ILLUSTRATIONS

TABLES

DISSOLVED PHOSPHORUS IN FLORIDA WATERS

by

Howard T. Odum[1]

ABSTRACT

A basic survey has been made of the concentrations of dissolved phosphorus in many types of Florida's surface waters. The extensive deposits of phosphate rock in Florida lead to unusually high dissolved phosphorus contents in the streams and lakes which drain these areas. Thus these waters are potentially of high fertility for growth of aquatic organisms. Additional quantities of dissolved phosphorus are being added by sewage and industry in some areas, although little recognition has been made of the possibly large biological effects that relatively small amounts of added phosphorus can have on those areas which are not receiving drainage from phosphate areas. The moderately low phosphorus content of basic springs in contrast to acid surface streams suggests a controlling role of pH in phosphorus solubility in Florida. It seems likely that percolating rainwaters are continually concentrating phosphorus in the layers just beneath the surface as the acid rainwater becomes basic. The natural and artificial phosphates contributed to Florida's surface streams hypothetically seem to be of the magnitude to contribute to red tide phenomena and the rapid growth of water hyacinths in prescribed areas.

INTRODUCTION

Over the surface of the earth as a whole phosphorus is a scarce substance and much in demand as it is an absolutely necessary requirement for Man's civilization and indeed for all life. Without phosphorus no plants can grow and no food production is possible for Man or for fish and wildlife.

Phosphorus is a magic word in Florida because the extensive natural phosphate rock deposits located near the surface have directly and indirectly made many profound changes in the culture of the State. Directly, benefits such as those developing from the phosphate industry and from agricultural advances due to low cost phosphate fertilizer have resulted. Indirectly, as the evidence

[1]The writer wishes to acknowledge the able assistance of Mr. Richard Highton, Laboratory assistant.

TABLE OF CONTENTS

CONTENTS

Part I

DISSOLVED PHOSPHORUS IN FLORIDA WATERS

By

Howard T. Odum

Department of Biology

College of Arts and Sciences

University of Florida

January 9, 1953

Report to the Florida Geological Survey

in this report suggests, sports fishing, commercial fishing, red tide, water hyacinth growth, and pollution are all related to the distribution of phosphorus dissolved in the Florida fresh and marine waters.

Purpose and Scope of Investigation

The purpose of this study has been to analyze representative samples of all kinds of Florida surface waters for dissolved phosphorus and to determine what relationships there are between: dissolved phosphorus and the type of geological rock formations underlying the area; between dissolved phosphorus and the type of body of water; between dissolved phosphorus in Florida and in other regions of the world; between dissolved phosphorus and the processes of formation of phosphate rock; between dissolved phosphorus and the growth of aquatic organisms such as plants and fish; between dissolved phosphorus and the increasing problem of pollution of streams and estuaries; and between dissolved phosphorus and the spectacular red tide.

Cooperation and Acknowledgements

The data and interpretations have resulted from the cooperation between the Department of Biology of the University of Florida in Gainesville and the Florida Geological Survey with the aid of many other persons. The Department of Biology furnished the investigator and laboratory facilities. The Florida Geological Survey furnished the financial support for the assistant Mr. Richard Highton and for supplies. The Office of Naval Research through its support of another project on the productivity of Florida Springs provided considerable aid indirectly since it was possible to collect water samples in the course of this work. Mr. A. O. Patterson, District Engineer, Surface Water Branch, United States Geological Survey, Ocala, Florida, furnished a large series of samples collected by his staff throughout Florida. Mr. Ellis Landquist furnished a series from Peace River. Series of marine samples were received from Mr. William Beck, Florida State Board of Health; Mr. David Karraker, University of Florida; Dr. Harold Humm, and Dr. Nelson Marshall, Oceanographic Institute, Florida State University; Mr. Forrest G. Wood, Marineland; Mr. William Jennings, Florida Game and Fresh-water Fish Commission; Mr. K. Hansen, University of Florida, Dr. Minter Westfall, University of Florida, Dr. J. B. Lackey, Department of Sanitary Engineering, University of

Florida; Mr. Kirk Strawn, University of Texas. The study was much aided by discussions with the above especially as indicated in the text. I am grateful to Dr. A. P. Black, Mr. R. Highton, Dr. J. B. Lackey, and Dr. E. B. Phelps, University of Florida; Dr. G. A. Riley, Bingham Oceanographic Institute, Yale University; and Dr. R. O. Vernon, Florida Geological Survey for comment and criticisms on the manuscript.

Previous Investigations

Over the world as a whole a very large number of studies have established the geochemical behavior of the element and importance of phosphorus to growth on land and in the lakes and ocean. Current knowledge on this may be found in Hutchinson (1952) and Riley (1951).

In Florida although much work has been done on phosphorus in land deposits and its behavior in terrestrial agriculture, relatively little knowledge has been accumulated about the phosphorus in water. Routine analyses of waters have not included phosphorus primarily because in contrast to the usual elements analyzed it is present usually in small quantities, much less than a part per million. However, it is this low concentration that makes the element important. Along with dissolved nitrogen dissolved phosphorus has been shown to be the usual limiting factor to growth in waters in other regions.

Specht (1950) has published a series of analyses of phosphorus dissolved in fresh water of Peace River in a report on phosphorus pollution. Additional analyses of this river have been made by Florida State Board of Health but have not been published.

Some data on the estuarine and marine waters from the Miami area have been published by Miller (1952) and from waters associated with the red tide phenomenon by Ketchum and Keen (1948).

A general survey of the phosphorus over the whole State has been needed in order that the values in special situations could have comparative meaning. The results and principles of general surveys of this sort which have been done in Wisconsin by Juday, Birge, Kemmerer and Robinson (1928) and in marine waters by Redfield, Smith and Ketchum (1937) can not be directly applied to Florida because the State has extensive rock phosphate deposits *and Wisconsin does not. In turn the study of phosphorus behavior in an area where phosphorus minerals occur abundantly can contribute to the general understanding of this critical chemical element the world over.*

Methods

Samples were collected in 100 to 400 cc. soft glass bottles with vinylite lined plastic caps. About two-thirds of the samples collected received several drops of chloroform in order to reduce the fixation by adsorption and bacteria of the dissolved phosphorus on the walls of the bottles. Where the quantity of phosphorus present is in concentrations of the magnitude of .020 ppm., the loss to bottle walls has been shown to be appreciable (Harvey, 1948). Phosphorus is present in waters as fine particulate matter, as dissolved organic compounds, and as dissolved inorganic phosphate. Except in a few cases no attempt was made to distinguish between these fractions because the partition of phosphorus changes rapidly due to the action of organisms in the sample bottles. Thus with the delay inherent in the sampling, it was only feasible to make determinations of total phosphorus in most cases. The total phosphorus is of primary interest because in the course of one day the phosphorus in a natural body of water may fluctuate between an inorganic fraction and an organic fraction during phytoplankton plant photosynthesis and decay.

Samples of 100 cubic centimeters were digested with acids over a hot plate to convert all fractions into inorganic phosphorus, a procedure used by Robinson and Kemmerer (1930). When this solution was diluted to 50 cubic centimeters, a blue color developed proportional to the phosphorus content. The intensity of color after five minutes was measured in a Klett Summerson colorimeter. A graph was prepared of the color intensity of known standards that had been treated in the same way as the samples. The concentration of phosphorus in unknown samples was obtained from this graph. With homogeneous materials this method has been reported with an accuracy of reproducibility of 5-10%. For a single series the data in Table 1 and the data for Silver Springs (Table 2) indicate a similar accuracy in these analyses. However for heterogeneous materials and for the lower concentrations it is likely that the errors are considerably greater. Fortunately the types of differences discussed below seem to be much greater than can be accounted for as experimental error by the largest estimate.

TABLE 1

TECHNIQUE TEST ON KNOWN STANDARD SOLUTIONS

Known concentration:	.033	.033	.033
Date of series:	July 12	July 13	July 13
Procedure:	Without Digestion	Without Digestion	With Digestion
Analyses:	.032	.036	.032
	.033	.040	.035
	.032	.036	.035
	.026	.030	.035
	.032	.028	.032
	.033	.038	.037
	.035	.028	.033
	.030	.033	.030
	.035	.030	.033
	.038	.034	.035
Mean:	.0326	.0333	.0337
Standard Deviation	.00327	.00421	.00205
With the amount of variation above, 95% of analyses made will be within the following percent of the correct value:	22%	29%	14%

Test of Phosphorus loss by digestion over hot plate	ppm P
Digestion continued until boiling stops	.120
Digestion continued until boiling stops	.127
Digestion continued 40 seconds after boiling stops	.125

TABLE 2

PHOSPHORUS VALUES IN SILVER SPRING RUN

August 9, 1952

	ppm P	
	Inorg. P	Total P
Boil	.041	.047
1/8 mile	.045	
1/2 mile	.045	.047
1 mile	.040	.046
1 1/2 mile	.051	.053
2 miles	.043	.046
2 1/2 miles	.042	.046
3 miles	.041	.041
4 miles	.040	.048
5 miles	.043	.046
Mean	.0431	.0466
Standard Deviation	.00332	.00307
95% of analyses can be expected to have less error than:	15%	13%

Organic phosphorus .0035 ppm 7.5% of Total

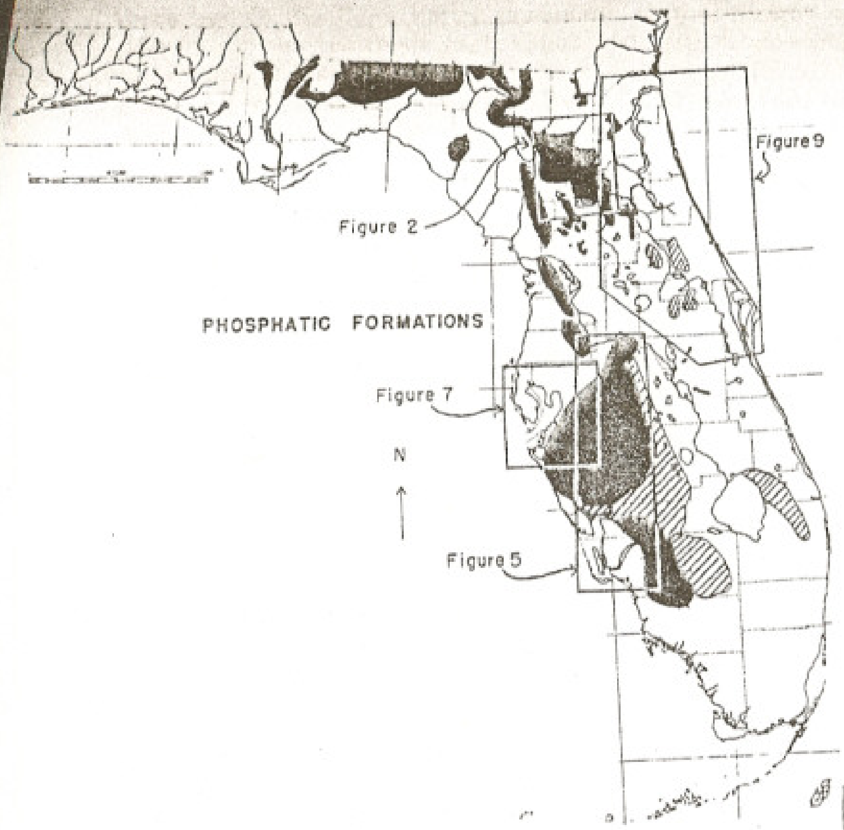

Figure 1.—Surface phosphate-bearing formations. (Position of formations after Cooke, 1945)

In waters that are highly saline the blue color has been shown to be depressed by some interaction with the salts (Robinson and Thomson 1948). This error is usually compensated by analyzing standards to which low phosphorus sea water has been added and deducing a correction usually between 1.1 to 1.35. In this survey a correction of 1.2 was used for saline waters. However for these very varied waters of contrasting qualitative salt compositions and varying salinities, considerable error has necessarily been incorporated by such a procedure. Thus the error is possibly 20% greater for saline than for fresh waters. The analyses include any small quantities of arsenic which may act with phosphorus in this test.

PATTERNS OF DISTRIBUTION OF DISSOLVED PHOSPHORUS

Dissolved Phosphorus and Geological Formations

In general most of the dissolved contents of waters are derived from the rocks over which the waters flow. Thus it is a reasonable hypothesis to expect the dissolved phosphorus in waters to correspond to the type of underlying rock.

The phosphate bearing formations in Florida are primarily the Miocene Hawthorn formation, Alachua formation, and Duplin marl and the Pliocene Bone Valley formation. The areas of outcrops of these rocks in Florida are shown in figure 1.

The streams that cross these formations and the total phosphorus content of their waters in parts per million are shown in figures 2, 3, 5, 7 and 9. In much of Florida a close correlation exists between the phosphate areas and the dissolved phosphorus in

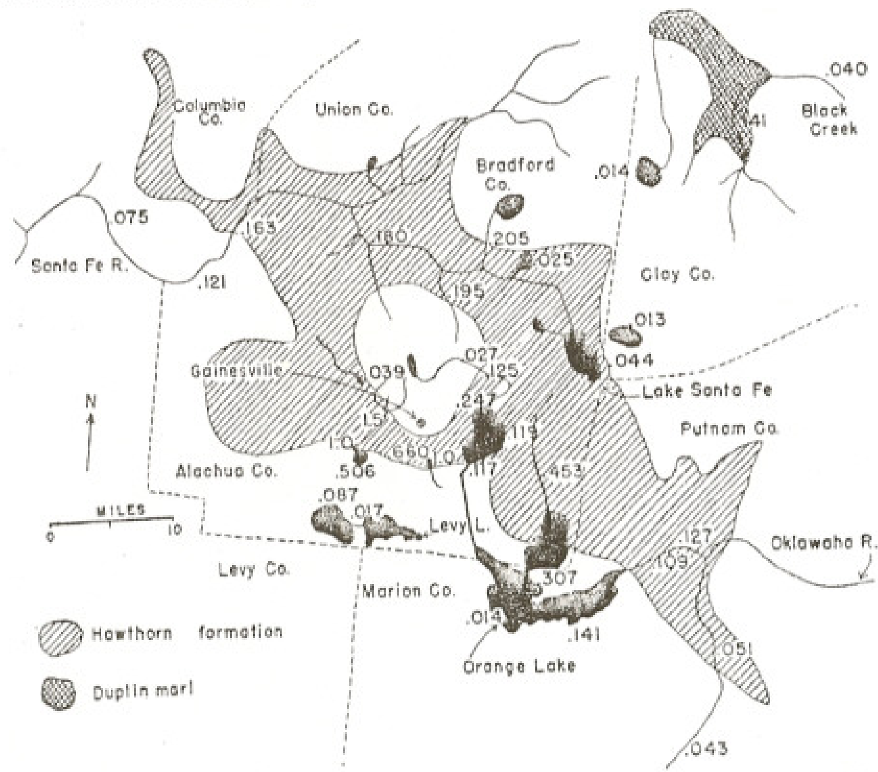

Figure 2.—Dissolved phosphorus in the region of Gainesville, Florida, and the phosphatic Hawthorn formation. (Position of formations after Cooke, 1945)

the waters. The correlation seems good in the north central Florida area and in the Bone Valley phosphate mining district in central Florida. Some relatively high values that are not associated with phosphatic geological formations are due to pollution. Some deposits are not crossed by major streams and therefore correlative data are lacking on these. The analyses for Alachua County, figure 2, show the manner in which the dissolved phosphate reflects the geology. In figure 3, lines of equal phosphate concentration have been drawn over the whole State much as one would draw lines of equal height on a topographical map. These are of course approximations but serve to emphasize the superposition of areas of high dissolved phosphate concentration over known phosphate deposits.

Deevey and Bishop (1940) had shown in Connecticut that crys-

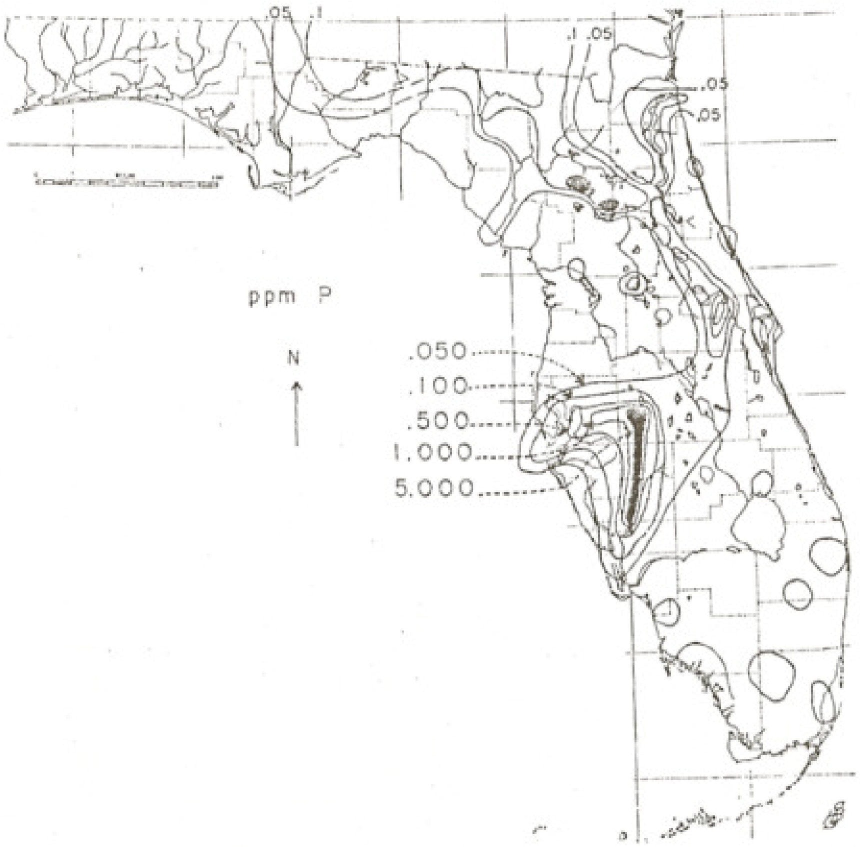

Figure 3.—Dissolved phosphorus in Florida Waters.

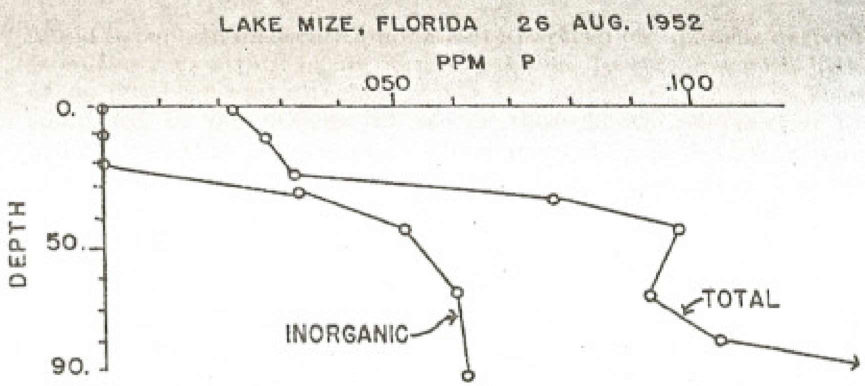

Figure 4.—Dissolved phosphorus in Lake Mize, Florida during summer stratification.

talline rock areas possess slightly lower dissolved phosphate contents than the central lowland sedimentary area. These results confirm in a striking way the general principle of the geologic control of phosphate content of the waters, and it is possible that future prospecting may be facilitated by analyses of dissolved phosphates in stream systems.[2] It has long been known that dissolved phosphorus is so scarce in the ocean that it is rapidly removed by phytoplankton and lost to the deeper water through sedimentation of organic detritus so that the upper ocean waters are maintained in an impoverished condition receiving a little phosphorus for growth only from turbulent exchange of the element brought up from the deeper waters and in from rivers (Riley, 1951). The analyses of estuarine waters of Florida further document this pattern by showing that Charlotte Harbor and Tampa Bay are one of the richest phosphatic areas and receive more dissolved phosphate from streams than any other estuary in Florida.

Dissolved Phosphorus and the Type of Water

The essential features of the distribution and circulation of phosphorus within streams, lakes, ground waters, and estuaries have been established in other regions (Juday, Birge, Kemmerer, and Robinson 1928; Mortimer 1941-1942; Hutchinson 1941; Newcombe 1940). In general, streams and ground waters have been

[2]It is amusing to remember the excitement that arose in the laboratory when waters from the Econlochatchee River were found to possess relatively enormous phosphorus concentrations although no phosphate districts were in the drainage. It was learned that a recent shift in the disposition of the Orlando sewage into this river accounted for these values.

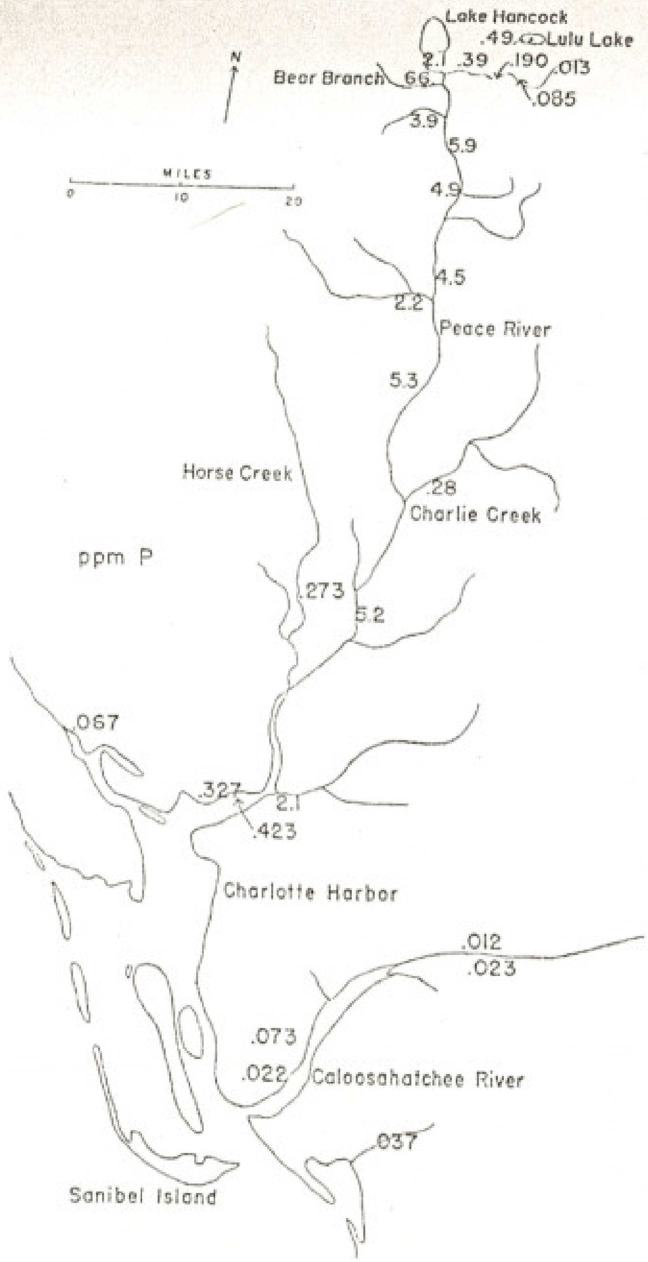

Figure 5.—Dissolved phosphorus in the Peace River system. Data obtained in cooperation with Mr. Ellis Landquist.

found to contain moderate amounts of dissolved phosphorus derived from the rock strata in an inorganic form. In streams with little or no plankton and attached plants the volume of water is large compared to the number of plants that derive phosphorus for growth and thus there is more phosphorus than is needed in plant metabolism. But the situation shifts when these waters flow into lakes where the relatively still waters in the upper levels support microscopic floating plants which take up the phosphorus and convert it into the phosphorus of organic matter. Then the lack of phosphorus often becomes limiting to plant growth. When these tiny single celled plants are eaten by microscopic plankton animals, the phosphorus may be transferred into other organisms and eventually returned to the water as dissolved organic phosphorus or deposited on the bottom as particulate phosphorus. Thus the inorganic phosphorus in shallow lakes and in the upper levels of deeper lakes is small and the organic phosphorus is only a little more. But in the bottom waters of the deeper lakes much larger concentrations of phosphorus are found during the summer stratification. Here the chemically reduced conditions associated with lower oxidation reduction potential and sometimes lower pH and the absence of green plants cause more phosphorus to remain in solution both as dissolved inorganic phosphorus and dissolved organic phosphorus. Thus the processes within the lake remove phosphorus from water as it flows through the lake and deposit it in the lake's lower waters and sediments. It has been shown thus

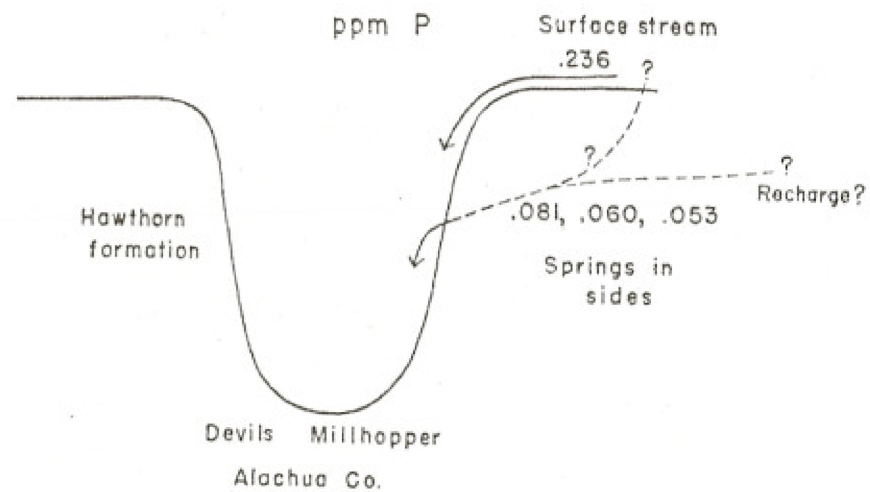

Figure 6.—Dissolved phosphorus in the Devils Millhopper, Alachua Co., Florida.

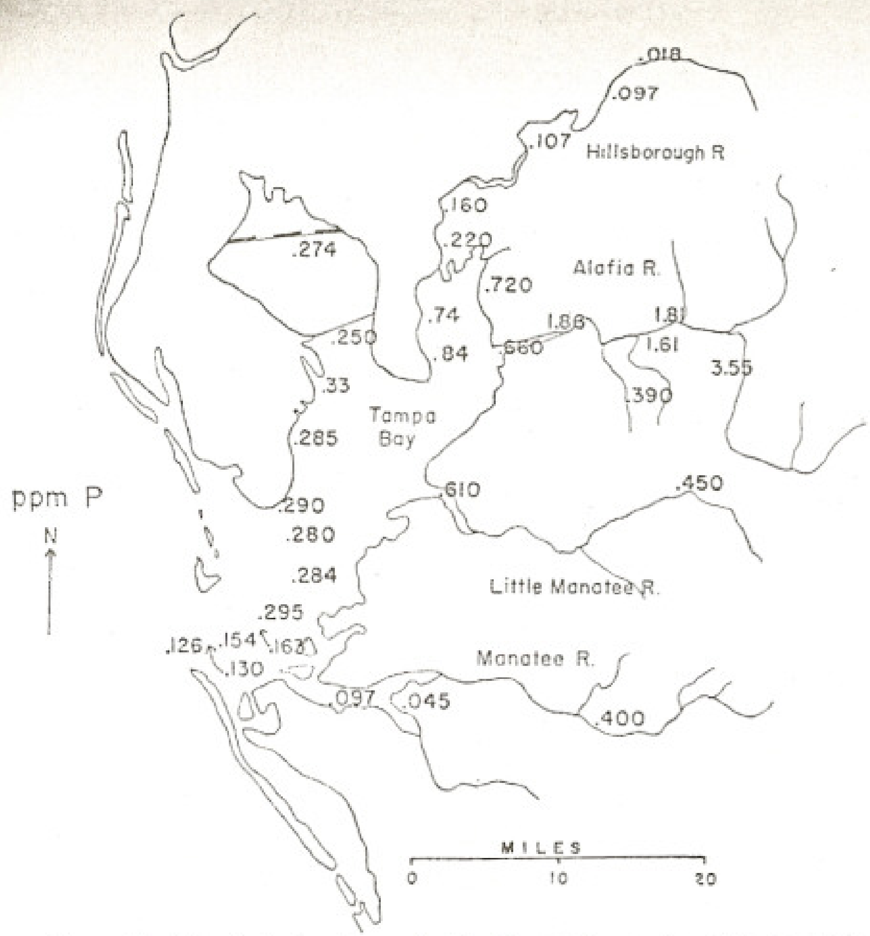

Figure 7.—Dissolved phosphorus in the Tampa Bay region, Florida. Data obtained in cooperation with Dr. Nelson Marshall, Florida State University in the fall, 1952.

that lakes are a phosphorus filter as in River Sussa, Denmark (Berg, 1945). In a similar manner, when phosphorus laden river waters reach the sea the phosphorus is removed and deposited on the bottom of the ocean in the sediments. Estuarine waters are zones of mixing where the phosphorus content is intermediate between rivers and sea.

With the above introductory account of the occurrence and distribution of phosphorus in natural waters, it is interesting to compare data from Florida as summarized in tables 2, 3, 5, 6, 7. It

will be noticed that streams are high and in fact enormously laden with phosphorus in the phosphate districts. The lake waters at the surface have smaller amounts than the streams because of the filtering action of the lakes. Estuarine waters contain more phosphorus than open water, as reported in the literature, but somewhat less than the streams from which the phosphate is derived. In comparison to lakes, streams and estuaries which receive high values in phosphate areas, the spring waters have moderate values irrespective of the area in which they occur. As shown in the Silver Springs analyses the springs have primarily inorganic phosphate, the organic phosphorus having been removed by the soils and rocks of the recharge areas. The spring waters in these limestone areas are basic so that little calcium phosphate is dissolved and very little can be held in solution. Thus pH is critical in regulating the amounts of dissolved phosphate of inorganic form but not that of the organic phosphorus. The solubility of calcium phosphate under a variable pH is represented in Table 4. However, calcium phosphate is found in nature usually in some type of apatite mineral, a complex chemical composition, upon which no such solubility tables are available.

TABLE 3

MEAN VALUES OF PHOSPHORUS IN TYPES OF FLORIDA WATERS

Water Types	ppm Total P: Phosphate District	ppm Total P: Other
Streams	.876 (18)	.046 (44)
Estuaries	.269 (2)	.044 (21)
Lakes	.290 (8)	.038 (31)
Springs	.061 (5)	.045 (27)

(The number of different bodies of water average in each case is indicated by the figure in parentheses).

TABLE 4

SOLUBILITY OF INORGANIC PHOSPHORUS AS A FUNCTION OF CALCIUM AND ACIDITY. (Based on theoretical data of Green and Holmes (1947) for 68 deg. F.)

Acidity as pH	Calcium ppm .4	4.	12.	20.	40.	80.
6.0	Greater					33.
6.5	Than			33.	12.	4.
7.0	40. ppm		10.	4.	1.6	.33
7.5		8.	1.6	.66	.3	.10
8.0		2.3	.33	.16	.066	.026
8.5	27.	.33	.16	.066	.026	.007

Dissolved phosphorus in ppm

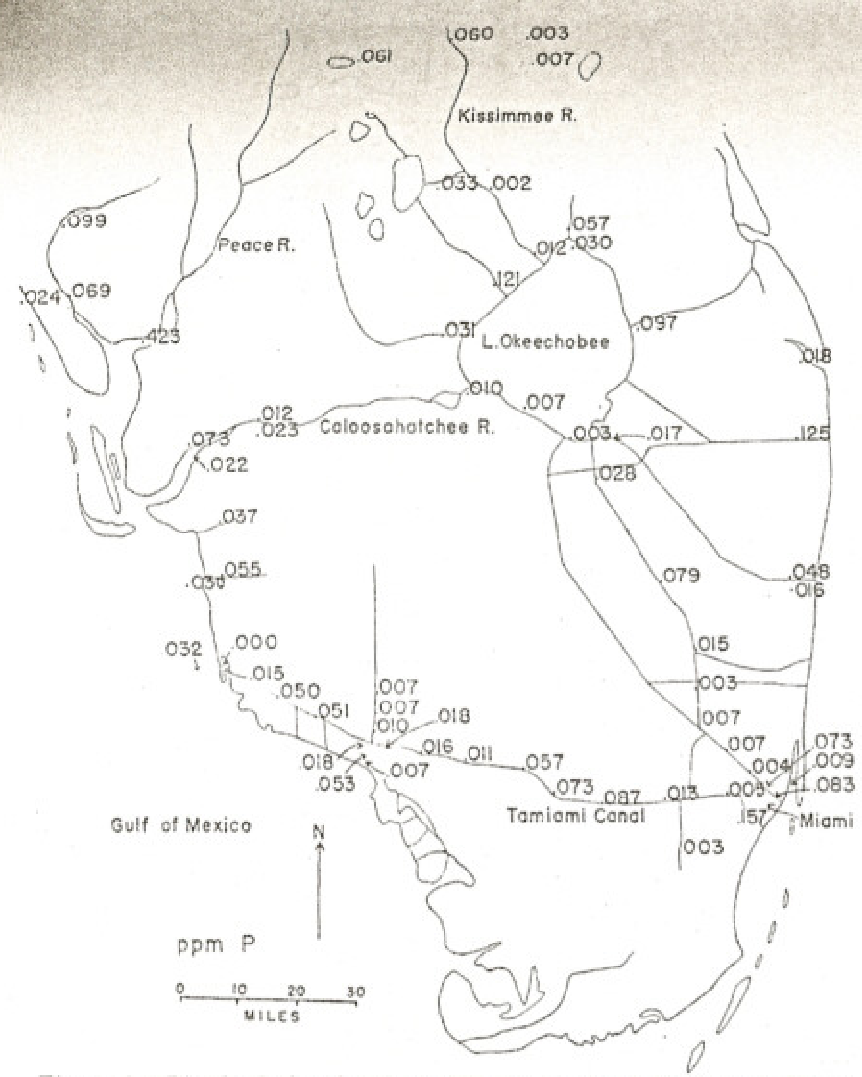

Figure 8.—Dissolved phosphorus in the rivers and canals of south Florida during August 1952.

Among the lakes there are great ranges of phosphate contents just as there are great ranges of conditions such as hardness, carbon dioxide and color. The vertical pattern of phosphorus distribution within Lake Mize, Florida, is similar to that of Lake Mary, Wisconsin, although the values are much higher for these two lakes than for most of the other lakes reported in Wisconsin or elsewhere

(see figure 4 and Juday and Birge, 1931). These lakes are similar in being deep soft seepage lakes with high phosphates possibly due to low pH. Lake Mary, Wisconsin, is very atypical. It is not known whether the stratification of phosphorus in Lake Mize is typical for Florida's relatively few deep lakes.

TABLE 5

REGIONAL COMPARISONS OF DISSOLVED PHOSPHORUS IN LAKES

(Modified from Hutchinson, 1937, 1952)

	ppm P Mean	ppm P Range
HUMID CLIMATE; EXTERNAL DRAINAGE:		
N. E. Wisconsin (Birge and Juday)	.023	.008—.140
Connecticut (Deevey)		
Eastern Highland	.011	.004—.021
Western Highland	.013	.007—.031
Central Lowland	.020	.010—.031
Japan (Yoshimura)	.015	.004—.044
Austrian Alps (Ruttner)	.020	.000—.046
Sweden (Lohammar)		
Uplands	.038	.002—.162
South	.026	.004—.092
North	.024	.007—.064
North Germany	.077	.005—.600
Florida		
Phosphate districts	.290	.100—.660
Other districts	.038	.000—.197
Gran Chaco, Paraguay (Carter and Beadle)		.5 —1.5
ARID CLIMATE; INTERNAL DRAINAGE; SALINE LAKES:		
Nevada (Hutchinson)	.90	.05—3.0
Aegean (Stankovic)	......	.097—.45
Central Africa (Beadle)	......	.16 —.76
South Africa (Hutchinson, Pickford, Schuurman)	......	.05—2.0
Indian Tibet (Hutchinson)	......	.023—.30
Owen's Lake, California	76.	—
Salt Range, Punjab (Hutchinson)	.17	—
Goodenough Lake, British Columbia	208.	—

The data in Table 6 indicate that some of the lowest values are found in waters where attached littoral plants have possibly had a rôle in depleting the waters such as in marshy pools surrounding lakes, pools along roads, and small lakes without appreciable drainage in the sandhills. The action of a lake in filtering phosphorus is illustrated in figure 2.

Data from analyses of water entering Orange Lake from the north and discharging eastward into the Oklawaha River show a marked decrease in phosphorus content. Also in figure 2, the waters entering Newnans Lake, the moderate sized lake just east of Gainesville, show a drop from a phosphorus content of .247 to .117 ppm.

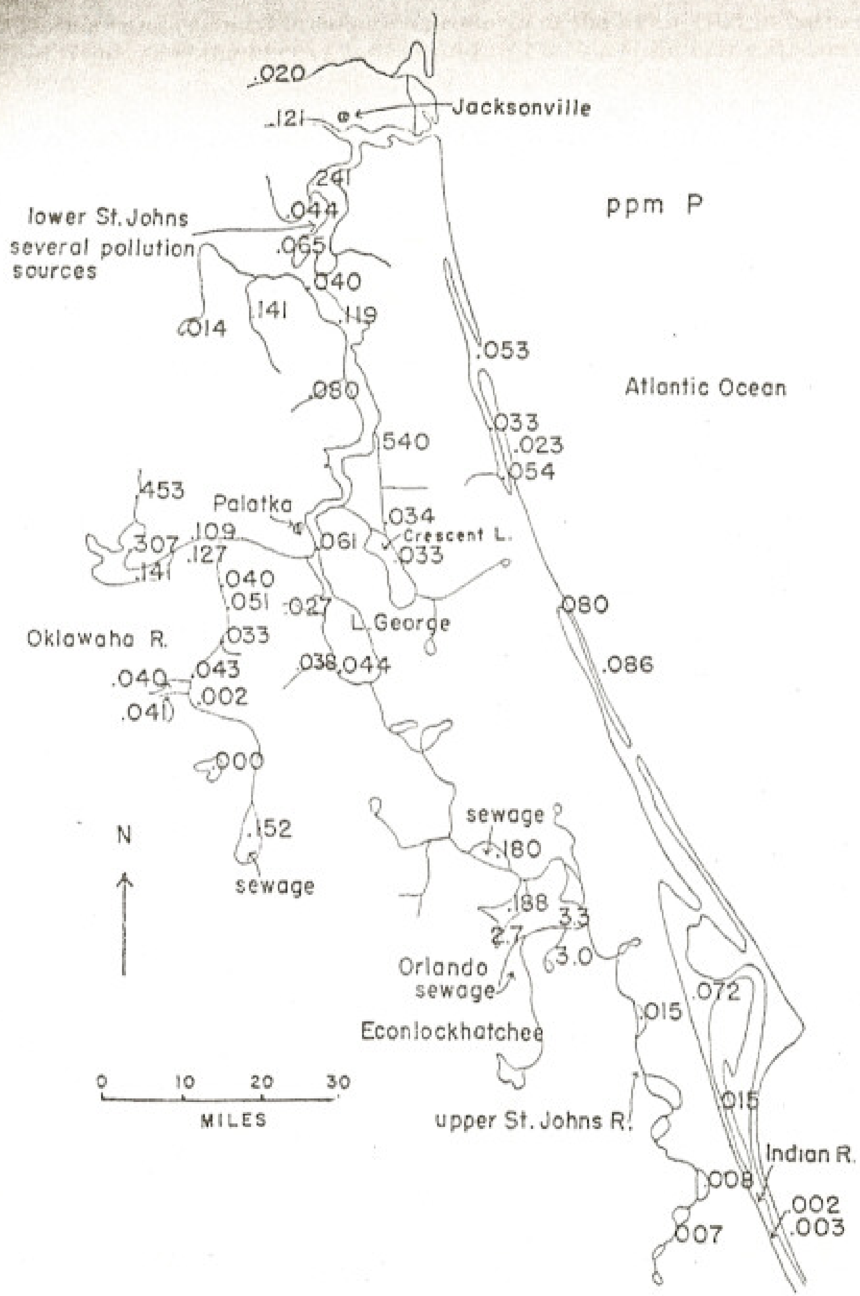

Figure 9.—Dissolved phosphorus in the St. Johns River system.

The general impression that one obtains, that water filled sinks are often fertile, is supported by the analyses of phosphorus. Apparently the water filling the basins are phosphorus laden in contrast to the deeper artesian aquifers as represented by the large springs which have moderate phosphate values.

TABLE 6

PHOSPHORUS IN FLORIDA LAKES AND STREAMS

Standing Waters:	Cases	ppm P Mean	Range
Grassy, sand bordered lakes	6	.008	.001— .014
Flatwoods ponds	4	.151	.030— .43
Sinks	4	.320	.028—1.01
Lakes with organic mud borders and extensive water hyacinths	5	.298	.100— .51
Larger lakes receiving sewage (Jessup, Monroe, Griffin, Lulu, Reedy, Tohopekaliga)	6	.185	.042— .49
Larger lakes not receiving sewage or phosphate district drainage (Geneva, Brooklyn, Kingsley, Eustis, Ola, Weir)	6	.007	.000— .014
Streams:			
Small streams, not polluted, not draining phosphatic formations	18	.019	.003— .034
Small, humic watered creeks, draining phosphatic formations, no pollution, generally acid	10	.413	.141—1.5
Streams not draining phosphate formations but receiving sewage	7	.836	.038—3.1

The classification of analyses according to the type of water as given in Table 6 suggests some relationship between the percentage of dissolved phosphate and the type of lake water but a general classification of the water types biologically is one outstanding problem not yet completed. In Table 6, it should be noted that the high phosphate contents are found in small acid streams which had relatively short surface courses since falling as rain. The more basic waters which have received ground waters and salts have lower values depending of course on the rocks through which the water passed.

Ohle (1934) found higher values in German dystrophic waters (brown waters) than in clear waters. Similar results noted in Florida are suggested as due to the soft acid nature and to the course of these waters. Also Barbier and Maroger (1950) have shown that colloidal humates increase the amount of calcium phosphate that is dissolved by binding action. Humates are brown molecular and colloidal breakdown products of the lignin that in natural wood holds the fibers together and in Florida stain many streams brown.

Dissolved Phosphorus in Florida Compared with Other Regions

Since Florida has such large resources of phosphate rock, it is reasonable to expect Florida's waters to contain on the average higher phosphorus concentrations than most other regions of the world. G. E. Hutchinson, in an unpublished manuscript, collected data on dissolved phosphorus in lakes to which averages of Florida data have been added and both are presented as Table 5. This table indicates that Florida has higher dissolved phosphorus concentrations than the rest of the world with humid climate, with the possible exception of those districts elsewhere that indicate major phosphate deposits. Of those analyzed only the salt lakes in arid parts of the world show higher phosphate contents than those of the phosphate districts of Florida. It is interesting that the areas that are most similar to Florida are the sedimentary North Germany area, which resembles Florida in some respects such as elevation and general geological structure, and the Gran Chaco of Paraguay, which has a somewhat similar climate. In contrast, waters in crystalline rock areas are low and the older and more modified sedimentary areas are intermediate in dissolved phosphorus concentrations such as shown for Connecticut and Sweden in Table 5. It is likely that other areas of the world possessing phosphate districts, such as North Africa, Idaho, Esthonia, Egypt, etc., (Johnson, 1952), would similarly possess high dissolved phosphorus.

Dissolved Phosphorus and the Origin of Phosphate Deposits

No wholly satisfactory explanation has become accepted for the origin of Florida's extensive and varied phosphate deposits. The status of knowledge on this is discussed in detail by Vernon (1943, 1951). Apparently a combination of initial deposition of phosphatic minerals, bones and teeth in marine and terrestrial sediments followed by a possible later concentration of these parts of the sediments have produced the existing deposits. Although there is little evidence of phosphate deposition during the Recent, other than at bird and mammal rookeries, following the hypothesis of uniformitarianism we look at contemporary Florida for answer to the processes in past geologic time for there is little evidence

that Florida is geologically much different now than it was in the Tertiary times.

An examination of the data on dissolved phosphate from the present Florida waters suggests two things: First, the marine estuarine deposits now forming off some rivers are forming in the presence of relatively high phosphate concentrations so that these sediments may be expected to contain a proportionately high phosphate content. Miller (1952) has shown for Biscayne Bay in the Miami area that the ratio maintained between dissolved phosphorus and the sedimentary phosphorus is about 1/1000. The high phosphorus contents of the rivers moving into sea water are possibly supersaturated in relation to the high calcium, basic, ocean waters as estimated theoretically by Dietz, Emery, and Shepard (1942). Second, the highest dissolved phosphorus contents have been found where soft acid streams crossed phosphatic formations suggesting that acidity regulates the amount of phosphorus which becomes dissolved.

Since the basic spring waters are moderately low in dissolved phosphorus, even in phosphatic districts, it seems that phosphorus may become dissolved in the surface drainage water but becomes removed again as the ground water passes through deeper strata. This suggests a mechanism by which the deposits already rich in phosphorus now found most abundantly a few feet below the surface have been enriched. First the phosphorus is dissolved and then redeposited as the water becomes more basic on reaching the deeper ground water levels and as the initial carbon dioxide acidity is neutralized with the limestone. Those acid surface waters moving down surface streams to the sea gradually become basic but much of the dissolved phosphorus by this time is converted into the organic phosphorus of plant and animal matter in particulate, colloidal, and dissolved form so that it remains in solution in estuarine waters for some time in spite of high pH. Thus the difference observed between the high phosphorus content of acid surface water and the low phosphorus content of more basic ground waters indicate that phosphorus leached out of one layer can be precipitated in the rocks through which it may pass or that the ground water was relatively free of phosphorus at the recharge area.

That enrichment of phosphorus may occur in existing formations due to the above causes does not imply that the present phosphatic formations are themselves older formations concentrated by leaching. The Alachua formation of Florida (Vernon, 1951) is typical of those phosphate deposits formed by the fixation of phosphatic acid solutions through reaction with carbonate rocks. Vernon (1951) using detailed stratigraphic data from Citrus and Levy counties, Florida, found that Miocene phosphatic formations (Hawthorn and Duplin marl) were probably laid down in shallow seas adjacent to a land mass upon which the phosphate of the Alachua formation was forming. He feels that the high phosphate content of these formations was derived from a high dissolved phosphate level in the sea and adjacent land at the time of formation.

The solubilities of calcium phosphate in fresh water of varying acidity shown in Table 4, have been modified from Green and Holmes (1947). These solubilities are based on the theoretical equation for the solution of excess tricalcium phosphate under equilibrium conditions, and in the ionic strength of fresh water. Although these assumptions rarely correspond exactly to natural conditions, the important rôle of pH and calcium concentration is demonstrated nevertheless. Acid soft water streams have capacity for taking up very large concentrations of phosphorus mineral matter through which they pass whereas basic hard waters such as in Florida's ground waters, even at equilibrium can hold less than one part per million. The values for the large typical Florida Springs of .020—.123 ppm P with pH ranges mostly between 7.3 and 8.3 with calcium concentrations 30 to 70 ppm are only slightly above those predicted by Table 4.

For salt waters the assumption used in calculating these data do not apply, for solubilities of many substances in saline waters are greater due to the greater ionic strength. The greater ionic strength in part counteracts the effects of high calcium in sea water. However, from similar calculations based on greater ionic strength Dietz, Emery, and Shepard (1942) found that the ocean is possibly saturated with phosphorus. The unusually high phosphorus values reported in Tampa Bay and Charlotte Harbor are of course total values including organic and colloidal fractions. Note that if some source of acidity such as industrial pollution should lower the pH much greater phosphate solubilities are possible and although later neutralized this mechanism would permit the introduction of high phosphate concentrations into organic fractions and into colloidal and soluble form. Bear Branch, which receives wastes from a superphosphate plant near the town of Bartow, was reported by Mr. Ellis Landquist in his biological

study of the Peace River during 1950-51 to possess a pH range from 2.5 to 6. Such acidity accounts for the dissolved phosphate contents up to 177 ppm phosphorus in this branch. Although subsequently diluted by the Peace Creek, the high values of 5 ppm which persisted in the Peace Creek below this point (see figure 5) seem to have been due to this pollution since other streams in the system at the same time had dissolved phosphorus values ranging .5 to 3 ppm.

Some observations made of the dissolved phosphorus in streams in the Devils Millhopper, a large sink near Gainesville, may be interpreted as in agreement with the hypothesis of concentration discussed above. Several small springs issue from the sides of the Millhopper and one stream falls into this sink from the surface. These flows rush down the sides and out through a fissure in the bottom of this 80-foot hole. The sink penetrates the Hawthorn formation which is heavily phosphatic. The data presented as figure 6 indicate that the water which has passed through the ground has a lower phosphate content than the water that flows in over the top of the sink. If surface water does lose its phosphorus upon passing through rock, there should be a concentration of phosphate not far below the soil surface in areas of ground water recharge. Such a concentration has not been determined, but may be present.

Dissolved Phosphorus and Potential Fertility

As indicated in the introduction, all life requires phosphorus as a basic chemical material for its metabolic processes. About two-tenths of one per cent of phosphorus is required to make chromosomes in the cells and to make coenzymes and other energy transforming substances. In most aquatic environments it has been substantiated by many workers (Hutchinson, 1952) that the growth of plants, and the subsequent growth of animals that derive nutrition from these plants, is limited by the amounts of phosphorus and nitrogen available and utilized by the plant. In fresh waters of many tropical areas blue-green algae are abundant and fix nitrogen from the air to help supply the nitrogen requirements, and thus cause phosphorus to be the limiting factor in plant growth. Hutchinson (1937), in discussing lakes in desert regions considered values of phosphorus over .050 as certainly not limiting. There is some evidence that this is true in Florida, for continual blooms of blue-green algae through the long summer have been reported to *me in personal communication by J. C. Dickinson and in the monograph on the St. Johns River by E. L. Pierce (1947).* There are of course many other factors affecting the biological productivity of waters and where phosphorus and nitrogen are not so scarce as to limit growth, these other factors will determine the production of protoplasm by the natural community of organisms. For example, trace elements such as copper and cobalt may be limiting.

The phosphorus distribution is not expected to be the same as the distribution of high production but the dissolved phosphorus can be thought of as a measure of potential productivity and fertility. The phrase potential fertility is used in the sense of phosphorus availability. Other things being equal regions of high phosphorus might be proposed as regions of high fertility. This is very important to Florida. The growths of microscopic plants that support fish and other fauna are fundamental to the prosperity of commercial and sports fishing, both of which are very important to Florida's tourist trade. Someone with experience in other regions quickly gains the impression that the waters of the State are fertile and contain much life. Indeed, with a very high annual sunshine average and with its waters carrying considerable phosphorus, one suspects that productivities may be high on a world basis. There are little data as yet to test such a hypothesis, but it can be said that the potential fertility of the State, as measured by the dissolved phosphorus, is very large.

Although a high fertility is generally a good thing from man's point of view in that more life is produced in the lakes, streams and estuarine waters, it is not necessarily so. If the fertility results in the proliferation of some objectionable organism or does not produce the desired type of organism, then either less fertility is needed or some control needs to be exercised over the type of organisms which are permitted to make use of the potential fertility. The clogging of waters by water hyacinths is an example of an undesirable result of high fertility. Another is the overproduction of undesirable fish species in some waters at the expense of species desired for food or sport.

Superficially the distribution of high potential fertility as measured by high concentrations of dissolved phosphorus in figure 3 suggests a possible relationship to the areas of water hyacinth nuisance. Certainly, rapid growths of these plants occur in the St. Johns, Peace and Suwannee river systems and in the lakes of the

phosphate district such as Newnan Lake and Orange Lake in Alachua County. Indeed, this possible correlation should be investigated and comparative growth of hyacinths measured in different waters.

Much work has been done in ponds of other areas to increas the fertility of water by artificial fertilization similar to that dor in terrestrial agriculture. However, nothing has been done to wor out a method for decreasing the potential fertility of a wat should it be deemed advisable. Actually this is a major engineerir need since great sums of money are spent each year killing alg blooms in lakes in which clear water is desired rather than rap production. The approach to the problem of using chemicals rather a backwards approach for whenever blooms of algae or rat of hyacinths are killed, the phosphorus within them is releas into the water and into the lake muds so that the remaining ganisms grow even faster. A much better approach would be o designed to remove the phosphorus. Commercially this might possible since the dissolved quantities involved are so small, bei usually much less than one part per million. As yet, no practic solution seems to be at hand. Perhaps a biological filter is feasil in which phosphorus and plant growth are removed from wat running through a lake, with resultant improvement downstrea or perhaps ferrous or aluminum salts could be added to remo the phosphorus as a precipitate.

An understanding of the quality and quantity of the aquat production under various situations in Florida is needed. A co certed research program should be made to uncover the basic fa tors and their interactions, which control this natural aquatic agr culture.

It is likely that phosphorus fertilization of the Florida wate which contain more than .050 ppm total phosphorus will not i crease biological production because it is probably not limiting these concentrations.

Dissolved Phosphorus and Pollution

Some types of pollution produce extreme effects on the potenti fertility of Florida's waters by adding large amounts of dissolve phosphorus relative to the amounts naturally present. By pollutio is here meant the addition of materials to a natural body of wate as a result of man's activity so that the conditions of the lake stream, or estuary are markedly changed with respect to the quality and quantity of biological growth. By this definition a pollution may not necessarily be bad if the man made changes are not undesirable to the long range welfare of all concerned. However, pollution by changing the natural situation often restricts the variety of organisms and often markedly affects the populations of fish organisms in indirect ways by affecting their plant and animal foods.

In Florida two sources are at present increasing the dissolved phosphorus in Florida waters: Industrial and municipal sewage and the byproducts of the phosphate industry. Phelps and Barry (1950) have summarized sources of pollution in Florida. When sewage is passed through chemical treatment many of its objectionable properties, such as disease organisms and organic matter, are removed, which if dumped directly in streams would use up the dissolved oxygen and kill the organisms. However, the very high content of phosphorus in urine and in the solid materials of raw sewage is not completely removed by sewage treatment plants. By the time the decomposing raw sewage reaches the plant there is already a high concentration of phosphorus in the dissolved inorganic form. Apparently this inorganic fraction passes through the plant without much loss. Raw sewage entering the university sewage plant in Gainesville, April 9, 1953, possessed a dissolved inorganic phosphorus content of 2.1 ppm. The final effluent emerging from the same plant contained 1.9 ppm dissolved inorganic phosphorus. These values in comparison to the natural concentrations in most streams are enormous.

A sample of the phosphorus developed from Lakeland sewage and taken out of Lake Hancock in Saddle Creek and analyzed was 2.0 ppm. and a sample of the Orlando sewage taken in the Econlochhatchee Creek analyzed 3.2 ppm. Standard engineering practice has not recognized these relatively small phosphorus quantities on a weight basis as being a pollution. Considering the possible stimulus to undesirable growths or undesirable species, it is clear that this may at times be harmful although a general increase in fertility is promoted in some fish culture. With the increasing population of Florida and the increased dumping of sewage into Florida's relatively small surface streams, the result of this practice must be studied. It is certainly not possible to say from the available evidence whether the character of Florida's fresh waters and estuaries, which are an important resource, are being markedly

changed and if so whether for the better or worse by these large changes in potential fertility. It is, however, important that the total biological character of the major water types be established before and after such increase in potential fertility to determine if there is a resultant increased hyacinth growth, game fish, or algae blooms in previously clear waters.

The phosphate industry particularly in the Peace and Alafia river systems is discharging phosphate slimes and, in the case of Bear Branch, Bartow, Florida, acid waters high in dissolved phosphorus into a river which must already have had high concentrations because of the underlying rock formations. A high original phosphorus concentration is indicated by the streams in the Peace and Alafia river area which do not receive industrial wastes but have very high values although not as great as the Peace and Alafia proper. It seems likely that the pollution somewhat accentuates the addition of phosphorus. The data in figure 5 support this. Relatively undisturbed Charlie Creek, for example, has a lower phosphorus value than the streams receiving wastes. It is unlikely that at these high levels phosphorus is limiting in the Peace River or that the potential fertility is in any way realized. But the effect on the fertility of Tampa Bay and Charlotte Harbor is probably being increased by the increase in phosphorus going down these rivers. Phosphorus also goes down the Peace River through Lake Hancock from Lakeland sewage. The problem of the possible effects of colloidal and slime phosphorus on river organisms is a separate problem that is being studied by Mr. Ellis Landquist of the University of Florida.

Dissolved Phosphorus and the Red Tide

If there are increasing quantities of phosphate going down some rivers, the question is raised whether this additional fertility is increasing the incidence of the red tide offshore. The so called red tide is a bloom of a microorganism *Gymnodinium brevis* in marine waters which becomes so concentrated that fish are killed in large numbers and are washed up in great quantities on the beaches (Gunter et al, 1948).

Much work has been done to show that similar phenomena occur in many parts of the world at widely timed intervals. Walton Smith (1949) postulated that the occurrence is due to nutrients becoming available, especially phosphorus. Ketchum and

Keen (1948) found unaccountably high total phosphorus concentrations in the 1947 growth off the coast at Sarasota. As yet, however, there is no definite proof that high phosphorus concentrations are required for red tide blooms.

Slobodkin (1952) has postulated that the relatively frequent red tide occurrence off the lower Florida west coast is a result of rains and northeast winds which carry low salinity waters containing a few of the *Gymnodinium* organisms and nutrients out over the saltier open waters where they develop a bloom and then drift northward and shoreward in the prevailing Gulf drift. The mechanism of this drift was demonstrated by E. L. Pierce (1951). Specht (1950) has shown high phosphorus concentrations entering Charlotte Harbor from the Peace River. From the data in figures 3 and 7 it is suggested that the Peace and Alafia rivers are sources of larger nutrient concentrations than the Caloosahatchee and Okeechobee which have smaller amounts of dissolved phosphorus. The Caloosahatchee river crosses phosphatic formations but is derived largely from phosphorus poor Lake Okeechobee and is not so acid when it crosses phosphorus rocks. A charge of phosphate laden low salinity water might accumulate in Tampa Bay or Charlotte Harbor and then be blown out to sea as a fairly intact mass of water before mixing.

The data in Table 7 suggest that adequate phosphorus is found in these waters in excess of that needed for a red tide bloom. After the initial bloom further fertilization can come from fish that swim

TABLE 7

PHOSPHORUS RELATIVE TO RED TIDE

	Cases	PPM Total Phosphorus Mean	PPM Total Phosphorus Range
Amber water off Ft. Myers			
July 1947 (Ketchum and Keen, 1947)	5	.335	.152—.630
Nov. 1952 (Marshall and Odum) during late stages of bloom	3	.052	.036—.076
Off Ft. Myers, not at times of Red tide			
Aug. 1947 (Ketchum and Keen, 1947)	5	.029	.019—.038
Dec. 1952 (Lackey and Odum)	4	.016	.008—.024
Estuaries which contribute phosphorus			
Tampa Bay (Marshall and Odum) September 27, 28, 1952	15	.318	.125—.840
Charlotte Harbor, June-Dec., 1952	2	.376	.327—.425
Caloosahatchee Estuary June, Nov., Dec., 1952	3	.071	.022—.118
Caribbean open water (Ketchum and Keen, 1947)		......	.0003 -.015
Indian River, summer 1952	3	.034	.001—.086

into the area, die and decompose. The data on samples collected from the recent red tide in 1952 by N. Marshall show that lower concentrations are required at least in these last stages of the bloom than might have been surmised from the values taken by Ketchum and Keen (1948). Perhaps, however, during the last stages, the bloom was being dispersed by mixing although the water was recognizably red at the time. To further test these hypotheses a continuous series of samples must be taken regularly until the initial formation stages of the red tide are covered. Of course adequate phosphorus does not guarantee a bloom for there are other factors, but certainly adequate phosphorus is a prerequisite (Specht, 1950; Smith, 1949; Ketchum and Keen 1948).[3]

If the phosphate going down the rivers into the coastal areas in large amounts is increasing due to expansion of industry and population, further examinations must be made to determine whether the general fertility of some coastal waters is being increased and whether or not this is following desirable lines or is producing undesirable products. The procurement of adequate fishing statistics may permit some examination of change in this respect.

---

[3](This note was added in press.) Three recent papers and a fresh outburst of red tide in September 1953 at the mouths of Tampa Bay and Charlotte Harbor have further increased interest in red tide phenomena. (Kierstead, H. and L. Slobodkin, 1953. Journ. of Marine Research, vol. 12, pp. 141-147; Slobodkin, L., 1953. Journ. of Marine Research, vol. 12, pp. 148-155; Chew, F., 1953. Bull. of Marine Science of the Gulf and Caribbean, vol. 2, pp. 610-625.) Slobodkin proposes that a lens of brackish water blowing out from shore on the surface provides a means of developing a critical minimum mass for starting a full bloom. He thinks that the nutrient phosphorus could be concentrated by organisms migrating vertically into the surface layer. Thus he thinks that the amount of phosphorus initially present need not be larger than usual. Chew found patches of low salinity water offshore but found that the red tide was not in these but was in slightly higher salinity waters nearby. He interpreted the lower salinity water as derived from rivers and the higher salinity water which was high in phosphorus as derived from offshore. It seems possible that Chew's lower salinity water could have been from the Caloosahatchee and the red tide water could have originated further north in the polluted Tampa Bay estuary and Charlotte Harbor. Slobodkin's idea of critical mass seems more applicable if applied to nutrient containing water from the polluted estuaries. Even if phosphorus is not a limiting nutrient to red tide blooms, it is likely to be correlated with limiting nutrients from the polluted bays and thus act as a water marker in tracing such water. The repeated localization of the red tide blooms in areas near the mouths of the phosphatic rivers suggests that some causal factor is localized there.

CONCLUSIONS

1. The dissolved phosphorus content of Florida fresh waters is correlated with the underlying phosphatic rock formations of the drainage area.

2. The dissolved phosphorus content of Florida estuarine waters is determined by the proximity of the rivers and the phosphorus content of these rivers.

3. In the phosphatic districts the dissolved phosphorus is highest in the soft acid streams, lower in lakes due to a biological filtering action, and lowest in springs possibly due to a geological precipitating action.

4. The dissolved phosphorus and thus the potential fertility in Florida waters especially in the phosphatic districts is considerably higher than in waters in most other humid regions of the world yet studied.

5. Dissolved phosphorus liberated by sewage and by the phosphate industry is producing a high potential fertility in many waters. There is no definite evidence whether or not this is desirable.

6. The high frequency of the red tide off the mouths of the Peace and Alafia rivers suggests causal relationship between the large quantities of natural and industrial phosphorus passing down these rivers.

7. A program of research is needed to discover what other factors determine how the high potential fertility of Florida's waters is expressed in terms of fish production, water hyacinth growth, and cloudy waters. The natural condition of Florida streams should be studied and recorded as a valid basis for resource use management before further pollution destroys our chance to establish the biological structure of the natural streams.

REFERENCES CITED

Barbier, G. and M. Maroger, 1950. Compt. Rendo, vol. 230, pp. 130-132.
Berg, Kaj, 1945. Physiographic studies on the river Sussa: Folia Limnologica Scandinavica, Einar Moksgaard, Copenhagen.
Cooke, C. W., 1945. Geology of Florida: Fla. Geol. Surv. Bull. 29, 339 pp.
Deevey, E. S. and J. S. Bishop, 1940. Limnology, a fishery survey of important Connecticut lakes: Conn. Geol. and Natural Hist. Surv. State Board of Fisheries and Game, Bull. no. 63, 69-298.
Dietz, R. S., K. O. Emery and F. P. Shepard, 1942. Phosphorite deposits on the sea floor off southern California: Bull. Geol. Soc. Amer., vol. 53, pp. 815-847.
Green, J. and J. A. Holmes, 1947. Calculation of the pH of saturation of tricalcium phosphate: Journ. Amer. Water Works Assoc., vol. 39, pp. 1090-1096.

Gunter, G., Robert M. Williams, C. C. Davis and F. G. Walton Smith, 1948. Catastrophic mass mortality of marine animals and coincident phytoplankton bloom on the west coast of Florida November 1946 to August 1947: Ecological Monographs, vol. 18, pp. 309-324.
Harvey, H. W., 1948. The estimation of phosphate and of total phosphorus in sea waters: J. Marine Biol. Assoc. U. K., vol. 27, pp. 337-359.
Hasler, A. D., 1947. Eutrophication of lakes by domestic drainage: Ecology, vol. 28, pp. 383-395.
Hutchinson, G. E., 1937. A contribution to the limnology of arid regions: Trans. of the Conn. Acad. of Arts and Sci. vol. 33, pp. 47-132.
Hutchinson, G. E., 1941. Limnological studies in Connecticut. IV. Mechanism of intermediary metabolism in stratified lakes: Ecol. Monographs, vol. 11 pp. 21-60.
Hutchinson, G. E., 1952. Biogeochemistry of phosphorus. in symposium on Biology of phosphorus: Mich. State College Press, pp. 1-35.
Hutchinson, G. E., 1952. Unpublished manuscript.
Johnson, B. L., 1952. Phosphate rock. in Van Royen, W. and D. Bowle 1952. Mineral resources of the world, atlas, vol. 2, pp. 141-146. Prentic Hall for the Univ. of Maryland.
Juday, C., E. A. Birge, G. I. Kemmerer, and R. J. Robinson, 1928. Phosphor content of lake waters of northeastern Wisconsin: Trans. Wisconsin Aca Sci. Arts. Let., vol. 23, pp. 233-248.
Juday, C., and E. A. Birge, 1931. A second report on the phosphorus conte of Wisconsin lake waters: Trans. Wisc. Acad. Sci., Arts, Let., vol. 2 pp. 353-382.
Ketchum, B. W. and J. Keen, 1948. Unusual phosphorus concentration the Florida "red tide" sea water: Journ. of Marine Res., vol. 7, pp. 17-21.
Miller, S. M. 1952. Phosphorus exchange in a sub-tropical marine basi Bull. of Marine Science of the Gulf and Caribbean, vol. 1, pp. 257-265.
Mortimer, C. H., 1941-1942. The exchange of dissolved substances betwe mud and water in lakes: Journ. Ecology, vol. 29, pp. 280-329; vol. 30, p 147-201.
Newcombe, C. L. 1940. Studies on the phosphorus content of the estuari waters of the Chesapeake Bay: Proc. Amer. Phil. Soc., vol. 83, pp. 621-6
Ohle, W., 1934. Chemische und physikalische Untersuchungen in nor deutschen Seen. Arch. F. Hydrobwol., vol. 26, pp. 386-464.
Phelps, E. B. and D. E. Barry, 1950. Stream sanitation in Florida: Flori Engineering and Industrial Expt. Sta. Bull. No. 34., Engineering Progre at the Univ. of Florida, vol. 4, No. 5, 56 pp.
Pierce, E. L. 1947. An annual cycle of the plankton and chemistry of fo aquatic habitats in northern Florida: Univ. of Florida Studies Biol. S Series, vol. 4, No. 3, 67 pp.
Pierce, E. L. 1951. The Chaetognatha of the west coast of Florida: Bi Bull., vol. 100, No. 3, pp. 202-228.
Redfield, A. C., H. P. Smith and B. Ketchum, 1937. The cycle of orga phosphorus in the gulf of Maine: Biol. Bull. vol. 73, pp. 421-433.
Riley, G. A., 1951. Oxygen, phosphate, and nitrate in the Atlantic Ocea Bull. Bingham Ocean. Coll., vol. 8, art, 1, 126 pp.
Robinson, R. J. and G. Kemmerer, 1930. Determination of organic phosphor in lake waters. Trans. Wisconsin Acad., vol. 25, pp. 117-121.
Robinson, R. J. and T. G. Thomson, 1948. The determination of phosphates sea water: Journ. of Marine Res., vol. 25, pp. 117-121.
Slobodkin, L. B., 1952. November and December press releases in Flori newspapers.
Smith, F. G. Walton, 1949. Probable fundamental causes of red tide off the we coast of Florida: Quart. Journ. of the Florida Academy of Sciences, v 11, No. 1, pp. 1-6.
Specht, R. C. 1950. Phosphate Waste Studies. Florida Industrial and E gineering Expt. Sta., Bull. No. 32, Engineering Progress at the Universi of Florida, vol. 4, No. 2, 28 pp.
Vernon, R. O., 1943. Florida mineral industry, with summaries of produ tion for 1940-41: Florida Geol. Surv. Bull., No. 24, 207 pp.
Vernon, R. O., 1951. Geology of Citrus and Levy counties, Florid Fla. Geol. Surv. Bull., No. 33, 256 pp.

APPENDIX

I. *Total Phosphorus Analyses of Marine and Estuarine Waters* (Collaboration with others as indicated)

Alligator Harbor Series: (With Nelson Marshall, Harold Humm of Oceanographic Institute, Fla. State. Univ.)

	Total P ppm
Bald Point, Ochlockonee Bay, Franklin Co., Aug. 21, 1952	.058
Panacea Bridge, Ochlockonee R., Aug. 21, 1952	.057
Camp Weed Pier, Alligator Harbor, Aug. 21, 1952	.013
Marine Lab. pier, Alligator Harbor, Aug. 21, 1952	.040
Mouth South Creek, Alligator Harbor, Aug. 30, 1952	.028
Midway South Creek, Alligator Harbor, Aug. 30, 1952	.040
Mouth North Creek, Alligator Harbor, Aug. 30, 1952	.028
Midway North Creek, Alligator Harbor, Aug. 30, 1952	.030
Station No. 208, Alligator Harbor, Aug. 30, 1952	.048
Station No. 210, Alligator Harbor, Aug. 30, 1952	.019
Station No. 217, Alligator Harbor, Aug. 30, 1952	.021
Station No. 213, Alligator Harbor, Aug. 30, 1952	.050
Peninsula Pt. Channel, Alligator Harbor, Aug. 30, 1952	.018

Sanibel Island—Tampa Bay series during Red Tide (with Nelson Marshall, Oceanographic Institute, Fla. State Univ.)

	ppm P (Total) Filtered	Unfiltered
Plantation Key, Surface, Nov. 19, 1952	.024	.021
Four miles off Sanibel in Red Water, Nov. 15	...	.043
Four miles off Sanibel, clear water, surface	.018	.017
Four miles off Sanibel, Red water, surface, Nov. 16	.041	.076
Buoy 4B Tampa Bay, Surface, Nov. 15, 1952	.096	.174
Buoy 4B Tampa Bay, 20 ft., Nov. 15, 1952	.025	.160
Twelve miles off Sanibel in Red Water, surface, Nov. 16	.018	.036
End of Naples Pier, Nov. 17, Surface	.021	.024
Nine miles off Sanibel, surface, Nov. 16		.038
Nine miles off Sanibel, 10 feet deep, Nov. 16	.012	.030
Sanibel, clear water, surface, Nov. 16	.025	
Boca Ciega shore, Nov. 14	.025	025

Sanibel Island—Tampa Bay series after Red Tide (With J. B. Lackey, Dept. of Sanitary Engineering, Univ. of Florida)

Peace R., Punta Gorda, Dec. 3, 1952, Temp. 23 deg. C.	.423
Estero Lagoon Dec. 2, Temp. 21.5 deg. C.	.030
Sanibel, Dec. 1, 1952	.025
Sanibel, Dec. 1, 1952	.032
Naples Harbor, centrifuged	.032
Gulf 8 Miles off Naples entire sample	.017
Naples Harbor, Dec. 2	.015
Two miles west of the pass, Naples	.008
Olga Bridge (Caloosahatchee R.), T. 24 deg. C.	.023
Jones Res. Caloosahatchee, T. 24. deg. C.	.000
Nokomis Bay, Venice, T. 22 deg. C.	.024
Myakka R. 22 deg. C., Dec. 3, 1952	.069
Caloosahatchee R. Ft. Myers Pier, T. 24 deg. C.	.073

Tampa Bay Series Sept. 27, 1952 (With Nelson Marshall, Oceanographic Institute. Fla. State Univ.)

	Depth feet	Salinity ppt	Total P ppm
On Ballast Pt. pier 300 yds. out	0	25.2	.74
McDill Field, east coast	0	25.6	.84

	Depth feet	Salinity ppt	Total P ppm
East end of longer bridge of Courtney-Campbell causeway	0	27.3	.271
St. Petersbury-Tampa causeway, west end of Gandy bridge	0	27.7	.250
St. Petersbury, S of Papys Bayou about 54th St.	0	28.4	.33
End of St. Petersbury pier	0	28.9	.285
50 yds. out from Bee line Ferry dock	0	30.0	.290
Buoy 5 off Pinellas Pt. (pH 8.3)	0	30.3	.280
Buoy 1	0	30.6	
	10	30.6	.256
Buoy Can 3B	0	29.1	.33
	10	30.0	
	20	32.8	.148
Buoy 3A	0	29.4	.284
	10	29.9	
	20	32.0	
	30	33.0	.136
Buoy 2A	0	...	.295
Buoy 14	0	...	.163
Buoy 13	0	...	.154
Buoy 11 at Harbor mouth	0	33.2	.130
	10	33.0	
	20	34.2	
	30	34.4	.073
Just outside harbor in Egremont Channel	0	34.0	.126
	10	34.2	
	20	34.2	
	30	34.0	.096

East Coast Marine Waters:

Indian River, Melbourne, June 23, 1952	.001
Surf, Melbourne Beach, June 23, 1952	.006
Indian River, Cocoa, June 23, 1952	.016
Sound, Bayfront Park, Miami, June 22, 1952	.189
Miami Inlet, June 22, 1952	.083
Tomaka River, July 19, 1952	.096
Matanzas R. Estuary, St. Augustine, July 19, 1952	.053
Moultrie Creek, St. Augustine, Aug. 29, 1952	.255
Indian R. at Indian R. City, July 19, 1952	.086
St. John's Estuary, Jacksonville, Aug. 10, 1952	.289
Surf, Daytona Beach, July 19, 1952	.086

Marineland Series (With Mr. Forrest G. Wood, Marineland)

Fresh Ocean Water—gallery water, Aug. 29, 1952	.023
Marineland Inlet, high tide, Aug. 29, 1952	.033
Gallery water, 2 hrs. after low tide, Sept. 14, 1952	.068
Marineland Inlet, low tide, heavy rain, Sept. 22, 1952	.054

West Coast Florida Marine Waters

Surf, Naples, June 21, 1952	.032
Naples Estuary, June 21, 1952	.000
Everglades, Florida, June 21, 1952	.100
Tampa Bay, along Rt. 541, June 19, 1952	.720
Alafia Estuary on Tampa Bay, June 19, 1952	.660
Manatee River estuary, Rt. 301, June 19, 1952	.097
Sarasota bay, City pier, Sarasota, June 20, 1952	.010
Charlotte Harbor, Punta Gorda, June 20, 1952	307
Suwannee Estuary, August 6, 1952	.061
Cedar Key main channel, Sept. 18, 1952 (E. L. Pierce)	.011

	Total P ppm
Cedar Key main channel, July 13, 1952 (E. L. Pierce)	.051
Bayport Estuary, May 30, 1952, sample 1	.018
Bayport Estuary, May 30, 1952 sample 2	.010
Bayport Estuary, May 30, 1952 sample 3	.024

Chassahowitzka Bay series (With William Jennings, Florida Game and Fresh Water Fish Commission)

	Total P ppm
July 22, 1952 aquatic plants listed	
Bay, *Chara* flats	.014
Mouth of Chassahowitzka, *Chara* and *Ruppia*	.025
Dog Island, *Sago, Ruppia*	.032
Alligator creek, Valisneria	.044
Porpoise Bay, Mangrove Island, *Sago*	.018

Homosassa series July 22, 1952 (With William Jennings, Florida Game and Fresh Water Fish Commission)

	Total P ppm
West of town of Homosassa ¼ mile	.030
North of town, ¼ mile	.040
Halls river	.023
Brices Cove west of Homosassa	.067

II. *Inorganic and Total Phosphorus of Spring Waters* (With Office of Naval Research) (samples from springs marked by asterisk are aged samples.)

	Inorganic P ppm	Total P ppm
Silver Springs, July 15, 1952, canal entrance		.045
June 30, 1952, 3 miles down run	.057	.037
June 30, 1952, 5 miles down run	.050	.040
June 30, 1952, in littoral plants	.025	.027
Aug. 16, 1952, boil	.036	......
Sept. 3, 1952, boil	......	.061
Warm Salt Springs, Murdock		
June 19, 1952*	......	.040
June 19, 1952	......	.050
June 19, 1952	.033	......
June 19, 1952	.013	......
June 19, 1952	.053	......
Alexander Springs, Astor Park		
March 8, 1952*, boil	.067	......
March 8, 1952	.070	......
Aug. 14, 1952, boil	.039	.068
Aug. 14, 1952, ½-mile downstream	.045	.061
Salt Springs, Marion County		
Oct. 9, 1951*	.020	......
Oct. 9, 1951	.018	......
Oct. 9, 1951	.005	......
Aug. 7, 1952	......	.027
Juniper Springs, Marion County		
Aug. 14, 1952	.013	......
Aug. 14, 1952	.017	......
Rock Spring, Apopka		
Dec. 27, 1951*	.140	.127
Dec. 27, 1951	.150	.120
Dec. 27, 1951	......	.127
Sulphur Springs, Tampa		
Dec. 1, 1951*	.007	......
Dec. 1, 1951	.017	......
Dec. 1, 1951	.020	......

	Inorganic P ppm	Total P ppm
Mud Spring, Welaka		
Nov. 1951*	.083	
Nov. 1951	.083	......
Beecher Spring, Welaka		
Nov. 24, 1951*	.145	......
Nov. 24, 1951*	.137	......
June 6, 1952	.101	......
June 6, 1952	.120	......
Weekiwachee Springs, Hernando County		
Nov. 29, 1951*	.083	......
Nov. 29, 1951	.073	......
May 29, 1952	.060	......
Wacissa Springs, Jefferson County		
August 3, 1952	......	.033
Ichtucknee Springs, run, Rt. 27, Hildreth		
Aug. 3, 1952	......	.072
Aug. 12, 1952	......	.060
Rainbow Springs, Marion County		
Aug. 22, 1952	.053	......
Wakulla Springs, Wakulla County		
Aug. 12, 1952, boil	......	.039
Chassahowitzka Springs, Citrus County		
Aug. 23, 1952, boil	.013	......
(with J. H. Davis)		
Neck below boil	.013	......
Boil of 2nd Spring	.013	......
Down run of 2nd Spring, ½ way	.022	......
Mouth of second spring	.033	......
First curve below head springs	.009	......
Second curve	.013	......
Boil of third spring	.019	......
Downstream, ¾-mile	.017	......
Downstream, 1¼ miles	.015	......
Downstream, 1¾ miles	.018	......
Downstream, 3 miles	.019	......
Downstream, 4 miles	.017	......
Downstream, 5 miles—estuarine water	.023	......
Downstream, 6 miles—in Gulf	.023	......
Su No Wa Springs		
Aug. 10, 1952	.013	......
Aug. 10, 1952	.022	......
Devils Millhopper Springs, Alachua County		
Aug. 26, 1952	.060	......
Aug. 26, 1952	.053	......
Aug. 26, 1952	.081	......
Bonita Springs		
June 21, 1952 Hotel	......	.013
Blue Springs, Orange City		
Undated	......	.123
Manatee Springs		
Aug. 6, 1952		
Boil	.037	.028
Down run	.023	......
Down run	.013	......
Down run	.039	......
Down run	.048	......
River sink, Wakulla County		
Feb. 9, 1951	.223	......
Feb. 9, 1951	.220	......
Buckhorn Spring, Hillsborough County		
June 18, 1952	.140	......

	Inorganic P ppm	Total P ppm
Crystal Springs, Pasco County June 18, 1952	.020	
Lithia Springs, Hillsborough County		
June 19, 1952	.050	
June 15, 1952		.067
Silver Glenn Springs, Marion County		
March 22, 1952 Boil	.001	......
August 14, 1952 Boil	.023	.042
Mouth of Run	.020	.036
Orange Springs, Marion Co., Aug. 7, 1952	......	.095
Blue Springs, Gilchrist Co., June 9, 1952	.032	......
Homosassa Springs, Citrus Co., May 29, 1952 Boil	.008	......
Blue Springs, Marianna, Jackson, Co., Aug. 1, 1952		
Boil	.013	.021
Among plants	.033	......
Downstream 100 yds.	.065	......
Glen Julia Springs, Gadsden Co., Aug. 1, 1952		
Boil	.003	.000
Downrun 50 yds.	.011	......
Mouth of run	.032	......
Ponce De Leon Spring, Holmes Co., Aug. 2, 1952		
Boil	.009	.027
Start of run	.005	......
End of run	.015	......
Morrison Springs, Walton Co., Aug. 2, 1952	......	.027
Blue Springs, Madison Co., Aug. 1952, (With William Beck of Florida State Board of Health)	......	.060
Green Cove Springs, Clay Co., Night Series 9-11 p.m. Aug. 16, 1952		
Boil	.005	.006
Pool outlet	.004	.006
Rapids below falls	.005	.005
Middle bridge	.005	.006
Next curve	.005	.012
Last curve	.006	.008
Green Cove Springs Day Series July 16, 1952 2-4 p.m. Many people in pool at Sta. B		
Boil	.022	......
Pool Outlet	.041	......
Rapids below falls	.041	......
Middle bridge	.018	......
Next curve	.008	......
Last curve	.005	......

III. Total and Inorganic phosphorus in streams of the Peace River system: (Station numbers of Florida State Board of Health) (With Ellis Landquist, Univ. of Fla., Dept of Biology)

	Inorganic P ppm	Total P ppm
Six mile creek south of Bartow, Station p-33, Aug. 8, 1952	3.86	......
Peace creek, Ft. Meade, Station p-9, Aug. 7, 1952	4.86	......
Bear branch, Station p-37, Bartow, pH 3.5		
Aug. 4, 1952	66.	......
Aug. 4, 1952	96.	......
March 2, 1952	178.	......
Bearbranch, Bartow, Station p-35, Aug. 9, 1952	......	25.3
Peace River, Homeland, Station p-11, Aug. 4, 1952	5.86	......
Peace River, Bowling Green, Station p-7, Aug. 5, 1952	4.53	......
Peace creek, Station p-16, Aug. 6, 1952	......	.39

	Inorganic P ppm	Total P ppm
Arcadia, Station p-4,		
Aug. 3, 1952	5.3	
June 26, 1952		>3.3
Peace River, Zolfo Springs, Station p-5,		
Aug. 3, 1952	5.3	
Aug. 2, 1952	5.1	......
Peace creek, east of L. Hancock, Station p-55a, Aug. 6, 1952	......	.18
Paines creek, below Bowling Green, Station p-18, Aug. 8, 1952	......	.72
Charlie creek, Garderner, Station p-17, Aug. 3, 1952	......	.8
Shell creek, Rt. 17, Cleveland, Fla. Punta Gorda, June 20, 1952	......	2.1
Charlotte Harbor, Punta Gorda, June 20, 1952	......	.2
Horse Creek, Arcadia, June 20, 1952	......	.2
Peace River, Bartow, March 2, 1952	......	>3.3
Peace creek, east of Eloise, March 2, 1952	......	.0
Saddle creek, south of L. Hancock, March 2, 1952 (including much animal plankton)	......	2.1
Citrus waste, canal, Snively Plant, Polk Co., March 2, 1952	......	.0
Peace creek, outlet near Alturus, (near station p-55a) Aug. 19, 1952	......	.0
Phosphate water, clear, Pembroke settling basin	1.00	
Lulu lake outlet, Eloise, (receives Winterhaven sewage, flows into Peace Cr. Aug. 15, 1952) (USGS)	......	.4

Suwannee-Santa Fe River System

(With William Beck, Florida State Board of Health)

	Inorganic P ppm	Total P ppm
Carver's camp, river backwater, near mouth, Suwannee River, Aug. 7, 1952	......	.1
Small creek, tributary of Santa Fe River, Monteocha, Alachua Co., Aug. 31, 1952	......	.1
Santa Fe River, Rt. 234, Brooker, Bradford Co., Aug. 31, 1952		.1
Creek, tributary of Santa Fe River, Graham, Bradford Co., Aug. 31, 1952		.2
Suwannee River at Fanning Springs, Aug. 6, 1952		.0
Santa Fe River, Camp O'leno Park,		
Sept. 16, 1952 High water		.1
Aug. 29, 1952		.15
May 27, 1952		.14
Santa Fe River, Rt. 441, Sept. 16, 1952		.12
Santa Fe River, Ft. White, Aug. 11, 1952		.07
Suwannee River, Bell, Aug. 11, 1952		.08
Suwannee River, White Springs, Aug. 12, 1952	......	.33
Suwannee River, Branford, Aug. 13, 1952		.08
Suwannee River, Ellaville, Aug. 12, 1952		.15
Withlacoochee River, Rocky Ford, Brooks Co., Ga., Aug. 1952		.25
Withlacoochee River, Rt. 145, Madison Co. Fla., Aug. 1952		.16
Withlacoochee River, Pinetta Bridge, Madison Co., Fla., Aug. 1952		.08
Withlacoochee River, Blue Springs Bridge, Madison Co., Fla., Aug., 1952	......	.19
Withlacoochee River, junction with Suwannee, Aug. 1952	......	.10

	Inorganic P ppm	Total P ppm
Streams Draining into sinks, Alachua Co.		
Hatchet creek, Monteocha Rd. 2.3 miles north of Waldo Gainesville road, Aug. 31, 1952		.027
Hatchet creek, Rt. 24,		
July 17, 1952	......	.184
Aug. 26, 1952 low water	......	.125
Alachua sink, north edge of Paynes Prairie receives Prairie creek, Sept. 11, 1952	......	1.0
Hatchet Creek, Rt. 26, Sept. 9, 1952	......	.247
Camp's Canal, near Rochelle,	......	.065
Hogtown Creek, Univ. Ave., Gainesville, Aug. 26, 1952	......	1.4
Hogtown Creek, west branch, 16th Ave. Gainesville, Aug. 26, 1952	......	>2.0
Hogtown Creek, east branch, 16th Ave., Gainesville, Aug. 26, 1952	......	>1.0
Hogtown sink, receives Hogtown creek, Sept. 2, 1952	......	>2.0
Prairie Creek, Rt. 20, east of Gainesville, Aug. 31, 1952	......	.114
Stream draining Hammock, Southwest of Paynes Prairie, Sept. 11, 1952	......	.087
Alafia River system		
Alafia estuary, June 19, 1952	......	.660
Fishawk creek, June 19, 1952	......	.390
Alafia River		
Above Lithia Springs, June 19, 1952	......	1.81
at Lithia Springs, June 19, 1952	......	2.37
Alafia River, Riverview, June 19, 1952		1.36
South branch of Alafia, Pinecrest, June 19, 1952	......	>3.33
Alafia River, Bloomingdale-Lithia Rd., June 19, 1952	......	1.25
Smaller West Coast Rivers (draining Phosphate districts)		
Manatee River estuary, Rt. 301, June 19, 1952	......	.097
Rt. 675, June 19, 1952	......	.450
Hillsborough River, Univ. of Tampa bridge, June 18, 1952	......	.220
Sulphur Springs, Tampa, June 18, 1952	......	.160
Myrtle's Fish Camp, June 18, 1952	......	.107
Hillsborough River State Park, June 18, 1952	......	.097
Rt. 39, June 18, 1952	......	.018
Drainage canal near Hillsborough River June 18, 1952	......	.057
Braden River, tidal estuary, June 19, 1952	......	.054
Myakka River		
West of Murdock, Rt. 41, June 20, 1952	......	.067
At State Park June 20, 1952	......	.059
Little Manatee River		
Rt. 674, June 19, 1952	......	.400
Rt. 301, June 19, 1952	......	.587
Anclote River, Elfers, Aug. 7, 1952	......	.014
Brooker Creek, Mt. Odess, Aug. 9, 1952	......	.011
Withlacoochee River		
Dunnellon, May 29, 1952	......	.063
Rt. 33, March 2, 1952	......	.028
Lake, Southshore, May 29, 1952	......	.045
Fenholloway River, Aug. 3, 1952	......	.013
Perry, July 30, 1952	......	.070
Palatlakaha Creek, Okahumpa, Sept. 11, 1952	......	.017

	Inorganic P ppm	Total P ppm
Canals and Rivers of South Florida (See figure 8) (with William Jennings, Florida Game and Fresh Water Fish Commission)		
Tamiami Canal, Ochopee, June 21, 1952		.018
West of Ochopee, 10 miles, June 21, 1952	......	.051
East of Ochopee, 7.5 miles, June 21, 1952	......	.01
East of Ochopee, 18 miles, June 21, 1952	......	.011
East of Ochopee, 30 miles, June 21, 1952	......	.05
East of Dade County line, 2 miles, June 21, 1952	......	.07
East of Ochopee, 40 miles, June 21, 1952	......	.08
Collier-Seminole State Park, June 21, 1952	......	.05
At Rt. 27	......	.01
At Coral Gables canal, June 22, 1952	......	.00
Coral Gables Canal, pool, Univ. of Miami Service Center, June 22, 1952	......	.15
Miami Canal		
At 26th Street, Miami, June 22, 1952	......	.07
At 37th St., Miami, June 22, 1952	......	.0
Eighteen miles north of Miami, June 22, 1952	......	.0
Rt. 29 canal running north from Everglades, Fla. estuarine for first 6 miles, June 21, 1952		
At Everglades	......	.1
North of Everglades, 1 mile	......	.0
North of Everglades, 2 miles	......	.0
North of Everglades, 4 miles	......	.0
North of Everglades, 6 miles	......	.0
North of Everglades, 9 miles	......	.0
North of Everglades, 12 miles	......	.0
Hillsboro Canal		
Deerfield, June 17, 1952	......	.0
Belle Glade, June 22, 1952	......	.0
Deerfield Beach, Aug. 22, 1952	......	.0
St. Lucie Canal, Port Mayaca, June 18, 1952	......	.0
South New River Canal, Rt. 27, June 22, 1952	......	.0
North New River Canal		
Rt. 27, June 22, 1952	......	.0
North of Miami, 45 miles, June 22, 1952	......	.0
At Bolles Canal, Okeelanta, June 22, 1952	......	.0
Lake Okeechobee		
Bean City, south dike canal, June 22, 1952	......	.0
Clewiston, June 22, 1952	......	.0
Near mouth of Taylor Creek, north shore, June 22, 1952	......	.0
Caloosahatchee River		
Moorehaven, June 22, 1952	......	.01
Olga, June 20, 1952	......	.01
Olga, Dec. 2, 1952 (J. B. Lackey)	......	.0
Ft. Myers, June 20, 1952	......	.0
Ft. Myers, Dec. 2, 1952 (J. B. Lackey)	......	.07
West Palm Beach Canal, West Palm Beach, Aug. 22, 1952	......	.1
Fisheating Creek, Rt. 78, June 22, 1952	......	.0
Indian Prairie Canal, Rt. 78, June 22, 1952	......	.1
Kissimmee River		
Rt. 78, June 22, 1952	......	.01
Below Kissimmee, Aug. 19, 1952	......	.0
Ft. Bassinger, June 16, 1952	......	.0
Taylor Creek, mouth at Lake Okeechobee, June 22, 1952	......	.05
Imperial River, Bonita Springs, June 20, 1952	......	.05
Estero River, Rt. 41, Estero, June 21, 1952	......	.03
Josephine Creek, De Soto City, Aug. 19, 1952	......	.04

	Inorganic P ppm	Total P ppm
Small Creek, Rt. 441, Osceola-Okeechobee		
County Line, June 23, 1952		.007
Small Creek, Rt. 441, 6 miles north of		
Yehaw Junction, June 23, 1952		.003
Streams of West and Northeast Florida		
Apalachicola River		
Chattahoochee, Aug. 26, 1952 (USGS)	......	.200
Chattahoochee, Aug. 3, 1952	......	.041
Perdido River, Barrineau Park, Aug. 23, 1952		
(USGS)	......	.021
Escambia River, Century, Aug. 23, 1952 (USGS)	......	.033
Chipola River, Altha,		
Aug. 11, 1952	......	.025
Aug. 1, 1952	......	.030
Coldwater Creek, Milton, Aug. 24, 1952 (USGS)	......	.005
Ochlockonee River, Bloxham,		
Aug. 11, 1952 (USGS)	......	.687
Aug. 1, 1952	......	.072
Choctawhatchee River, Caryville,		
Aug. 2, 1952	......	.033
Aug. 26, 1952 (USGS)	......	.047
St. Mary's River, Macclenny, Sept. 16, 1952 (USGS)	......	.033
Nassau River, Rt. 1, Aug. 10, 1952	......	.020
Oklawaha River System		
Above Silver River, Aug. 9, 1952	.003	.041
Rt. 40, Aug. 1952	......	.043
Eureka, Aug. 7, 1952		.040
Eureka, 1952	......	.051
Moss Bluff, Aug. 18, 1952	......	.027
Orange Springs, Aug. 20, 1952	......	.050
Lake Griffin (headwater of Oklawaha,		
receives sewage), June 23, 1952	......	.152
Orange Lake Outlet, Citra, July 22, 1952	......	.141
Lochloosa Lake outlet, Lochloosa, July 22, 1942	......	
Lochloosa Creek, Grove Park,	......	.453
Orange Creek, Aug. 20, 1952	......	.127
Creek near Mud lake, Aug. 7, 1952	......	.033
Haines Creek, Lisbon, Aug. 18, 1952	......	.027
St. John's River System (see figure 9)		
Lake George, at Silver Glen Springs,		
Aug. 14, 1952	......	.044
St. John's River, Green Cove Springs,		
July 16, 1952	......	.119
Doctor's Lake, Rt. 17, Aug. 9, 1952	......	.065
Ortega River, Rt. 21, Aug. 9, 1952	......	.044
Black creek, Rt. 17, Aug. 9, 1952	......	.040
Trout creek, Dinsmore, Rt. 1, Aug. 19, 1952	......	.121
St. Johns River, Crows Bluff, Volusia Co.,		
(K. Strawn) Sept. 3, 1952	......	.117
St. Johns River, Rt. 192, June 23, 1952	......	.007
St. Johns River, Rt. 50, June 23, 1952		.015
St. Johns River (Palatka), July 19, 1952	.015	.061
Econlockhatchee River,		
Rt. 419, Oviedo, June 23, 1952	3.1	......
Chulota (USGS), July 29, 1952	......	2.67

	Inorganic P ppm	T
Lake Jessup, June 23, 1952		
Lake Monroe, Sanford, June 23, 1952		
Wekiva River, Rt. 46, June 23, 1952		
Creek, north shore of Crescent Lake,		
Andalusia, July 19, 1952		
Lake Washington, marshes, August, (W. Jennings)		
Creek, Hastings, Rt. 207, July 14, 1952		
Crescent Lake, Andalusia, July 19, 1952		
Clarke creek, south of Green Cove Springs,		
Aug. 9, 1952		
IV. *Lakes, ponds, sinks*		
(Some data on lakes in appendix sections on Oklawaha and St. Johns rivers)		
Sinks		
Green sink, Univ. of Fla., Gainesville,		
Aug. 31, 1952	1.01	
Dairy sink, Univ. of Fla., Gainesville,		
Aug. 31, 1952		
Sink, Administration Building, Univ. of		
Fla., Gainesville, Aug. 31, 1952		
Lakes		
Lake Alice, Gainesville,		
(fertilized surrounding fields, Heron rookery)		
July 16, 1952 (D. Karraker)	.550	
July 16, 1952 (D. Karraker)	.530	
Lake Santa Fe, July 13, 1952	.015	
Lake Geneva, Keystone Heights, July 16, 1952		
Brooklyn Lake, Keystone Heights, July 16, 1952		
Kingsley Lake, July 16, 1952		
Hampton Lake, Bradford Co., Aug. 31, 1952		
Newnan's Lake, Gainesville, Aug. 31, 1952		
West edge	......	
Outlet	......	
May 16, 1952		
Lake Kanapaha, Gainesville, Aug. 31, 1952		
East Tohopekaliga Lake outlet, St. Cloud,		
Aug. 21, 1952 (USGS)	......	
Tohopekaliga Lake Outlet, St. Cloud,		
Aug. 21, 1952 (USGS)		
Lake Rochelle, town of Lake Alfred, March 2, 1952		
Johnson Lake, Clay Co., June, 1952 (M. Westfall)		
Pebble Lake, Putnam Co., June, 1952 (M. Westfall)		
Lake Ola, Mt. Dora, June 20, 1952 (W. Jennings)		
Spring Lake, Winterhaven, Fla., March 2, 1952		
Lake Dora, Mt. Dora, June 20, 1952 (W. Jennings)		
Lake Weir, Oklawaha, June 20, 1952 (W. Jennings)		
Lake Okeechobee,		
Clewiston, June 22, 1952		
North shore, June 22, 1952	......	
Bivin's Arms, Gainesville, July 11, 1952		
Unfiltered	.070	
Filtered		
Lake Eustis, Tavares, June 23, 1952	......	
Clubhouse Lake, 7 miles east of Keystone		
Heights, June 15, 1952 (H. Hansen)	......	
Reedy Lake, outlet, Frostproof, Aug. 19, 1952 (USGS)	......	
Istokpoga Lake, outlet canal, Cornwell,		
Aug. 19, 1952 (USGS)	......	

	Inorganic P ppm	Total P ppm
Red Water Lake, 6 miles southeast of Hawthorne, Sept. 10, 1952 (H. Hansen)		.197
Johnson Lake, 4 miles north of Gainesville, Sept. 8, 1952	......	.039
Hanna Lake, outlet, Lutz, Aug. 8, 1952 (USGS)	......	.061
Hutchins Lake, outlet, Lutz, Aug. 8, 1952 (USGS)	......	.016
Lake Wauberg, Gainesville,		
July 6, 1952	......	.087
July 25, 1952	......	.091
June 27, 1952	......	.127
Lake Winnemesset, DeLand, Aug. 29, 1952	......	.024
Small Ponds, Pools, Marshes		
Flatwoods pond, roadside ditch connection, Alachua Co., 4.2 miles north of Rt. 24 on Monteocha road, Aug. 31, 1952	......	.072
Pool, marshy margins of Lake Kerr, north shore, Marion Co., Aug. 7, 1952	......	.000
Swampy tributary in Suwannee floodplain, Carver's camp, 10 miles south of Oldtown, Aug. 6, 1952	......	.112
Pond in Hammock, Duckweed covered, Rt. 329, 4 miles south of Rt. 235, 3 miles east of La Crosse, Alachua Co., Aug. 31, 1952	......	.190
Flatwoods pond, Rt. 301, 1 mile north of Orange Heights, Alachua Co., Aug. 31, 1952	......	.030
Boat basin, near mouth of Silver Springs,	......	.035
Creek, sluggish meander in cypress swamp, Rt. 52, San Antonio, June 18, 1952	......	.004
Pond, sandy dunes, maidencane, in scrub area, Rt. 19, north of Weekiwachee Springs, Hernando Co., May 30, 1952	......	.001
Pond, sand dunes, maidencane, in scrub area, Rt. 19, Weekiwachee Springs, Hernando Co., May 30, 1952	......	.004
Pond, sand dunes, maidencane, in scrub area, Rt. 19, north of Weekiwachee Springs, Hernando Co., May 30, 1952	......	.008
Marsh water, seepage from Fowlers Prarie, Rt. 20, Putnam Co., June 9, 1952	......	.260
Flatwoods pond, ¼-½ mile south of Devils Millhopper, Alachua Co., Sept. 11, 1952	......	.070
Edgar Clay Pits, Edgar, Putnam Co., 25 miles east of Gainesville, Sept. 10, 1952	......	.027
Pond, 7/10 miles south of Wachoota, Alachua Co., Sept. 11, 1952	......	1.0
Slough between Kanapaha Prarie and Levy Lake, Alachua Co., Sept. 11, 1952	......	.017
Pond, hyacinth filled, along road, 12.2 miles south of Wachoota, Alachua Co., Sept. 11, 1952	......	.077
Flatwoods pond, along road, 11.3 miles south of Wachoota, Alachua Co., Sept. 11, 1952	......	.433
Watermelon pond, Archer, July 30, 1952	......	.044
Pond, watershield, just north of Watermelon Pond, Archer, July 30, 1952	......	.136
Cummer Limestone Co. Quarry, Ocala, Aug. 18, 1952	......	.353
Tsala Apopka Lake, pond-like coves, Rt. 200, June 18, 1952	......	.013
Tsala Apopka Lake, small stream draining margins, Rt. 200, June 18, 1952	......	.027
Pond, Marion Co., 1½ miles east of Rt. 42 and Rt. 450, Aug. 30, 1952	......	.121

Part II

PETROLOGY OF EOCENE LIMESTONES IN AND AROUND THE CITRUS-LEVY COUNTY AREA, FLORI

By

Alfred George Fischer

University of Kansas, Lawrence, Kansas

May 21, 1949

Report to the Florida Geological Survey