part) is proposed for this area. In addition, however, the natural configuration of one tributary, the Chandler Slough system, lends itself to the provision of a project-type feature as a part of the overall management program. Both features of the proposal are designed to reduce nutrient concentrations rather than to reduce total outflow from the area.

The proposal with regard to the Chandler Slough area would involve as its project-type element:

1. The maintenance of the lower 1,000± acres of marsh as a viable marsh system, either through acquisition or by other suitable means; and

2. The construction at the C-38 edge of the marsh of a flow regulation system such as to provide under 10-year frequency storm runoff conditions a minimum retention time of five days and a peak discharge rate of 1"/day.

Such a flow regulation system could be designed and built within a period of 18 months. If acquisition of the marsh area is required, special legislation would be needed to permit its acquisition by the District.

A system of this type for Chandler Slough would serve as a prototype for application of this approach at other locations along C-38.

CONCLUSION:

Continued water quality and biological monitoring, data collection, analysis and evaluation, and research is required. The management actions proposed do not mean that these other activities can or should cease. The District has several such programs now underway in and around the Lake and in the Kissimmee Basin, and intends to continue funding this work. Other management proposals will undoubtedly evolve from these programs. The point being made here is that the staff believes that as such studies identify in understandable and supportable fashion specific problems, management action designed to affirmatively address those problems should be taken.

The proposals outlined above constitute a four-part program for affirmative and immediate management action. Each action is individually supportable by factual data which is readily understandable. Together they represent a total package based on a rational and reasonable perception of needs, problem sources, and manageability.

LAKE OKEECHOBEE - KISSIMMEE BASIN WATER QUALITY INFORMATION

CENTRAL AND SOUTHERN FLORIDA FLOOD CONTROL DISTRICT

MARCH 20, 1975

SUMMARY

A nutrient (nitrogen and phosphorus) loading study on Lake Okeechobee for the period January 1969-January 1970 was conducted by the U. S. Geological Survey. A similar nutrient loading study was conducted by the District for the period May 1973-May 1974. Lake Okeechobee water quality data collected in connection with these two studies show that in the span of five years covered there has been no basic change in the Lake's water chemistry.

Both nutrient loading studies showed approximately the same thing with respect to the principal sources of nutrient loads to the Lake. Rainfall is a substantial contributor of both inflow (35%-40%) and nutrients (about 20%) to the Lake. Removing rainfall from consideration because its input is "uncontrollable", the District's study shows that the Kissimmee River with 57% of the inflow contributes 23% of the phosphorus load to the Lake, whereas the Taylor Creek/Nubbin Slough area with 11% of the inflow contributes 43% of the phosphorus load. On the same basis the Kissimmee River contributes 36% of the nitrogen load, while the Everglades Agricultural Area with 14% of the inflow contributes 38% of the nitrogen load.

Since water quality management is a function of the amount of water to be handled, and the land area on which that water is generated, it appears clear that any such management effort should be first applied to those areas where the unit nutrient load per unit of water is the greatest. Such a "nutrient loading index" can be applied to the various areas tributary to the Lake. For phosphorus loading the index is 3.9 for Taylor Creek/Nubbin Slough in comparison with 0.4 for the Kissimmee River and 0.6 for Fisheating Creek. For nitrogen loading the indices are 2.7 for the Agricultural Area and 0.6 for both the Kissimmee River and Fisheating Creek.

In the Kissimmee Basin the District's water quality data and that of the U. S. Geological Survey indicate that the water entering the north end of C-38 is of good quality. Man's activities in the Upper Basin at present have no adverse impact on Lake Okeechobee. Although nitrogen concentrations are nearly uniform throughout the length of C-38, phosphorus concentrations increase from north to south. It is estimated that in a normal year about 55% of the total phosphorus load entering the Lake would come from the 255 sq.mile area tributary to the lower end of C-38, with about 15% of the inflow from the Kissimmee Basin. The "nutrient loading index" for this area, for phosphorus loading, would be 3.5.

District studies in one of the watersheds (Chandler Slough) tributary to the lower end of C-38 indicate that a segment of undisturbed marsh at the lower end of the watershed is effective in reducing the phosphorus concentrations. Average retention time for water flowing through this 3.5 mile long, 1,000 acre, marsh was estimated to be 3 days. Phosphorus concentrations were reduced 25%-55%, with flow rates varying from 50 cfs to 400 cfs.

These studies identify three specific areas to which immediate and affirmative water quality management attention should, and can, be directed:

1. Taylor Creek/Nubbin Slough
2. That portion of the Everglades Agricultural Area tributary to Pumping Stations 2 and 3
3. The area tributary to C-38 downstream of Structure 65C.

LAKE OKEECHOBEE - WATER CHEMISTRY

In January 1969, the U.S.Geological Survey under its cooperative program with the District initiated a study of the enrichment characteristics of Lake Okeechobee. As a part of that study a water and nutrient budget for the Lake was calculated for the period January 1969 through January 1970. Upon the termination of that study the District continued and intensified the water quality sampling program in the Lake and at the inflow points to the Lake. A similar water and nutrient budget for the Lake was calculated by the District for the period May 1973-May 1974. The total period spanned from the initiation of the U.S.Geological Survey nutrient budget study and the cut-off point of the first year of the District's nutrient budget study is a little over 5 years. Nutrient loads to the Lake were computed in both studies.

Total inflow to the Lake for the 13-month period of the U.S.Geological Survey study was above the long-term average; being approximately 8.86 million acre feet. For the 12-month period of the District study the total inflow was about 75% of the long-term average; or approximately 3.00 million acre feet. The following table lists the normal inflows from each major tributary, the calculated inflows during each study period, and the percent of normal inflow (adjusted approximately for the difference in length of the study periods).

Inflow Point	Normal Inflow (MAF)	1969-70 Inflow (MAF)	1969-70 % Normal	1973-74 Inflow (MAF)	1973-74 % Normal
Kissimmee River	1.58	3.47	210%	1.02	65%
Taylor Creek/ Nubbin Slough	.07	.37	520%	.20	286%
C-40 and C-41	.19	.41	210%	.19	100%
S-2 and S-3	.25	.04	25%	.26	100%
Fisheating Creek	.19	.64	330%	.14	74%
Rainfall	1.75	3.57	200%	1.01	58%
Other Sources	-	.36	-	.18	-
TOTAL	4.03	8.86	220%	3.00	74%

The three sets of inflow values listed above reveal several features of importance. One of these is that volumetrically the input from direct rainfall on the Lake closely tracks that of inflow from the Kissimmee River. Another is that the long-term average inflow on Taylor Creek (dating back to 1955) may no longer be a valid indicator of present flow conditions in that watershed.

This table also shows that the 1973-74 data represent a reasonable approximation of the "normal" water inflow regime of Lake Okeechobee. It is presented in order to provide a framework for the comparisons made in the following table, which lists for both study periods average nutrient concentrations of the inflow water at each of the inflow locations, and the percentages of total water and nutrient load contributed at each location.

	Average Nutrient Concentration (mg/l)				% Contribution					
	N		P		Inflow		N		P	
Inflow Point	1969-70	73-74	69-70	73-74	1969-70	73-74	69-70	73-74	69-70	73-74
Kissimmee River	1.0	1.39	0.08	0.08	39%	34%	40%	30%	38%	21%
Taylor Creek/ Nubbin Slough	1.8	1.89	0.62	0.77	4%	7%	7%	8%	30%	39%
C-49 and C-41	1.4	2.40	0.08	0.31	5%	6%	6%	9%	5%	16%
S-2 and S-3	3.8	5.93	0.15	0.15	1%	9%	12%	32%	6%	9%
Fisheating Creek	1.4	1.55	0.07	0.12	7%	5%	9%	4%	5%	4%
Rainfall	0.7	0.73	0.04	0.04	40%	34%	25%	16%	16%	10%
Other Sources	-	-	-	-	4%	5%	1%	1%	-	1%
Average Lake Values	1.4	1.71	0.04	0.05						

Both sets of data show certain of the same things:

1. Nutrient concentrations of the Kissimmee River inflow are less than the concentrations of any other inflow, except precipitation.

2. The percentage of Fisheating Creek and Kissimmee River's contributions to toal nutrient loading is closely related to their water flow contributions.

3. The contribution of phosphorus from Taylor Creek/Nubbin Slough is disproportionately high in relation to its flow contribution; being equal to or greater than that from the Kissimmee River with only 10%-20% of its flow.

4. The contribution of nitrogen from the Agricultural Area (S-2 and S-3) is disproportionately high in relation to its flow contribution; being about equal to that of the Kissimmee River with only about 25% of its flow (1973-74 data).

5. The Taylor Creek/Nubbin Slough and S-2/S-3 data, together with that from C-40/C-41, indicate a definite relationship between type of agricultural land use, soil type, and character of the nutrient loading. The highest phosphorus concentrations and loadings are found in an area used intensively for dairy-farming, and next highest in an area (C-40/C-41) largely devoted to pasture. The highest nitrogen concentrations and loadings derive from a muckland area devoted to row crops and cane.

6. There has been no basic change in the chemical water quality of the Lake in the five-year period, nor has there been any material change in the relative significance of the nutrient loading values from the various contributing sources, with the possible exception of the phosphorus loading from the Indian Prairie area. (C-40/C-41).

7. Water inputs to the Lake from direct precipitation are roughly equivalent to inputs from the Kissimmee River, and total nutrient loads from that source are approximately half of that from the Kissimmee River.

Although the nutrient loads entering the Lake from direct rainfall on the Lake are substantial and contribute to its enrichment status, this input is uncontrollable. Therefore, it will be useful to put the water and nutrient loading data from the immediately preceding table into a form which is related to potentially "controllable" inflows by excluding direct precipitation from the calculations. The following table presents the 1973-74 data in this form; this data being more representative of an "average" or "normal" condition than that for 1969-70. (The value for "other sources" is also excluded in this table.)

Inflow Point	% of Total "Controllable" Inflow	% of "Controllable" Nutrient Loading	
		N	P
Kissimmee River	57%	36%	23%
Taylor Creek/ Nubbin Slough	11%	9%	43%
C-40 and C-41	10%	12%	18%
S-2 and S-3	14%	38%	11%
Fisheating Creek	8%	5%	5%

The above table can be used to provide some rough measure of cost-effectiveness if it is assumed that: (a) the cost of reducing the nutrient load is directly proportional to the volume of water to be handled, and (b) the cost of nutrient removal or control in each tributary area is the same. The percentages in the above tabulation can be considered as units of water, nitrogen load and phosphorus load respectively. Dividing the nutrient load units by the water units produces a number representing the unit of nutrient load per unit of water. With the assumptions given above, the larger the number so produced, the more cost-effective will be the nutrient removal measures. The following tabulates these indices:

Inflow Point	N Loading Indices	Inflow Point	P Loading Indices
Kissimmee River	0.63	Kissimmee River	0.40
Fisheating Creek	0.63	Fisheating Creek	0.63
Taylor Creek/ Nubbin Slough	0.82	S-2, S-3	0.79
C-40 and C-41	1.20	C-40, C-41	1.80
S-2 and S-3	2.71	Taylor Creek/ Nubbin Slough	3.91

Although the first assumption made above is valid, the second one is not necessarily so. Therefore, the table does not necessarily represent a set of cost-effectiveness indices. However, it does serve as a strong indicator of where nutrient reduction measures should be taken which would be most productive in terms of reducing nutrient load impact on the Lake.

It is clear that in terms of nitrogen load attention must be focused on the S-2, S-3 area, and in terms of phosphorus load the Taylor Creek/Nubbin Slough area must be addressed.

These indices serve to provide a better perspective of the relative importance of nutrient loads entering the Lakes from various sources, in consideration of the potential manageability of those loads as expressed by the volume of water requiring handling. In these terms Fisheating Creek and the Kissimmee River are relatively unimportant whereas Taylor Creek/Nubbin Slough and the northwesterly portion of the Agricultural Area are relatively more important.

KISSIMMEE BASIN - WATER CHEMISTRY

Intensive water quality sampling in C-38 initiated by the U.S.Geological Survey in 1971 under its cooperative program with the District, and expanded under the District's own program in C-38, in the tributaries to C-38 and in the

lakes of the Upper Basin clearly indicates that the water leaving Lake Kissimmee and entering C-38 is of good quality. These data irrefutably show that the picture of pollutants from Central Florida "sluicing" down C-38 to Lake Okeechobee which was painted for the Governor and Cabinet as recently as December 1972 is grossly inaccurate. The lakes of the Upper Basin, and in particular Lake Tohopekaliga, are at present assimilating these pollutants. This is not to say that the nutrient loads entering at the north end of Lake Tohopekaliga are not adversely impacting that lake. It is to say, however, that the impact of those loads is being absorbed quite probably by the time water leaves Lake Tohopekaliga and most certainly by the time it enters C-38.

The following tabulates average nitrogen and phosphorus concentrations in C-38, for various time periods, observed by both the U. S.Geological Survey and the District:

	Average N concentration, Annual (mg/l)			Average P concentration, Wet Season (mg/l)			
Location	1971-72	1972-73	1973-74	1971	1972	1973	1974
S-65	2.10	1.53	1.27	-	0.017	0.033	0.032
S-65A	1.65	1.20	1.14	0.069	0.021	0.030	0.042
S-65B	1.50	1.14	1.09	0.048	0.023	0.042	0.042
S-65C	1.60	1.08	1.06	0.055	0.045	0.050	0.053
S-65D	1.55	1.15	1.03	0.100	0.063	0.061	0.069
S-65E	1.60	1.09	1.14	0.187	0.082	0.090	0.088

These data show a relatively uniform distribution for nitrogen concentrations along the length of C-38. Less than 10% of the total nitrogen is in the inorganic form, the form most readily available for biological uptake. The data also show that phosphorus concentrations increase rather dramatically in the reach of C-38 downstream of Structure S-65C.

For study purposes the lower Kissimmee Valley has been divided into planning units, based on watershed boundaries adapted from the SCS. There are five such units (13-17) between Structure 65 at the Lake Kissimmee Outlet and Structure 65E, which discharges Kissimmee Basin outflow to Lake Okeechobee. Planning unit 18 is located downstream of Structure 65E.

An index of drainage capability, called the "drainage density", has been developed for and applied to various planning units and watersheds in the lower valley. This index is simply the total length of defined waterways (both natural and man-made) within the watershed divided by the watershed area. No attempt is made, in developing this index, to distinguish between natural and man-made channels; both are given the same weight. The following table lists, from north to south, the drainage density index for each of the planning units upstream of S-65E and the average phosphorus concentrations in the reach of C-38 to which the planning unit is tributary:

Planning Unit	Area (sq.mi.)	Drainage Density (mi/sq.mi.)	Tributary Pool	Average P Concentration (mg/l)
13	146	3.42	S-65A	0.025
14	225	2.92	S-65B	0.037
15	68	4.92	S-65C	0.038
16	161	5.79	S-65D	0.059
17	59	5.68	S-65C	0.082

A further indication of the relationship between drainage density (degree of watershed drainage) and phosphorus concentrations is revealed in the following table. This table lists average phosphorus concentrations in the outflow water from selected watersheds together with the drainage density index for those watersheds:

Watershed	Area (sq.mi.)	Located Within Planning Unit	Drainage Density (mi/sq.mi.)	Average P Concentration (mg/l)
Ice Cream Slough	60.3	13	1.49	0.02
Pine Island and Seven Mile Slough	98.9	14	2.92	0.03
Chandler Slough	49.0	16	9.23	0.33

Drainage effectiveness, of which drainage density is a rough measure, is, of course, not the only factor which affects phosphorus loading. The Lake Okeechobee loading data presented earlier shows that the type of land use is a major factor in phosphorus concentrations and resultant loadings. The S-2 and S-3 tributary areas have drainage density indices which unquestionably are far larger than those which have been calculated for the lower Kissimmee Valley. However, in the lower valley the type of land use is predominantly oriented toward animal-culture; beef cattle pasture throughout, with dairy operations at the southern extremity. Consequently, with the type of agricultural land use being basically the same, drainage density provides a valid general indicator of phosphorus concentrations. It should be kept in mind, nevertheless, that given the same drainage density, greater phosphorus loadings can be expected from a dairy operation in comparison with a beef-cattle operation due to the greater animal density in the former case and the wider dispersal of animals in the latter case.

These Kissimmee Basin water quality data clearly indicate the following:

1. Man's activities in the Upper Basin (upstream of S-65) at present do not contribute to whatever enrichment problems may be present in Lake Okeechobee.

2. Man's activities in the Lower Basin upstream of Structure S-65C at present contribute little to whatever enrichment problems may be present in Lake Okeechobee.

3. At present the major contribution of enrichment to Lake Okeechobee in the form of phosphorus from the 2,320 sq.mi.* Kissimmee Basin derives from the 220 sq.mi. area contributory to the S-65D and S-65E pools of C-38, and the 35 sq.mi. area entering downstream of S-65E from the east; together a little more than 10% of the entire drainage area.

*Note: Excludes the Lake Istokpoga area.

Focusing attention on this 255 sq.mi. area, using values derived by Heaney and Huber in Phase I of their report "Environmental Resources Management Studies in the Kissimmee River Basin", prepared under contract with the District, we can expect this area to produce an average annual runoff of 12 inches with the present land use. This is approximately 160,000 A.F., annually. This is about 80% of the runoff generated in the 1973-74 study period from the Taylor Creek/ Nubbin Slough area, an area of generally similar land use.

Using an average phosphorus concentration of 0.30 mg/l, the annual loading from this area to Lake Okeechobee would be approximately 65 Tons. In the 1973-74 study period the total Kissimmee River loading was 117 Tons of phosphorus with 1.017 MAF of runoff.

This 255 sq.mi. drainage area, therefore, could be expected to produce 56% of the total phosphorus load from the Kissimmee Basin with only an estimated 16% of the total runoff. Using the same "effectiveness" index as was used to evaluate the relative potential productiveness of nutrient removal measures for tributaries to Lake Okeechobee, an index of 3.50 is derived for this area. This number is almost identical to that derived for the Taylor Creek/Nubbin Slough area.

It seems clear that, in the Kissimmee Basin, immediate attention must be focused on this comparatively small area; such attention having the potential of producing the most effective results in terms of Lake Okeechobee enrichment.

CHANDLER SLOUGH-WATER QUALITY AND FLOW

Because of the high observed phosphorus concentrations of the water entering C-38 from Chandler Slough, the District initiated an intensive study in the lower end of this drainage system. The upper reach of the Chandler Slough drainage and the Cypress Creek drainage (49 sq.mi. and 67 sq.mi. respectively) join together 3.5 miles east of C-38 and from that point flows from both drainage areas move toward C-38 across a marsh having an average width of approximately 2,300 feet and an area of about 1,000 acres.

Intensive sampling runs, involving the quality of the water both entering and leaving the marsh, were conducted during the wet season of 1974 and the following dry season. Wet season flow rates at the upper end of the marsh approximated 400 cfs; dry season flow rate was less than 50 cfs.

Dye studies were conducted in order to approximate the rate of water flow through the marsh and, from these, to estimate the water retention time on the marsh; that is, the length of time the inflow water was exposed to the nutrient assimilation mechanisms of the marsh. For the observed discharges the retention time was estimated to be about 3 days.

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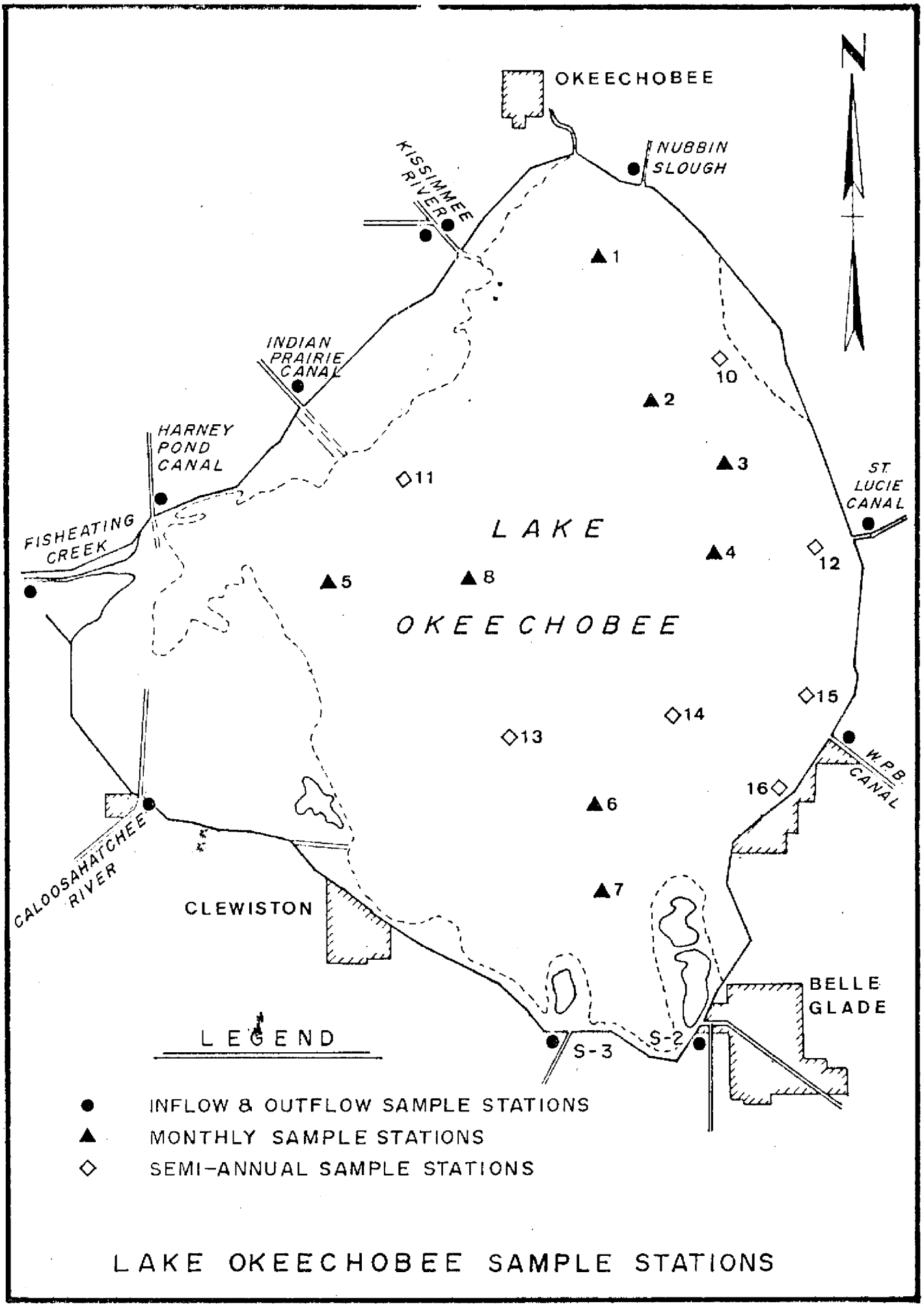
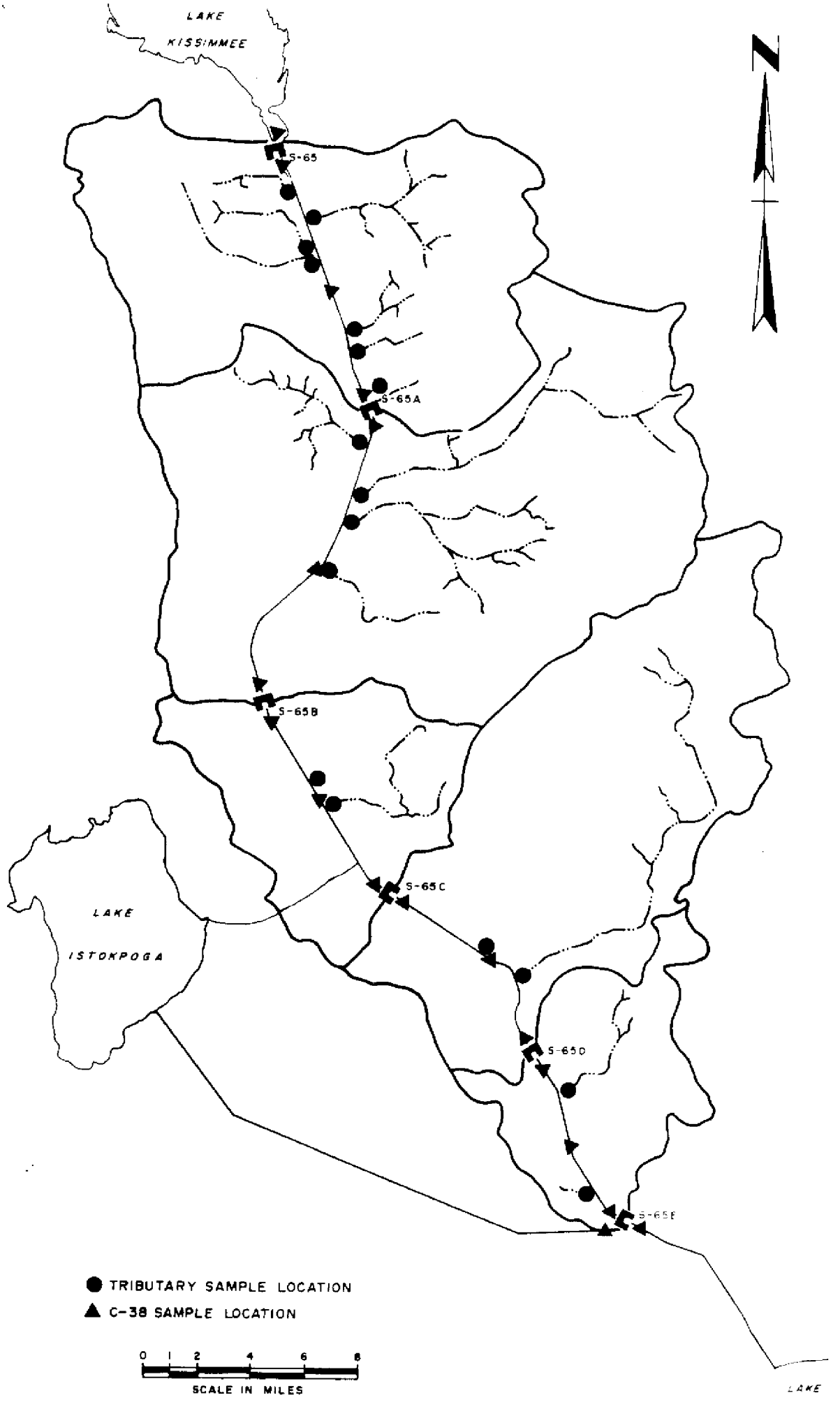
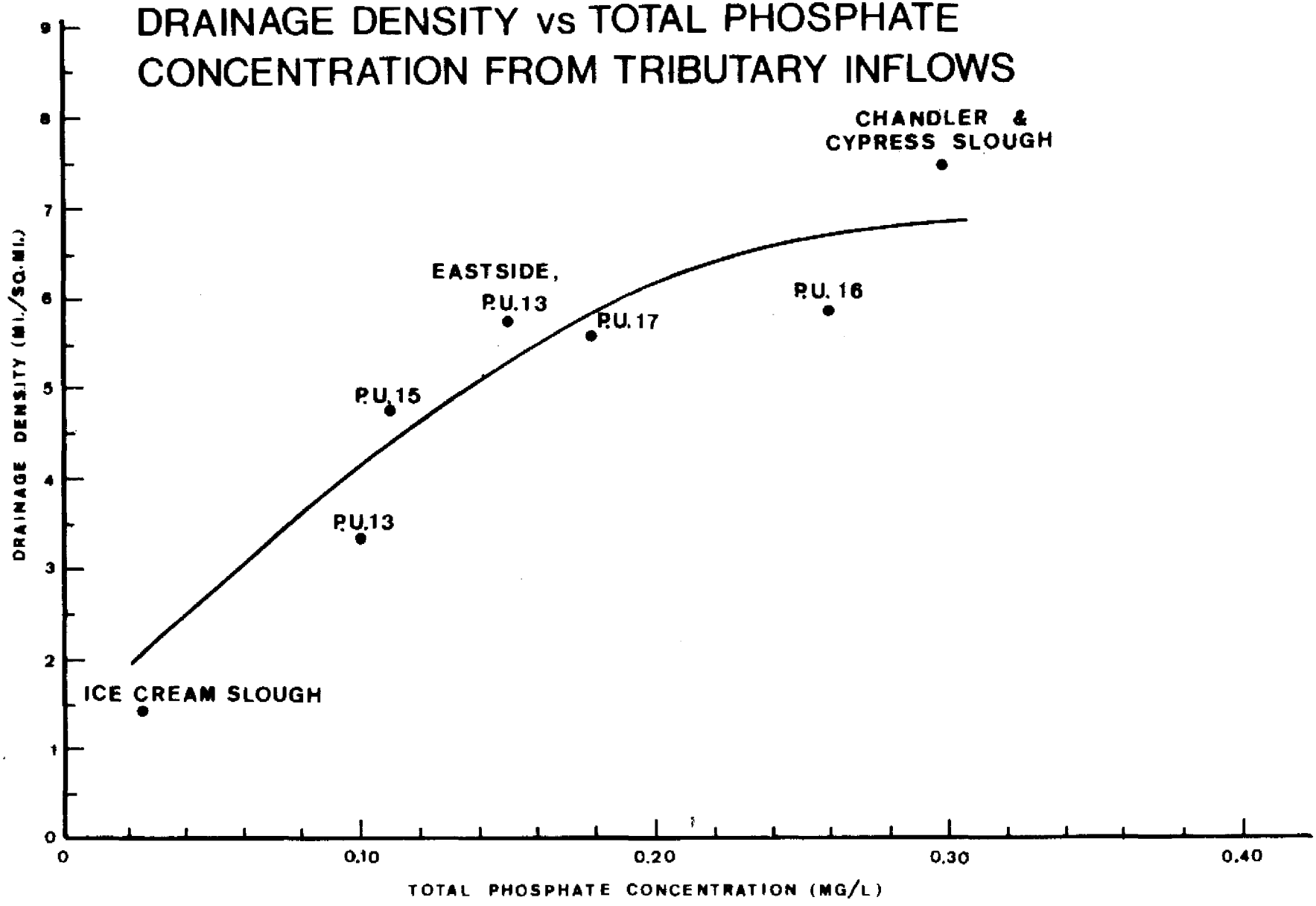
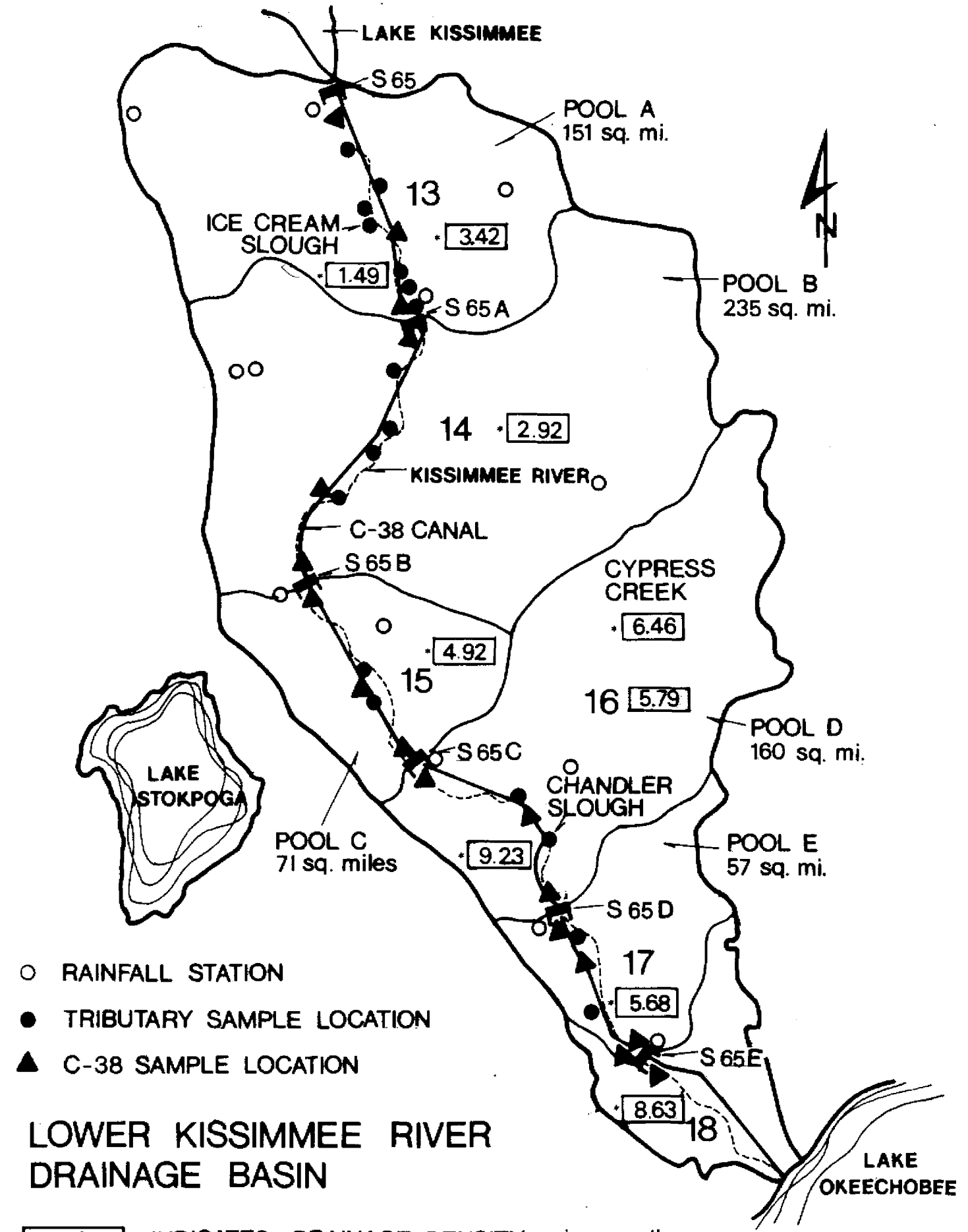


LAKE OKEECHOBEE SAMPLE STATIONS



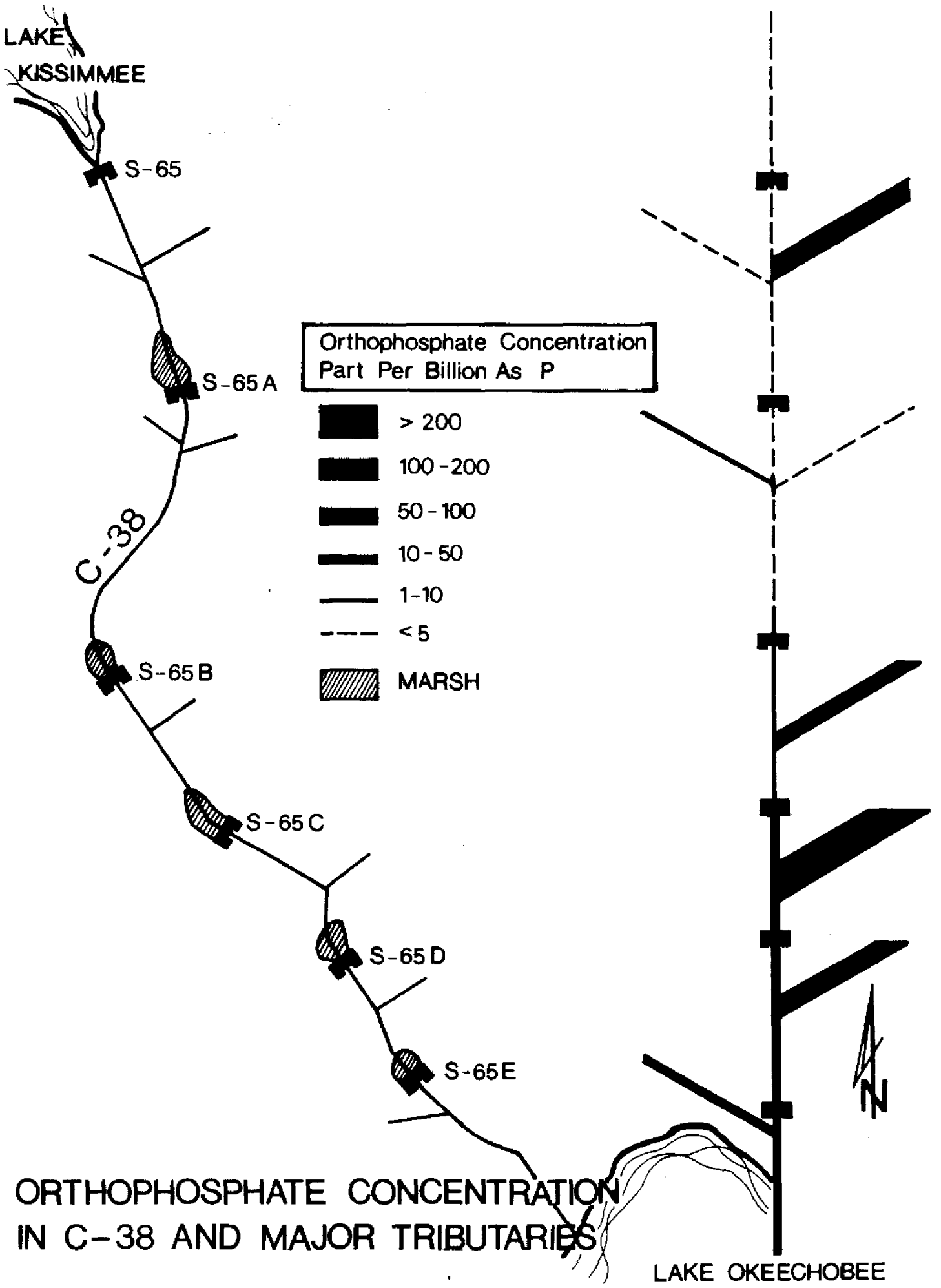
WATER QUALITY MONITORING


DRAINAGE DENSITY vs TOTAL PHOSPHATE CONCENTRATION FROM TRIBUTARY INFLOWS
CHANDLER & CYPRESS SLOUGH
EASTSIDE, P.U.13
P.U. 16
P.U.17
P.U.15
P.U.13
ICE CREAM SLOUGH
DRAINAGE DENSITY (MI./SQ.MI.)
TOTAL PHOSPHATE CONCENTRATION (MG/L)
0
1
2
3
4
5
6
7
8
9
0.10
0.20
0.30
0.40

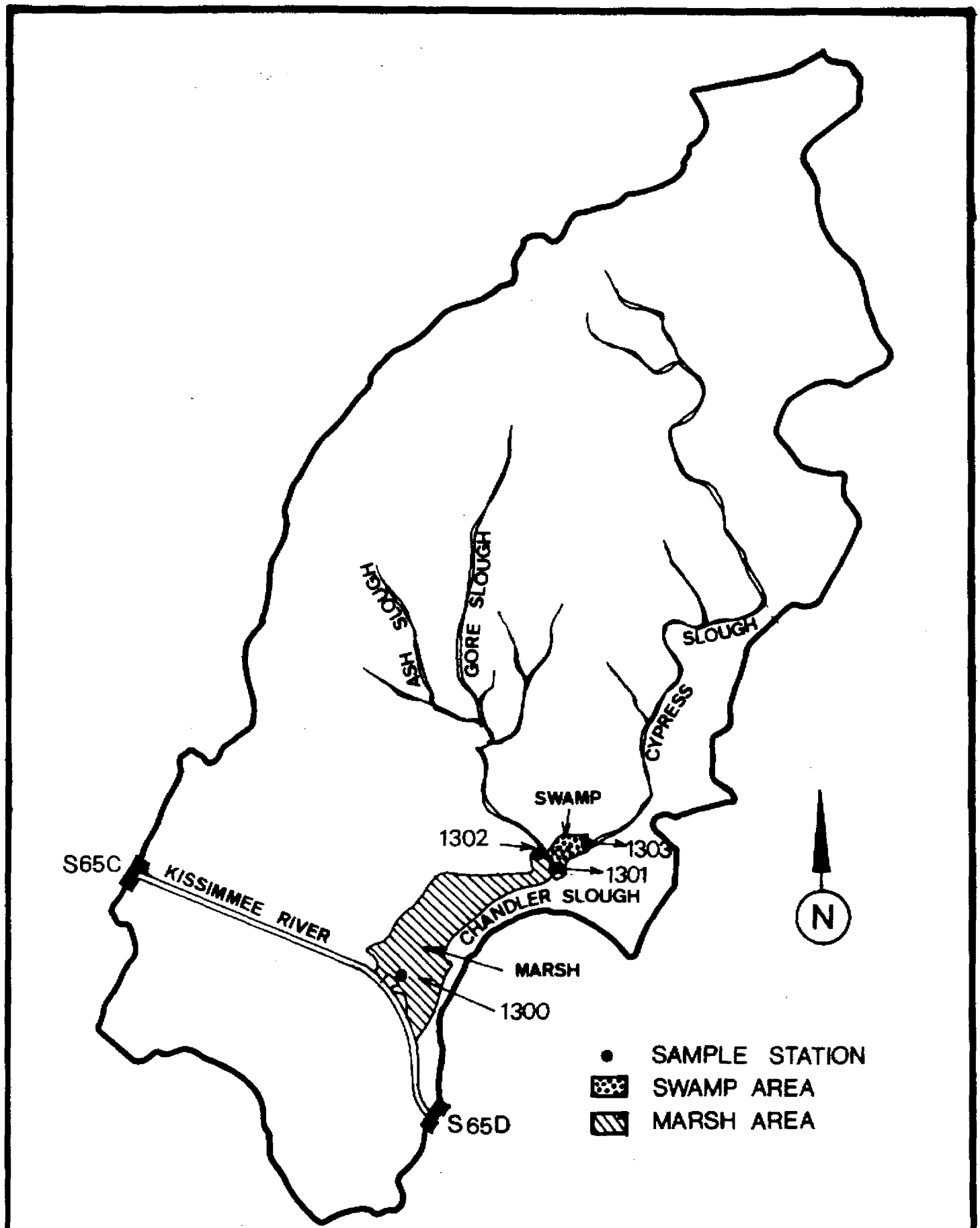


LOWER KISSIMMEE RIVER DRAINAGE BASIN

· [number] : INDICATES DRAINAGE DENSITY - mi./sq. mile

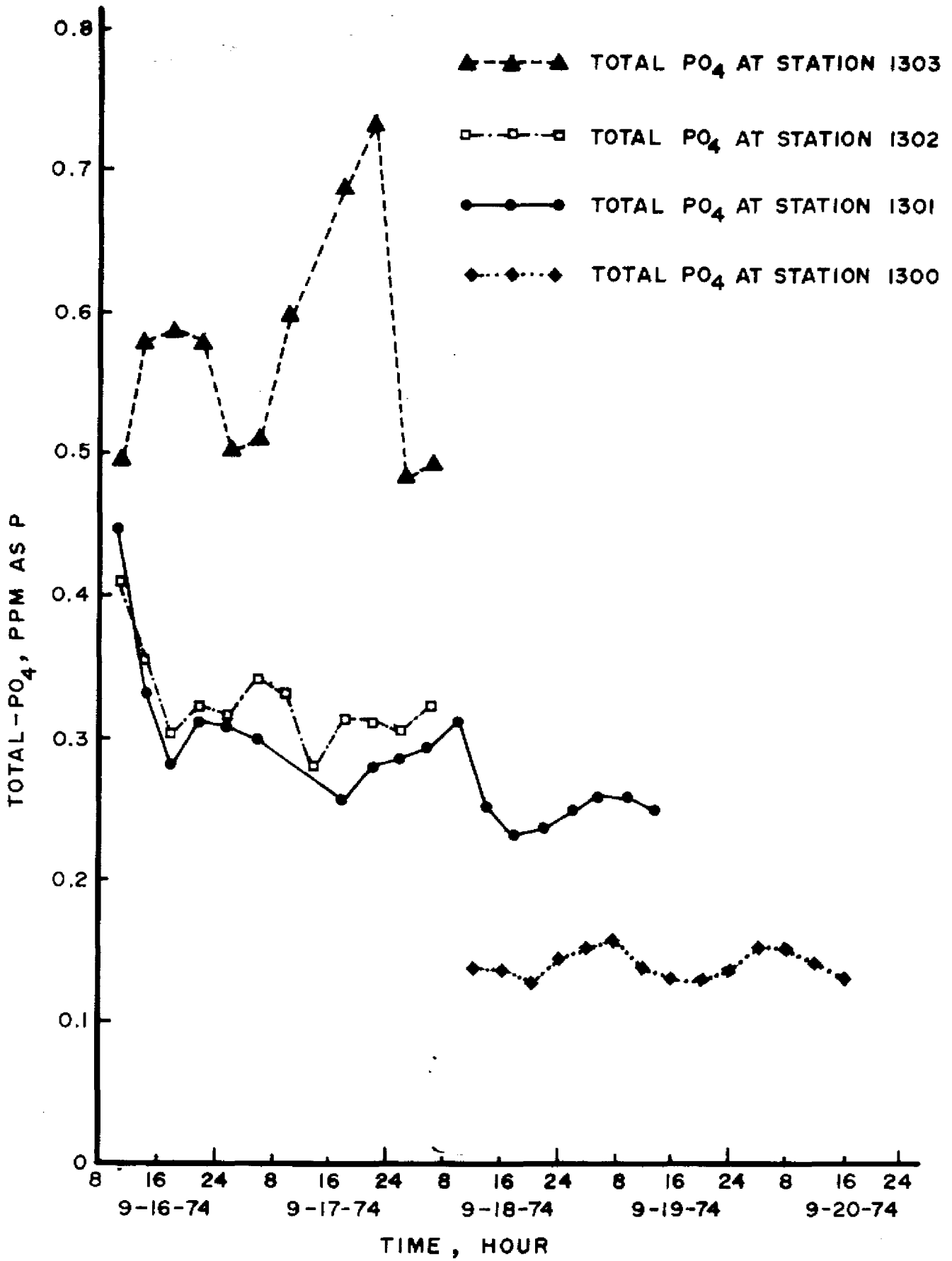


ORTHOPHOSPHATE CONCENTRATION IN C-38 AND MAJOR TRIBUTARIES

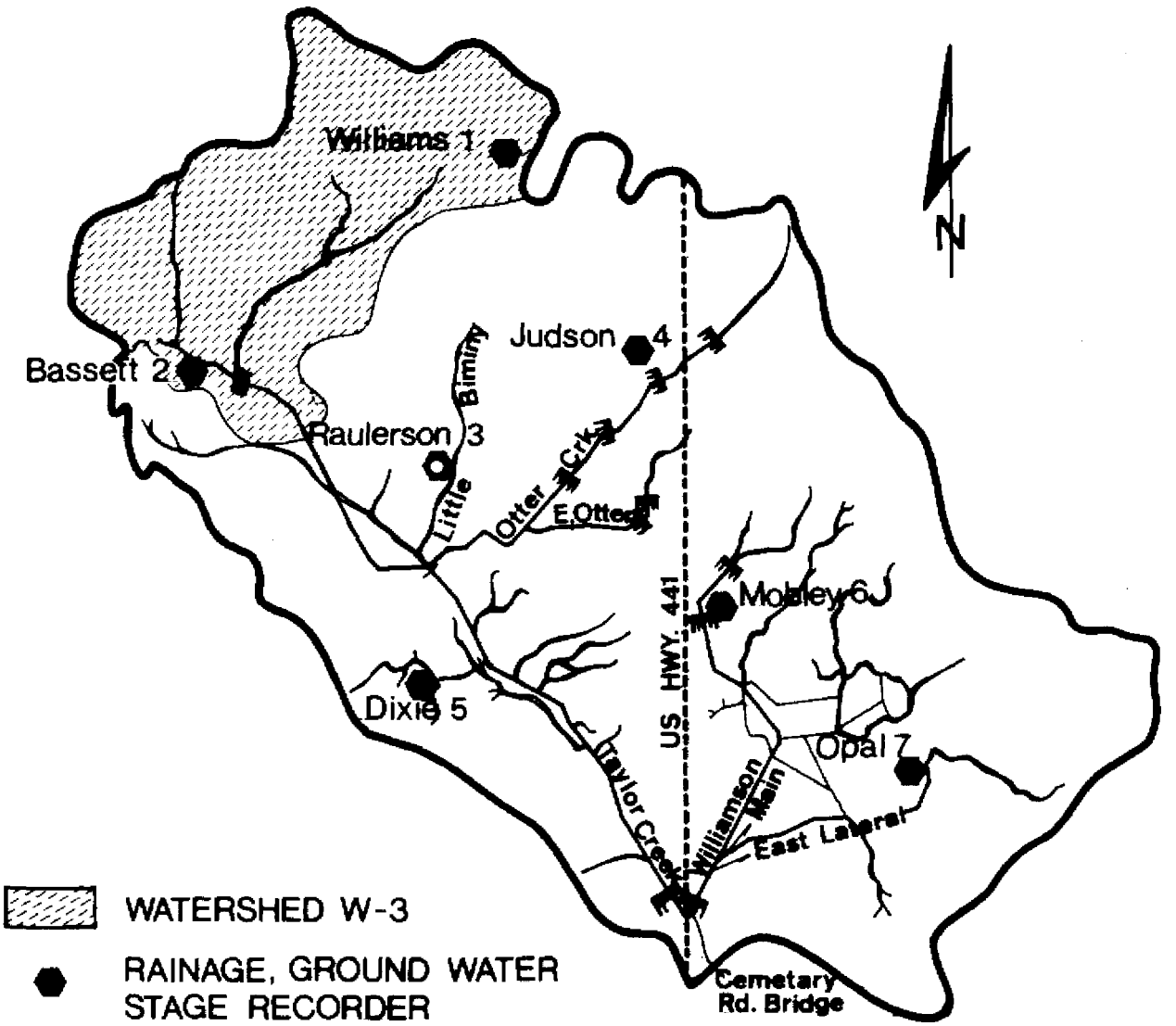


LAYOUT OF STUDY AREA

FIGURE 1



CHANDLER SLOUGH PHOSPHORUS



WATERSHED W-3

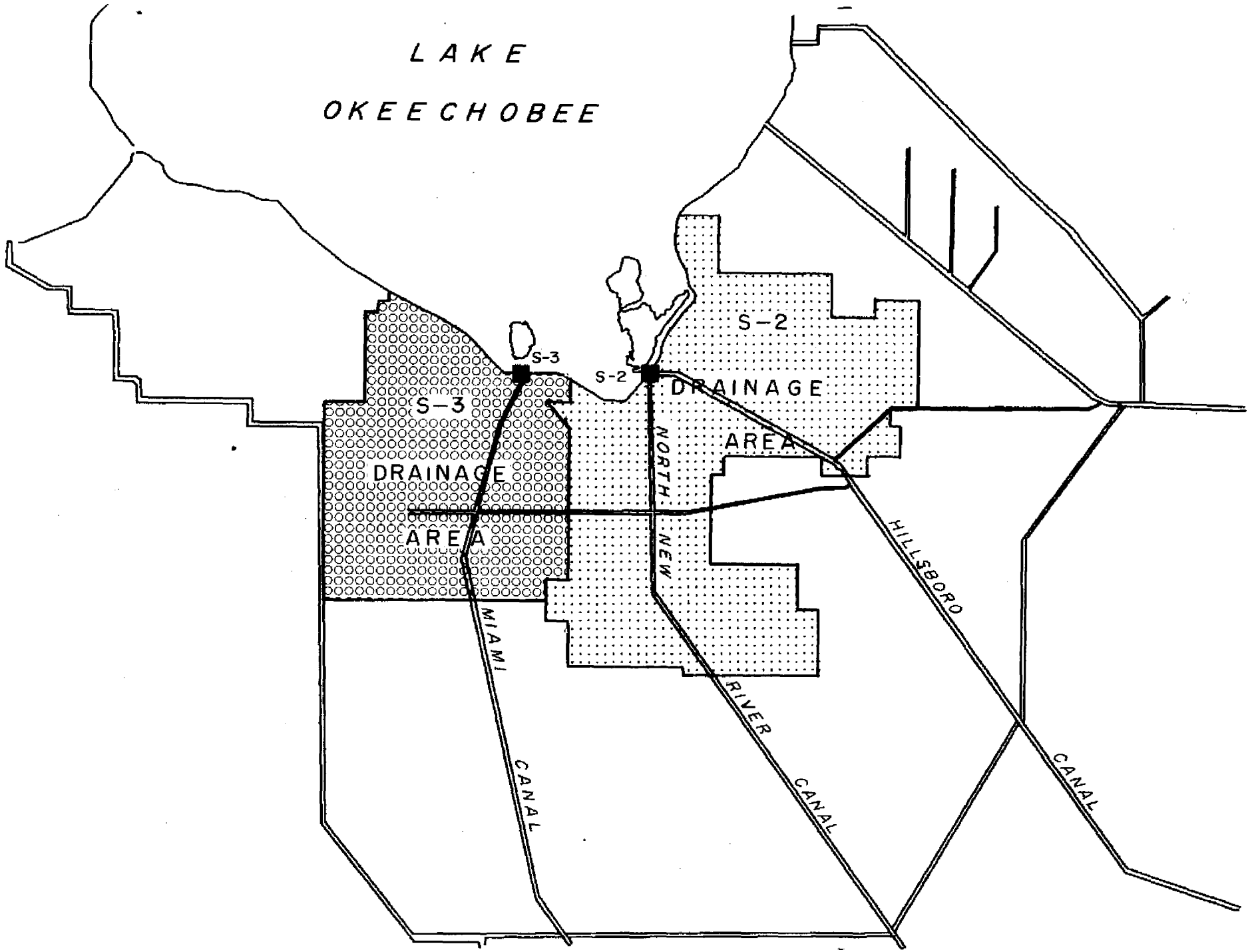
RAINAGE, GROUND WATER STAGE RECORDER

EVAPORATION PAN, RAINAGE GROUND WATER STAGE RECORDER

------ HIGHWAY

FCD STREAM STRUCTURE

UPPER TAYLOR CREEK
FLORIDA WATERSHEDS W-2 & W-3



EVERGLADES AGRICULTURAL AREA
S-2 AND S-3 DRAINAGE AREAS

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LAKE OKEECHOBEE - KISSIMMEE BASIN WATER QUALITY INFORMATION

CENTRAL AND SOUTHERN FLORIDA FLOOD CONTROL DISTRICT

MARCH 20, 1975

SUMMARY

A nutrient (nitrogen and phosphorus) loading study on Lake Okeechobee for the period January 1969-January 1970 was conducted by the U. S. Geological Survey. A similar nutrient loading study was conducted by the District for the period May 1973-May 1974. Lake Okeechobee water quality data collected in connection with these two studies show that in the span of five years covered there has been no basic change in the Lake's water chemistry.

Both nutrient loading studies showed approximately the same thing with respect to the principal sources of nutrient loads to the Lake. Rainfall is a substantial contributor of both inflow (35%-40%) and nutrients (about 20%) to the Lake. Removing rainfall from consideration because its input is "uncontrollable", the District's study shows that the Kissimmee River with 57% of the inflow contributes 23% of the phosphorus load to the Lake, whereas the Taylor Creek/Nubbin Slough area with 11% of the inflow contributes 43% of the phosphorus load. On the same basis the Kissimmee River contributes 36% of the nitrogen load, while the Everglades Agricultural Area with 14% of the inflow contributes 38% of the nitrogen load.

Since water quality management is a function of the amount of water to be handled, and the land area on which that water is generated, it appears clear that any such management effort should be first applied to those areas where the unit nutrient load per unit of water is the greatest. Such a "nutrient loading index" can be applied to the various areas tributary to the Lake. For phosphorus loading the index is 3.9 for Taylor Creek/Nubbin Slough in comparison with 0.4 for the Kissimmee River and 0.6 for Fisheating Creek. For nitrogen loading the indices are 2.7 for the Agricultural Area and 0.6 for both the Kissimmee River and Fisheating Creek.

In the Kissimmee Basin the District's water quality data and that of the U. S. Geological Survey indicate that the water entering the north end of C-38 is of good quality. Man's activities in the Upper Basin at present have no adverse impact on Lake Okeechobee. Although nitrogen concentrations are nearly uniform throughout the length of C-38, phosphorus concentrations increase from north to south. It is estimated that in a normal year about 55% of the total phosphorus load entering the Lake would come from the 255 sq.mile area tributary to the lower end of C-38, with about 15% of the inflow from the Kissimmee Basin. The "nutrient loading index" for this area, for phosphorus loading, would be 3.5.

District studies in one of the watersheds (Chandler Slough) tributary to the lower end of C-38 indicate that a segment of undisturbed marsh at the lower end of the watershed is effective in reducing the phosphorus concentrations. Average retention time for water flowing through this 3.5 mile long, 1,000 acre, marsh was estimated to be 3 days. Phosphorus concentrations were reduced 25%-55%, with flow rates varying from 50 cfs to 400 cfs.

These studies identify three specific areas to which immediate and affirmative water quality management attention should, and can, be directed:

1. Taylor Creek/Nubbin Slough
2. That portion of the Everglades Agricultural Area tributary to Pumping Stations 2 and 3
3. The area tributary to C-38 downstream of Structure 65C.

LAKE OKEECHOBEE - WATER CHEMISTRY

In January 1969, the U.S.Geological Survey under its cooperative program with the District initiated a study of the enrichment characteristics of Lake Okeechobee. As a part of that study a water and nutrient budget for the Lake was calculated for the period January 1969 through January 1970. Upon the termination of that study the District continued and intensified the water quality sampling program in the Lake and at the inflow points to the Lake. A similar water and nutrient budget for the Lake was calculated by the District for the period May 1973-May 1974. The total period spanned from the initiation of the U.S.Geological Survey nutrient budget study and the cut-off point of the first year of the District's nutrient budget study is a little over 5 years. Nutrient loads to the Lake were computed in both studies.

Total inflow to the Lake for the 13-month period of the U.S.Geological Survey study was above the long-term average; being approximately 8.86 million acre feet. For the 12-month period of the District study the total inflow was about 75% of the long-term average; or approximately 3.00 million acre feet. The following table lists the normal inflows from each major tributary, the calculated inflows during each study period, and the percent of normal inflow (adjusted approximately for the difference in length of the study periods).

Inflow Point	Normal Inflow (MAF)	1969-70 Inflow (MAF)	1969-70 % Normal	1973-74 Inflow (MAF)	1973-74 % Normal
Kissimmee River	1.58	3.47	210%	1.02	65%
Taylor Creek/ Nubbin Slough	.07	.37	520%	.20	286%
C-40 and C-41	.19	.41	210%	.19	100%
S-2 and S-3	.25	.04	25%	.26	100%
Fisheating Creek	.19	.64	330%	.14	74%
Rainfall	1.75	3.57	200%	1.01	58%
Other Sources	-	.36	-	.18	-
TOTAL	4.03	8.86	220%	3.00	74%

The three sets of inflow values listed above reveal several features of importance. One of these is that volumetrically the input from direct rainfall on the Lake closely tracks that of inflow from the Kissimmee River. Another is that the long-term average inflow on Taylor Creek (dating back to 1955) may no longer be a valid indicator of present flow conditions in that watershed.

This table also shows that the 1973-74 data represent a reasonable approximation of the "normal" water inflow regime of Lake Okeechobee. It is presented in order to provide a framework for the comparisons made in the following table, which lists for both study periods average nutrient concentrations of the inflow water at each of the inflow locations, and the percentages of total water and nutrient load contributed at each location.

	Average Nutrient Concentration (mg/l)				% Contribution					
	N		P		Inflow		N		P	
Inflow Point	1969-70	73-74	69-70	73-74	1969-70	73-74	69-70	73-74	69-70	73-74
Kissimmee River	1.0	1.39	0.08	0.08	39%	34%	40%	30%	38%	21%
Taylor Creek/ Nubbin Slough	1.8	1.89	0.62	0.77	4%	7%	7%	8%	30%	39%
C-49 and C-41	1.4	2.40	0.08	0.31	5%	6%	6%	9%	5%	16%
S-2 and S-3	3.8	5.93	0.15	0.15	1%	9%	12%	32%	6%	9%
Fisheating Creek	1.4	1.55	0.07	0.12	7%	5%	9%	4%	5%	4%
Rainfall	0.7	0.73	0.04	0.04	40%	34%	25%	16%	16%	10%
Other Sources	-	-	-	-	4%	5%	1%	1%	-	1%
Average Lake Values	1.4	1.71	0.04	0.05						

Both sets of data show certain of the same things:

1. Nutrient concentrations of the Kissimmee River inflow are less than the concentrations of any other inflow, except precipitation.

2. The percentage of Fisheating Creek and Kissimmee River's contributions to toal nutrient loading is closely related to their water flow contributions.

3. The contribution of phosphorus from Taylor Creek/Nubbin Slough is disproportionately high in relation to its flow contribution; being equal to or greater than that from the Kissimmee River with only 10%-20% of its flow.

4. The contribution of nitrogen from the Agricultural Area (S-2 and S-3) is disproportionately high in relation to its flow contribution; being about equal to that of the Kissimmee River with only about 25% of its flow (1973-74 data).

5. The Taylor Creek/Nubbin Slough and S-2/S-3 data, together with that from C-40/C-41, indicate a definite relationship between type of agricultural land use, soil type, and character of the nutrient loading. The highest phosphorus concentrations and loadings are found in an area used intensively for dairy-farming, and next highest in an area (C-40/C-41) largely devoted to pasture. The highest nitrogen concentrations and loadings derive from a muckland area devoted to row crops and cane.

6. There has been no basic change in the chemical water quality of the Lake in the five-year period, nor has there been any material change in the relative significance of the nutrient loading values from the various contributing sources, with the possible exception of the phosphorus loading from the Indian Prairie area. (C-40/C-41).

7. Water inputs to the Lake from direct precipitation are roughly equivalent to inputs from the Kissimmee River, and total nutrient loads from that source are approximately half of that from the Kissimmee River.

Although the nutrient loads entering the Lake from direct rainfall on the Lake are substantial and contribute to its enrichment status, this input is uncontrollable. Therefore, it will be useful to put the water and nutrient loading data from the immediately preceding table into a form which is related to potentially "controllable" inflows by excluding direct precipitation from the calculations. The following table presents the 1973-74 data in this form; this data being more representative of an "average" or "normal" condition than that for 1969-70. (The value for "other sources" is also excluded in this table.)

Inflow Point	% of Total "Controllable" Inflow	% of "Controllable" Nutrient Loading	
		N	P
Kissimmee River	57%	36%	23%
Taylor Creek/ Nubbin Slough	11%	9%	43%
C-40 and C-41	10%	12%	18%
S-2 and S-3	14%	38%	11%
Fisheating Creek	8%	5%	5%

The above table can be used to provide some rough measure of cost-effectiveness if it is assumed that: (a) the cost of reducing the nutrient load is directly proportional to the volume of water to be handled, and (b) the cost of nutrient removal or control in each tributary area is the same. The percentages in the above tabulation can be considered as units of water, nitrogen load and phosphorus load respectively. Dividing the nutrient load units by the water units produces a number representing the unit of nutrient load per unit of water. With the assumptions given above, the larger the number so produced, the more cost-effective will be the nutrient removal measures. The following tabulates these indices:

Inflow Point	N Loading Indices	Inflow Point	P Loading Indices
Kissimmee River	0.63	Kissimmee River	0.40
Fisheating Creek	0.63	Fisheating Creek	0.63
Taylor Creek/ Nubbin Slough	0.82	S-2, S-3	0.79
C-40 and C-41	1.20	C-40, C-41	1.80
S-2 and S-3	2.71	Taylor Creek/ Nubbin Slough	3.91

Although the first assumption made above is valid, the second one is not necessarily so. Therefore, the table does not necessarily represent a set of cost-effectiveness indices. However, it does serve as a strong indicator of where nutrient reduction measures should be taken which would be most productive in terms of reducing nutrient load impact on the Lake.

It is clear that in terms of nitrogen load attention must be focused on the S-2, S-3 area, and in terms of phosphorus load the Taylor Creek/Nubbin Slough area must be addressed.

These indices serve to provide a better perspective of the relative importance of nutrient loads entering the Lakes from various sources, in consideration of the potential manageability of those loads as expressed by the volume of water requiring handling. In these terms Fisheating Creek and the Kissimmee River are relatively unimportant whereas Taylor Creek/Nubbin Slough and the northwesterly portion of the Agricultural Area are relatively more important.

KISSIMMEE BASIN - WATER CHEMISTRY

Intensive water quality sampling in C-38 initiated by the U.S.Geological Survey in 1971 under its cooperative program with the District, and expanded under the District's own program in C-38, in the tributaries to C-38 and in the

lakes of the Upper Basin clearly indicates that the water leaving Lake Kissimmee and entering C-38 is of good quality. These data irrefutably show that the picture of pollutants from Central Florida "sluicing" down C-38 to Lake Okeechobee which was painted for the Governor and Cabinet as recently as December 1972 is grossly inaccurate. The lakes of the Upper Basin, and in particular Lake Tohopekaliga, are at present assimilating these pollutants. This is not to say that the nutrient loads entering at the north end of Lake Tohopekaliga are not adversely impacting that lake. It is to say, however, that the impact of those loads is being absorbed quite probably by the time water leaves Lake Tohopekaliga and most certainly by the time it enters C-38.

The following tabulates average nitrogen and phosphorus concentrations in C-38, for various time periods, observed by both the U. S.Geological Survey and the District:

	Average N concentration, Annual (mg/l)			Average P concentration, Wet Season (mg/l)			
Location	1971-72	1972-73	1973-74	1971	1972	1973	1974
S-65	2.10	1.53	1.27	-	0.017	0.033	0.032
S-65A	1.65	1.20	1.14	0.069	0.021	0.030	0.042
S-65B	1.50	1.14	1.09	0.048	0.023	0.042	0.042
S-65C	1.60	1.08	1.06	0.055	0.045	0.050	0.053
S-65D	1.55	1.15	1.03	0.100	0.063	0.061	0.069
S-65E	1.60	1.09	1.14	0.187	0.082	0.090	0.088

These data show a relatively uniform distribution for nitrogen concentrations along the length of C-38. Less than 10% of the total nitrogen is in the inorganic form, the form most readily available for biological uptake. The data also show that phosphorus concentrations increase rather dramatically in the reach of C-38 downstream of Structure S-65C.

For study purposes the lower Kissimmee Valley has been divided into planning units, based on watershed boundaries adapted from the SCS. There are five such units (13-17) between Structure 65 at the Lake Kissimmee Outlet and Structure 65E, which discharges Kissimmee Basin outflow to Lake Okeechobee. Planning unit 18 is located downstream of Structure 65E.

An index of drainage capability, called the "drainage density", has been developed for and applied to various planning units and watersheds in the lower valley. This index is simply the total length of defined waterways (both natural and man-made) within the watershed divided by the watershed area. No attempt is made, in developing this index, to distinguish between natural and man-made channels; both are given the same weight. The following table lists, from north to south, the drainage density index for each of the planning units upstream of S-65E and the average phosphorus concentrations in the reach of C-38 to which the planning unit is tributary:

Planning Unit	Area (sq.mi.)	Drainage Density (mi/sq.mi.)	Tributary Pool	Average P Concentration (mg/l)
13	146	3.42	S-65A	0.025
14	225	2.92	S-65B	0.037
15	68	4.92	S-65C	0.038
16	161	5.79	S-65D	0.059
17	59	5.68	S-65C	0.082

A further indication of the relationship between drainage density (degree of watershed drainage) and phosphorus concentrations is revealed in the following table. This table lists average phosphorus concentrations in the outflow water from selected watersheds together with the drainage density index for those watersheds:

Watershed	Area (sq.mi.)	Located Within Planning Unit	Drainage Density (mi/sq.mi.)	Average P Concentration (mg/l)
Ice Cream Slough	60.3	13	1.49	0.02
Pine Island and Seven Mile Slough	98.9	14	2.92	0.03
Chandler Slough	49.0	16	9.23	0.33

Drainage effectiveness, of which drainage density is a rough measure, is, of course, not the only factor which affects phosphorus loading. The Lake Okeechobee loading data presented earlier shows that the type of land use is a major factor in phosphorus concentrations and resultant loadings. The S-2 and S-3 tributary areas have drainage density indices which unquestionably are far larger than those which have been calculated for the lower Kissimmee Valley. However, in the lower valley the type of land use is predominantly oriented toward animal-culture; beef cattle pasture throughout, with dairy operations at the southern extremity. Consequently, with the type of agricultural land use being basically the same, drainage density provides a valid general indicator of phosphorus concentrations. It should be kept in mind, nevertheless, that given the same drainage density, greater phosphorus loadings can be expected from a dairy operation in comparison with a beef-cattle operation due to the greater animal density in the former case and the wider dispersal of animals in the latter case.

These Kissimmee Basin water quality data clearly indicate the following:

1. Man's activities in the Upper Basin (upstream of S-65) at present do not contribute to whatever enrichment problems may be present in Lake Okeechobee.

2. Man's activities in the Lower Basin upstream of Structure S-65C at present contribute little to whatever enrichment problems may be present in Lake Okeechobee.

3. At present the major contribution of enrichment to Lake Okeechobee in the form of phosphorus from the 2,320 sq.mi.* Kissimmee Basin derives from the 220 sq.mi. area contributory to the S-65D and S-65E pools of C-38, and the 35 sq.mi. area entering downstream of S-65E from the east; together a little more than 10% of the entire drainage area.

*Note: Excludes the Lake Istokpoga area.

Focusing attention on this 255 sq.mi. area, using values derived by Heaney and Huber in Phase I of their report "Environmental Resources Management Studies in the Kissimmee River Basin", prepared under contract with the District, we can expect this area to produce an average annual runoff of 12 inches with the present land use. This is approximately 160,000 A.F., annually. This is about 80% of the runoff generated in the 1973-74 study period from the Taylor Creek/ Nubbin Slough area, an area of generally similar land use.

Using an average phosphorus concentration of 0.30 mg/l, the annual loading from this area to Lake Okeechobee would be approximately 65 Tons. In the 1973-74 study period the total Kissimmee River loading was 117 Tons of phosphorus with 1.017 MAF of runoff.

This 255 sq.mi. drainage area, therefore, could be expected to produce 56% of the total phosphorus load from the Kissimmee Basin with only an estimated 16% of the total runoff. Using the same "effectiveness" index as was used to evaluate the relative potential productiveness of nutrient removal measures for tributaries to Lake Okeechobee, an index of 3.50 is derived for this area. This number is almost identical to that derived for the Taylor Creek/Nubbin Slough area.

It seems clear that, in the Kissimmee Basin, immediate attention must be focused on this comparatively small area; such attention having the potential of producing the most effective results in terms of Lake Okeechobee enrichment.

CHANDLER SLOUGH-WATER QUALITY AND FLOW

Because of the high observed phosphorus concentrations of the water entering C-38 from Chandler Slough, the District initiated an intensive study in the lower end of this drainage system. The upper reach of the Chandler Slough drainage and the Cypress Creek drainage (49 sq.mi. and 67 sq.mi. respectively) join together 3.5 miles east of C-38 and from that point flows from both drainage areas move toward C-38 across a marsh having an average width of approximately 2,300 feet and an area of about 1,000 acres.

Intensive sampling runs, involving the quality of the water both entering and leaving the marsh, were conducted during the wet season of 1974 and the following dry season. Wet season flow rates at the upper end of the marsh approximated 400 cfs; dry season flow rate was less than 50 cfs.

Dye studies were conducted in order to approximate the rate of water flow through the marsh and, from these, to estimate the water retention time on the marsh; that is, the length of time the inflow water was exposed to the nutrient assimilation mechanisms of the marsh. For the observed discharges the retention time was estimated to be about 3 days.

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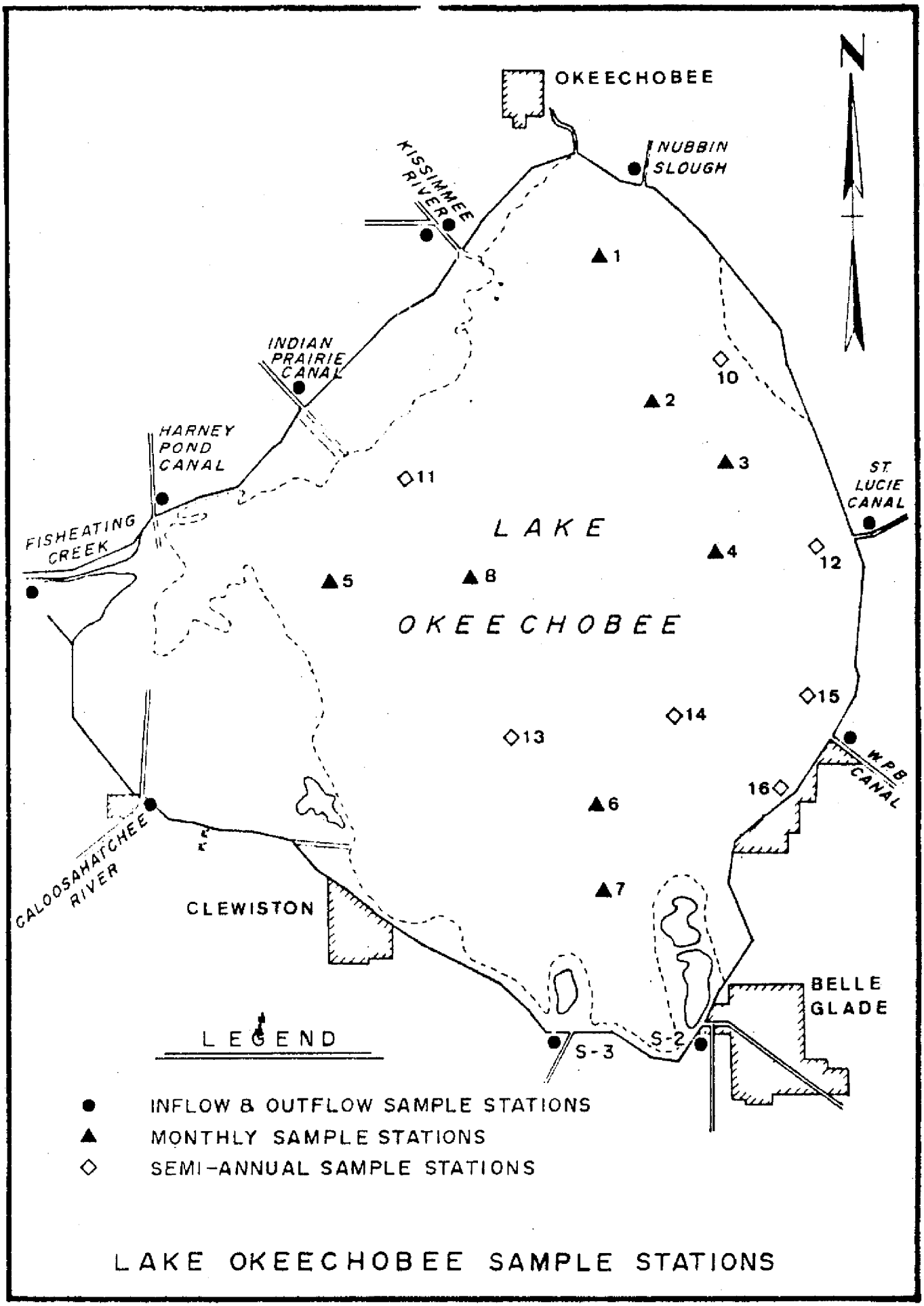
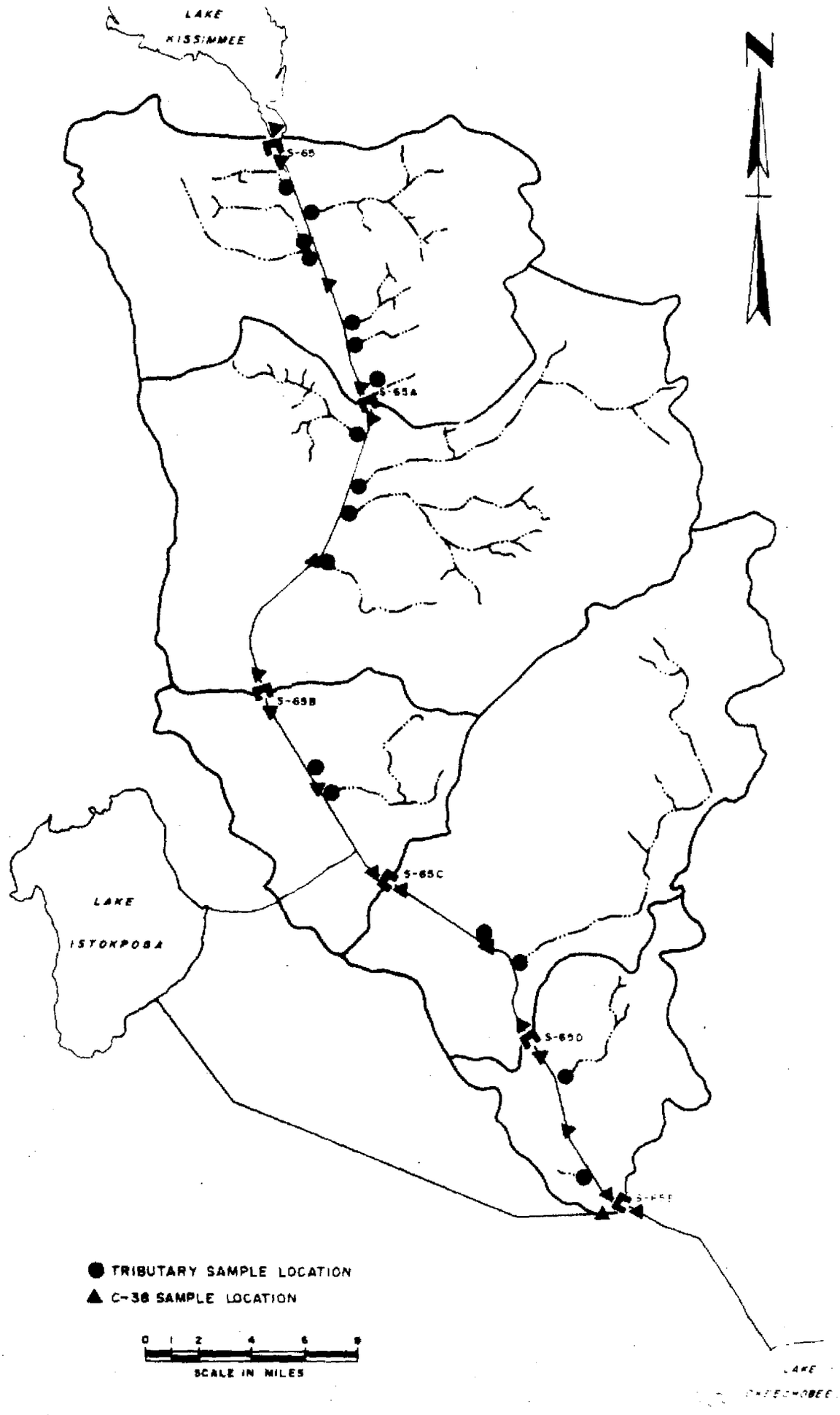
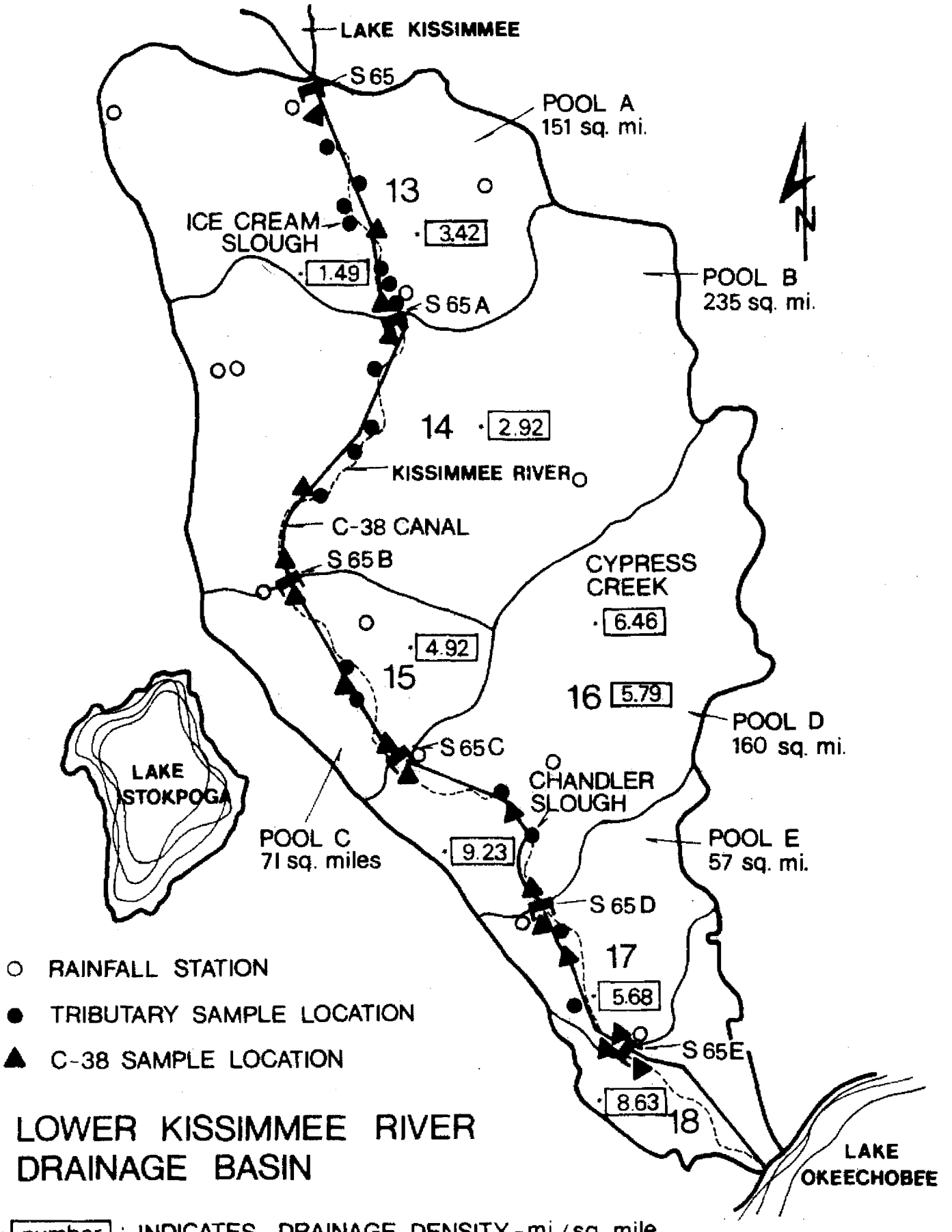
The data from this study point to a way in which to address the phosphorus enrichment question of the lower reaches of C-38 on which attention was focused as a result of realistically considering and evaluating the water quality data from the entire Kissimmee Basin.

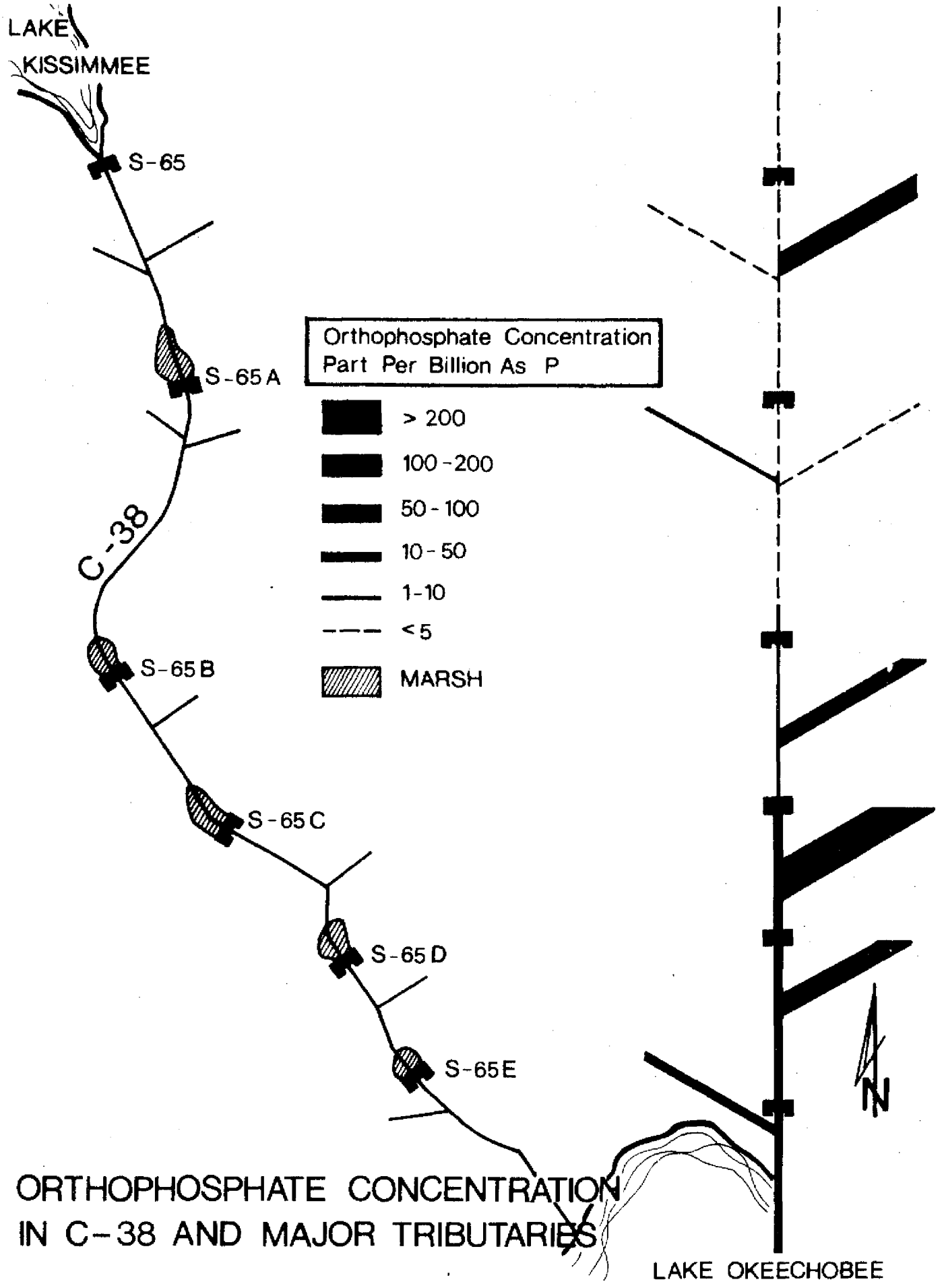


LAKE OKEECHOBEE SAMPLE STATIONS



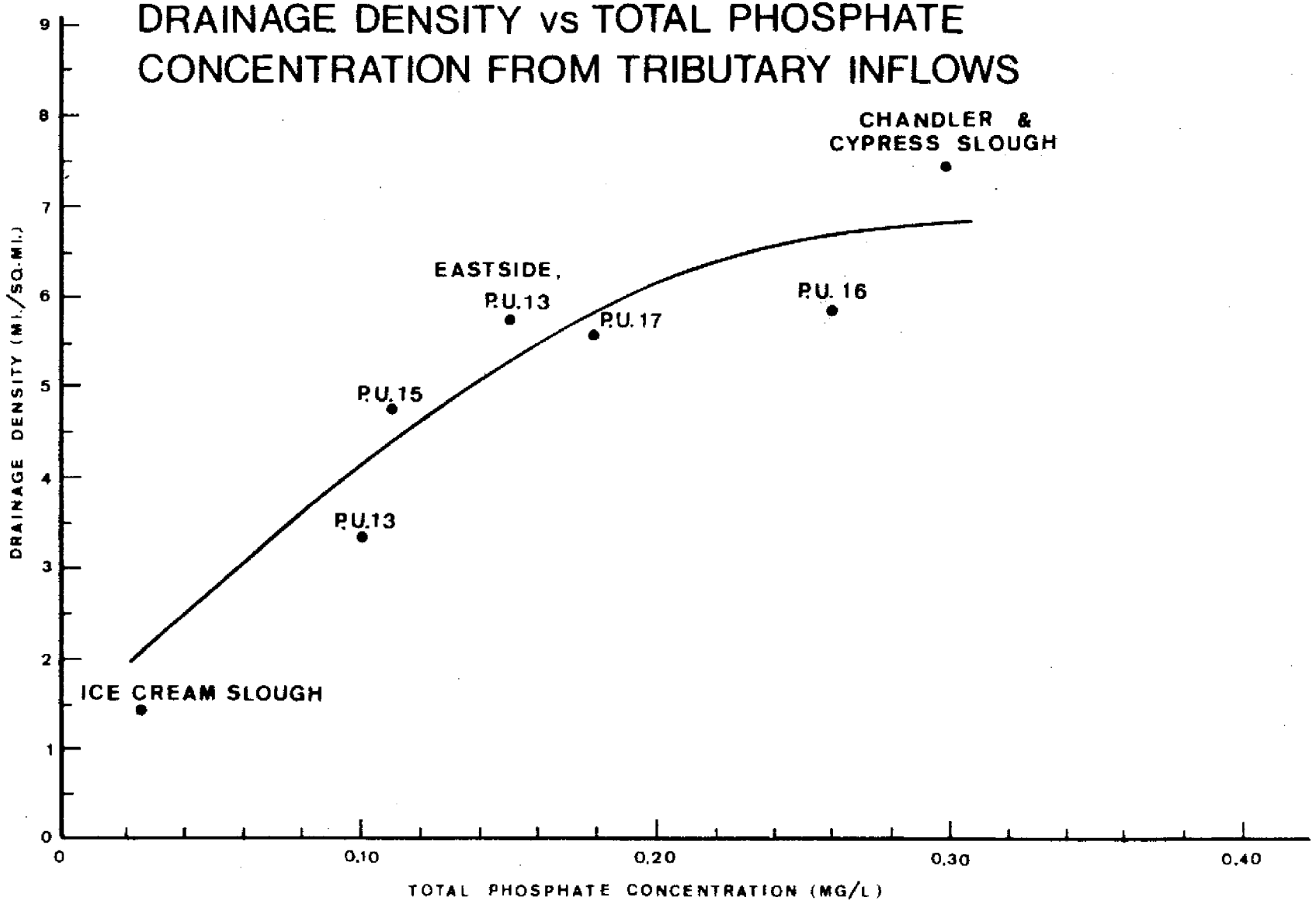
WATER QUALITY MONITORING

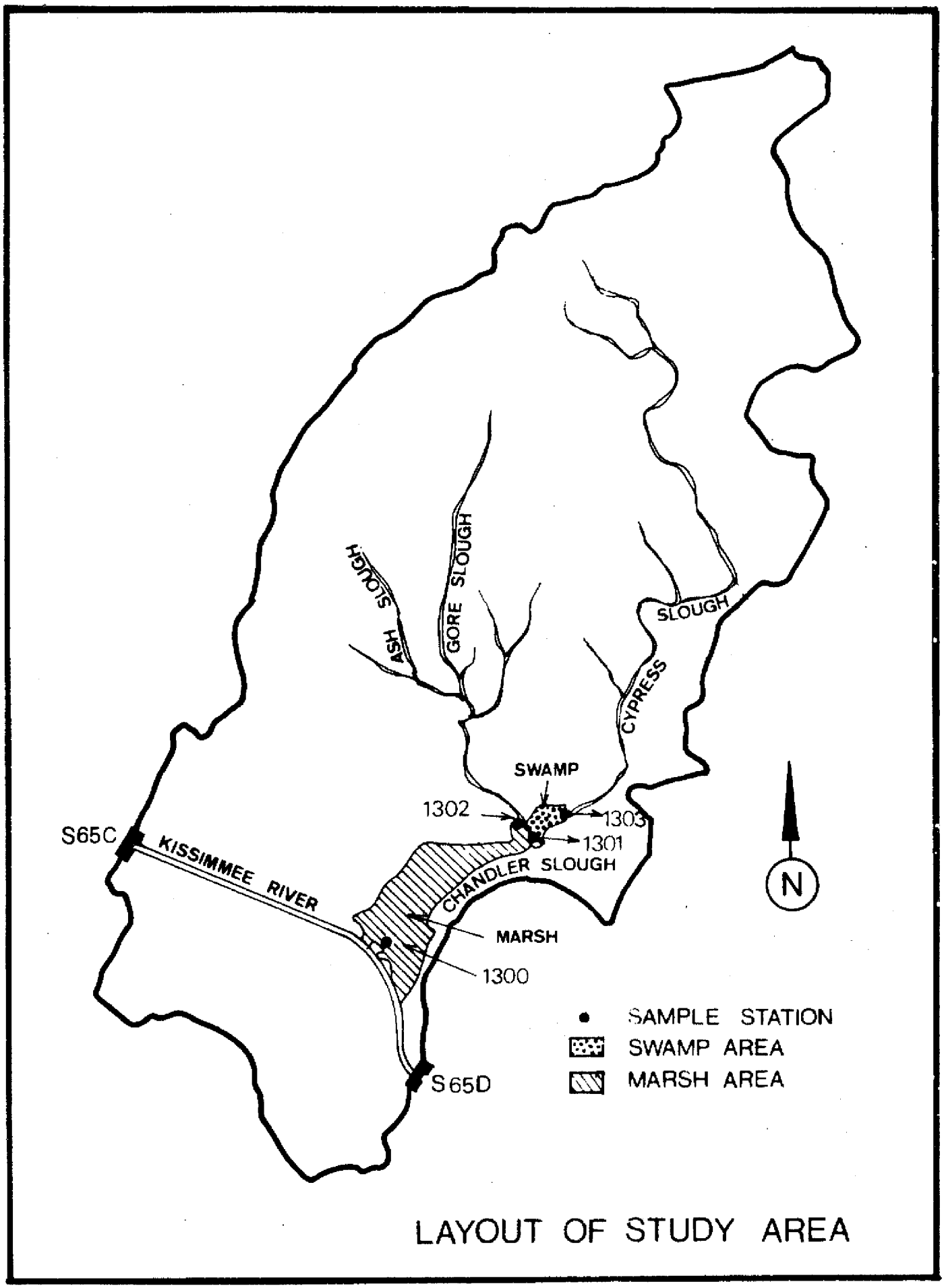

LAKE KISSIMMEE
S 65
POOL A
151 sq. mi.
13
3.42
ICE CREAM SLOUGH
1.49
S 65 A
POOL B
235 sq. mi.
14
2.92
KISSIMMEE RIVER
C-38 CANAL
S 65 B
CYPRESS CREEK
6.46
4.92
15
16
5.79
POOL D
160 sq. mi.
S 65 C
CHANDLER SLOUGH
LAKE STOKPOGA
POOL C
71 sq. miles
9.23
POOL E
57 sq. mi.
S 65 D
17
5.68
S 65E
8.63
18
LAKE OKEECHOBEE
RAINFALL STATION
TRIBUTARY SAMPLE LOCATION
C-38 SAMPLE LOCATION
LOWER KISSIMMEE RIVER
DRAINAGE BASIN
number : INDICATES DRAINAGE DENSITY - mi./sq. mile



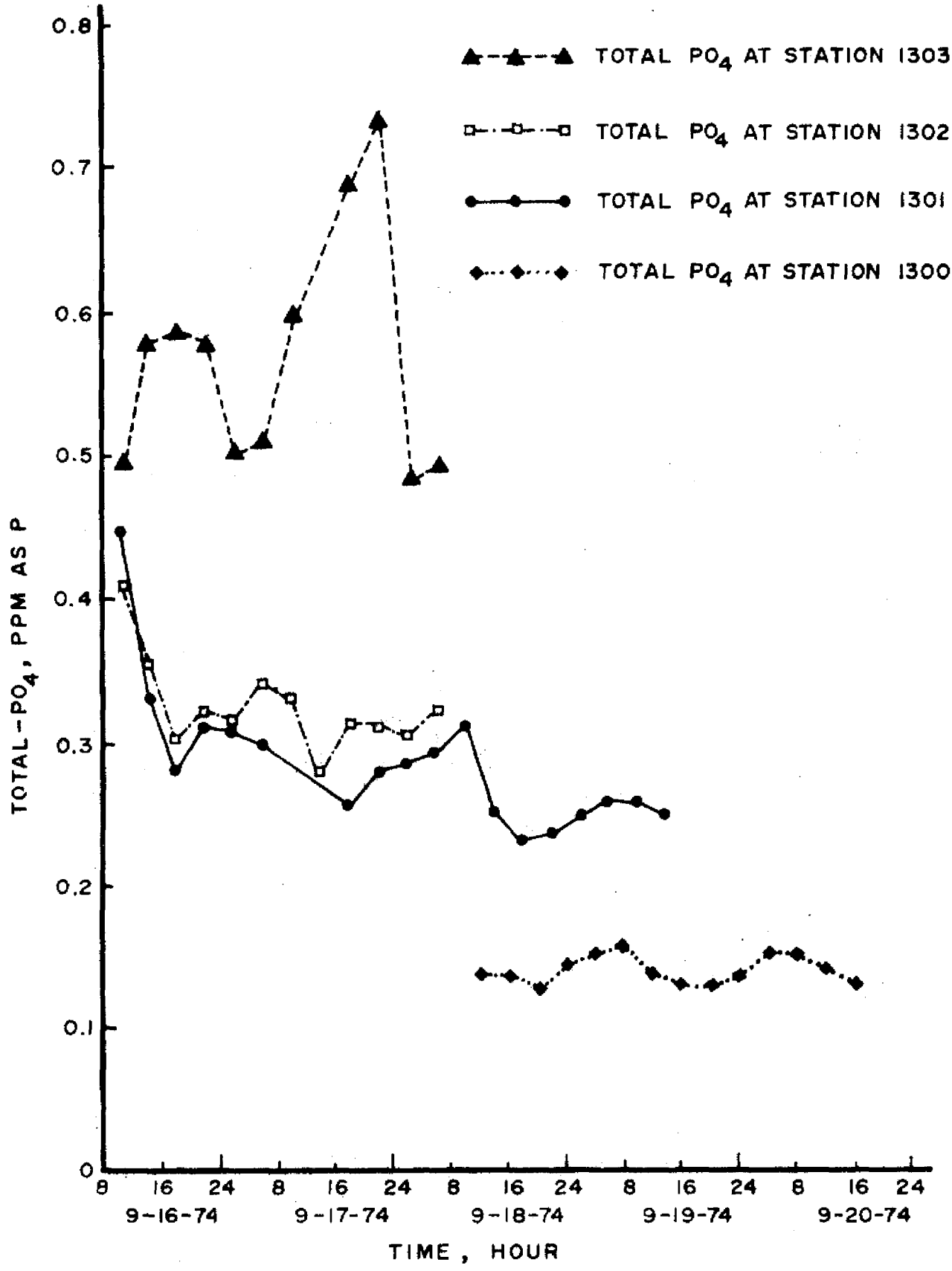
ORTHOPHOSPHATE CONCENTRATION
IN C-38 AND MAJOR TRIBUTARIES

DRAINAGE DENSITY vs TOTAL PHOSPHATE CONCENTRATION FROM TRIBUTARY INFLOWS

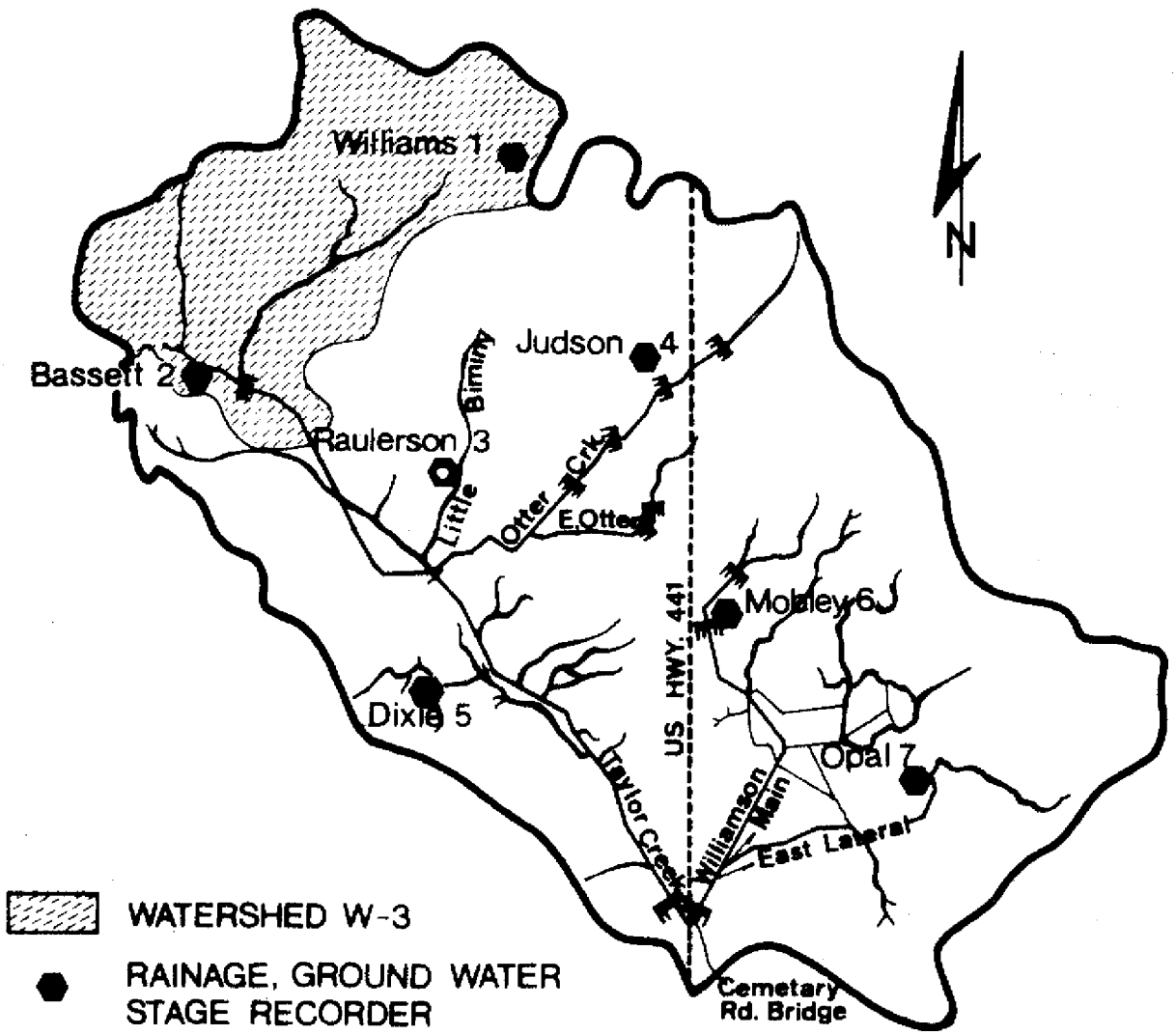




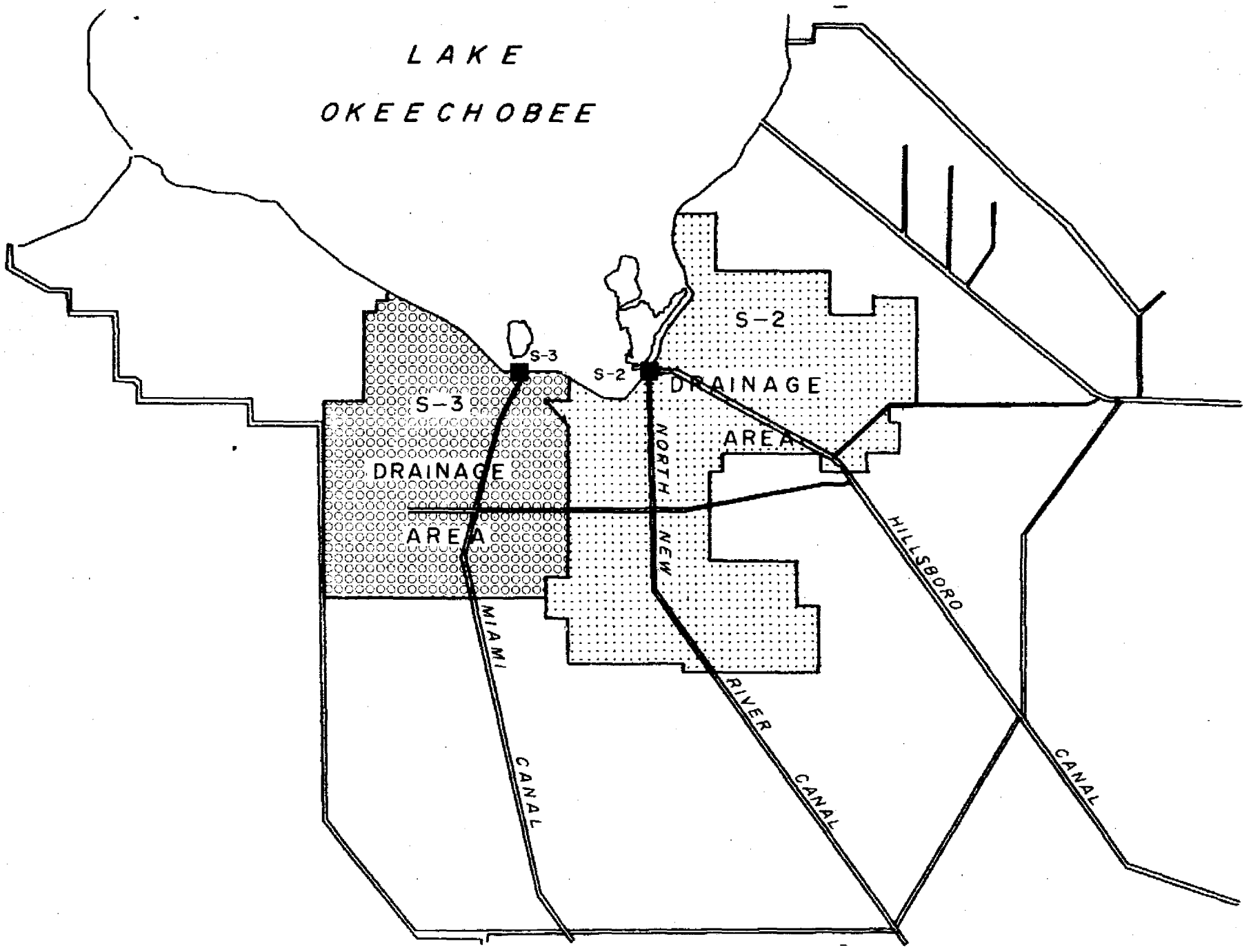
LAYOUT OF STUDY AREA



CHANDLER SLOUGH PHOSPHORUS



UPPER TAYLOR CREEK
FLORIDA WATERSHEDS W-2 & W-3



EVERGLADES AGRICULTURAL AREA
S-2 AND S-3 DRAINAGE AREAS