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GENERALIZED DISTRIBUTION AND CONCENTRATION OF ORTHOPHOSPHATE IN FLORIDA STREAMS

By
Matthew I. Kaufman

Prepared by the
U. S. GEOLOGICAL SURVEY
in cooperation with the
BUREAU OF GEOLOGY
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INTRODUCTION

A knowledge of the occurrence of phosphorus in surface waters, from natural as well as man-influenced sources, is essential to the understanding and management of the quality aspects of Florida's surface-water resources. Statewide distributions of orthophosphate in surface waters exist which can be related in part to naturally-occurring phosphatic rock formations, wildlife habitats and streamflow, and in part to cultural influences (industrial, municipal, and agricultural pollution). The distribution and concentration of orthophosphate, and to a limited degree total phosphorus, in Florida streams is described herein. Regional, time, and flow variations of concentrations and loads and their interrelationships are briefly discussed.

SIGNIFICANCE OF PHOSPHORUS

Phosphorus, one of the major elements required in the synthesis of proteins, is a primary nutrient in the food chains and as such regulates the extent of plant growth and ultimately food production within the life cycle. Among phosphorus-containing compounds the inorganic phosphates are of major significance, occurring in the orthophosphate form, or as condensed phosphates which gradually hydrolyze in aqueous solution to the orthophosphate form. (Task Group Report, 1966.) Orthophosphate includes the three ionized forms of phosphoric acid, $H_2PO_4^-$, HPO_4^{2-} , and PO_4^{3-} , whose relative concentrations in water are a function of pH (Rainwater and Thatcher, 1960). The combined orthophosphates are reported in terms of milligrams per liter (mg/l) PO_4^{3-} . Orthophosphate values serve as an index of total soluble phosphorus, which must be determined to permit a comprehensive assessment of the nutrient supply of an area.

Effects associated with the presence of excessive dissolved phosphates include: (1) reduced efficiency of the coagulation-flocculation-sedimentation process and lime-soda ash softening in water treatment, due particularly to the condensed phosphates (>0.1 mg/l); (2) Over-abundant growth of algae and other aquatic plants (i.e., water hyacinths) in both flowing and non-flowing surface waters, and the associated problems of objectionable algal blooms, undesirable tastes and odors, filter clogging, increased color, turbidity, chlorine demand and increased treatment costs, and (3) a high oxygen demand due to oxidation of organically derived phosphorus entering an ecosystem, resulting in a reduction of dissolved oxygen in a lake or stream (Task Group Report, 1966, 1967; FWPCA, 1968; Sawyer, 1965; McKee and Wolf, 1965). The most serious effects of excess dissolved phosphate occur downstream from sources of high concentrations of this nutrient, especially in impoundments or lakes where natural eutrophication processes can be greatly accelerated. In order to retard some of the associated effects—i.e., over-abundant growth of algae and other aquatic plants—FWPCA (1968) suggests that the concentration of total phosphorus should not exceed 0.05 mg/l where streams enter lakes or reservoirs.

SOURCES OF PHOSPHATE

Phosphates are one of the end products of the decomposition of organic matter and in addition may be derived from leaching of naturally occurring phosphatic minerals such as fluorapatite ($Ca_5(PO_4)_3F$), an important constituent of phosphatic sediments in Florida. Phosphates are contributed to water in significant quantities from several man-made and natural sources, including: (1) industrial wastes; (2) sewage-treatment plant effluent (human wastes and detergents); (3) agricultural drainage, including farm-animal wastes and fertilizers; (4) urban drainage including municipal water-treatment wastes; (5) drainage from natural phosphatic terranes; (6) rural runoff; and (7) rainfall. Evaluation of the various sources of phosphorus suggests that the greatest contribution of phosphorus to water is directly or indirectly a result of the activities of man (Task Group Report, 1967).

REGIONAL DISTRIBUTION

The distribution and concentration of dissolved orthophosphate in Florida streams is shown on the large map. The orthophosphate content of streams in parts of the state can be correlated with phosphatic-rock formations of the drainage area whereas high values not associated with natural drainage from phosphatic terranes are due primarily to pollution. These results are consistent with the earlier work of Odum (1953) who reported on and mapped the distribution of total dissolved phosphorus in Florida waters. The data and interpretations herein are based on statewide mass-samplings in May 1966, 1967 (coinciding with periods of low stream-flow and minimum uptake of nutrients by plants during their growth period), plus sampling at several long-term stations in west-central peninsular Florida (late 1950's through 1966). Most samples lacked the addition of a preservative to prevent algae and bacteria from either assimilating or synthesizing soluble phosphorus. Thus laboratory values may, and probably in some cases do, vary from field values. As the data are quite limited over much of the state, regional concentration patterns are of necessity generalized and local variations may be expected to exist.

Orthophosphate concentrations greater than 5 mg/l can be attributed directly to cultural influences (pollution); however, concentrations in excess of 1 mg/l (and in some cases 0.5 mg/l), where not associated with phosphatic terranes, may also be indicative of cultural influences. Exception exist in southernmost Florida, where high orthophosphate concentrations that occur during low-flow periods are attributed to wildlife (i.e., bird excrement). Figure 1 shows the dissolved orthophosphate load in Florida streams in May 1966. The concentration and dissolved-load maps identify drainage areas contributing significant concentrations and quantities of orthophosphate to Florida's surface waters and illustrate regional differences.

Orthophosphate concentrations and loads of selected streams and springs are listed in Table 1, providing an "order of magnitude" estimate for the contributions from each source. Industrial waste from phosphate-mining areas in west-central peninsular Florida is the greatest single source of orthophosphate. The highest orthophosphate concentrations and loads (>200 mg/l and $>100,000$ lbs. per day, respectively) are contributed to Tampa Bay and thence to the Gulf of Mexico from the Alafia River drainage system (large map and figure 1).

Major secondary sources include other industrial wastes, sewage effluent, and drainage from agricultural lands. On a statewide basis, significant quantities of dissolved orthophosphate in Florida streams occur as the result of drainage from natural phosphatic terranes. On the basis of data from several springs, the orthophosphate increment to Florida's surface waters from the Floridan aquifer is relatively minor.

VARIATIONS WITH DISCHARGE AND TIME

The dissolved orthophosphate load and dissolved orthophosphate concentration/discharge relation in several Florida rivers are shown on figures 2 and 3, respectively. A direct relation is noted between discharge and load, and a slight inverse relation between discharge and concentration. The latter relation, however, is poorly defined for natural streams draining non-phosphatic terranes. Seasonal variations of orthophosphate load and concentration in west-central peninsular Florida are portrayed on figures 4 and 5. Where streams are not affected by pollution (Myakka River, fig. 4), there is no consistent relation between orthophosphate concentration and time of year. However, the loads vary seasonally, tending to be high in March and again during the period July to September, coincident with high rates of discharge. Where affected by pollution (Alafia River, fig. 5), load is directly related and concentration is inversely related to effluent discharge. Figure 6 illustrates fluctuations of total phosphorus load and concentration for the Escambia River in western Florida. The highest concentrations and loads appear to occur in the winter and early spring, coincident with periods of high discharge.

Frequency curves of dissolved orthophosphate concentration in selected streams in west-central peninsular Florida are portrayed on figure 7 and show the range in concentration from relatively uncontaminated streams draining slightly phosphatic terranes (Myakka River) to highly polluted streams (Alafia River). Evaluation of orthophosphate data from several streams for the period 1957-58 to 1965-66 utilizing plots of concentration and load versus time are inconclusive with respect to long-term trends. Frequency curves for the Alafia River at Lithia, however, show that orthophosphate concentrations were considerably higher (at comparable discharges) during 1965-66 (median concentration: 100 mg/l) than during 1957-58 (median concentration: 48 mg/l). Data are insufficient to ascertain whether similar increases are occurring in other Florida streams due to expansion of industry, agriculture, and/or population.

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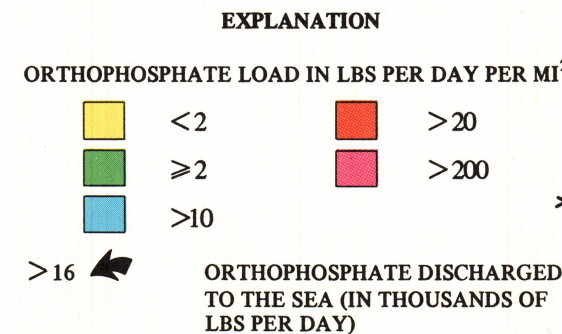


Figure 1. Dissolved orthophosphate loads of Florida streams, May 1966.

TABLE 1. ORTHOPHOSPHATE CONCENTRATIONS AND LOADS OF SELECTED STREAMS AND SPRINGS

Stream/Spring	Drainage Area (mi²)	Principal Source	Date	Discharge (cfs)	Ortho-PO ₄ Conc. (mg/l)	Lbs./day	Lbs./day/mi²	Ortho-PO ₄ Load Lbs./yr/mi²	Lbs./yr
Alafia R. at Lithia	335	Ind. Waste	1957-58	*415	57	127,800	382	141,020	47.2 X 10 ⁶
Peace R. at Arcadia	1367	"	1964-65	*843	*6.8	31,000	22	16,400	11.2 X 10 ⁶
Fenholloway R. at Foley	110	"	5/16/66	138	46	34,200	312	—	—
Escambia R. near Chuluota	241	Sewage Effluent	5/9/66	101	7.7	4,200	18	—	—
New R. nr Lake Butler	212	Agric. Drainage	5/10/66	1770	0.36	3,400	16	—	—
Manatee R. nr Bradenton	80	Natural PO ₄ Terrane	1964/65	*112	*1.4	840	10	3,760	0.3 X 10 ⁶
Yellow R. nr Holt	1210	Natural, non-PO ₄ Terrane	6/2/66	1540	0.08	660	<2	—	—
Withlacoochee R. nr Holder	1710	"	5/26/66	951	0.06	300	<2	—	—
Blue Spr nr Orange City	—	Floridan Aquifer	5/26/66	156	0.39	320	—	—	—
Silver Spr nr Ocala	—	"	5/11/67	854	0.13	600	—	—	—
Lithia Spr nr Lithia	—	"	5/18/67	20.7	0.13	20	—	—	—
Wakulla Spr nr Crawfordville	—	"	5/19/66	380	0.07	140	—	—	—

*Time weighted average

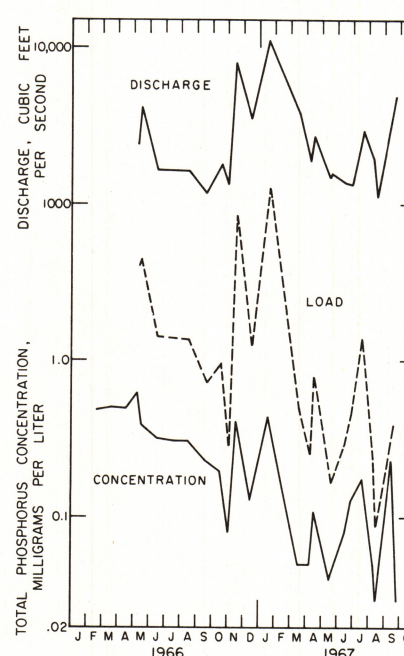


Figure 4. Seasonal variations of discharge, dissolved orthophosphate load and concentration, Myakka River near Sarasota, 1962-63.

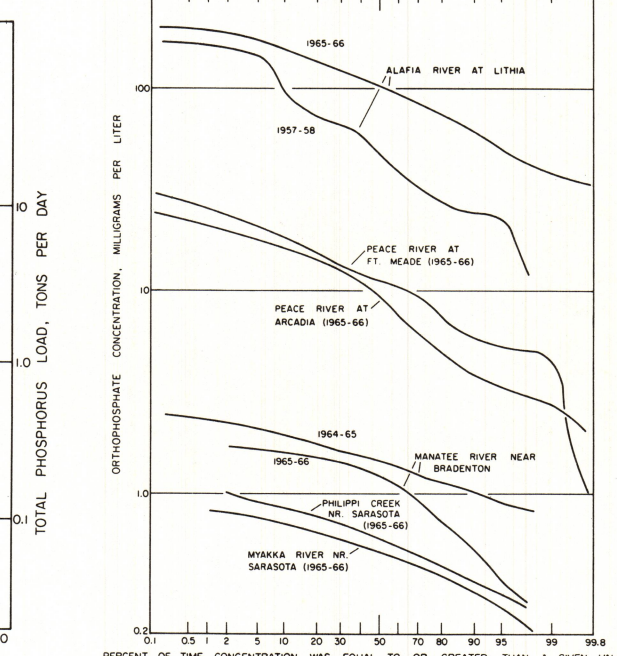


Figure 5. Seasonal variations of discharge, dissolved orthophosphate load and concentration, Alafia River at Lithia, 1957-58.

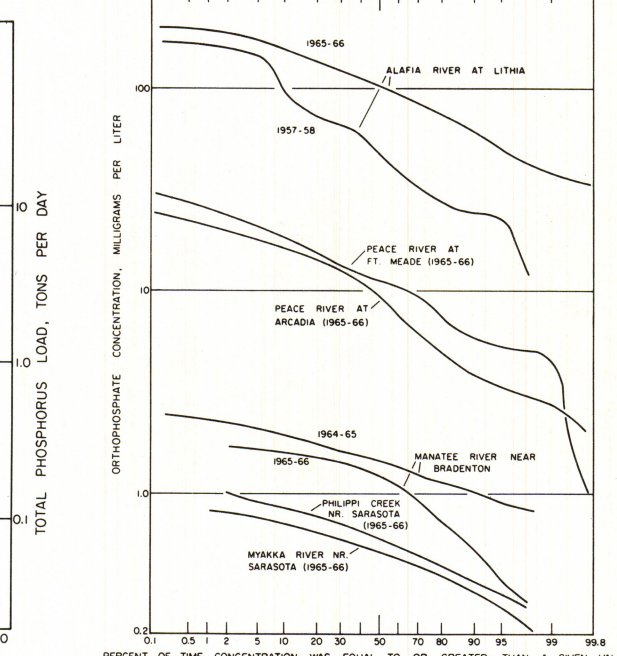


Figure 6. Monthly discharge, total phosphorus load and concentration, Escambia River near Century, 1965-67.

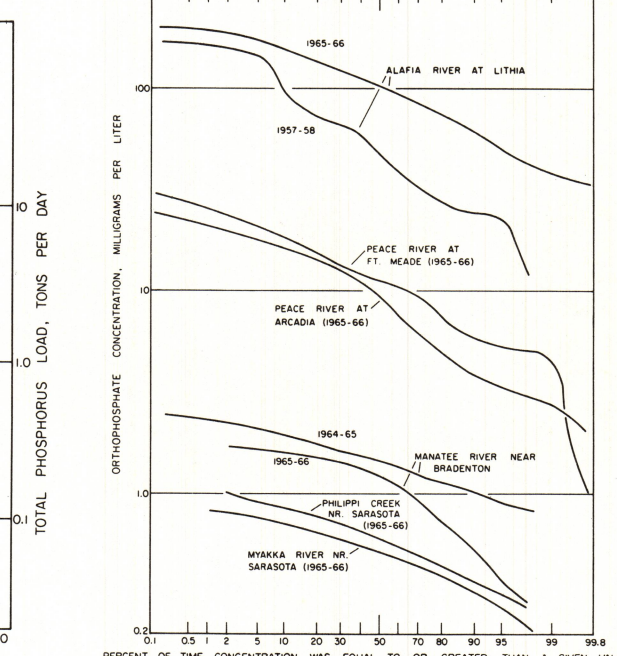
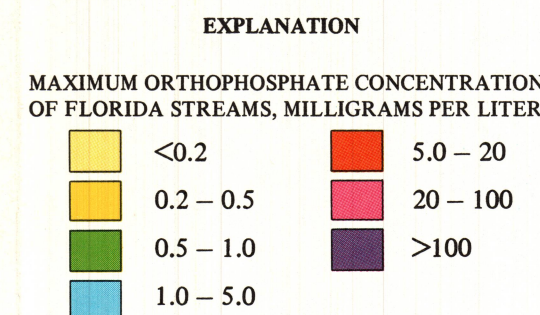


Figure 7. Frequency curves of dissolved orthophosphate concentration in selected streams in west-central peninsular Florida.



○ SAMPLING SITE
● FLORIDAN AQUIFER SPRING

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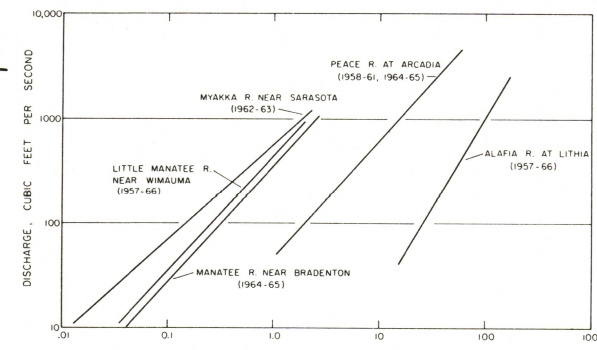


Figure 2. Relation between dissolved orthophosphate load and discharge of selected Florida streams.

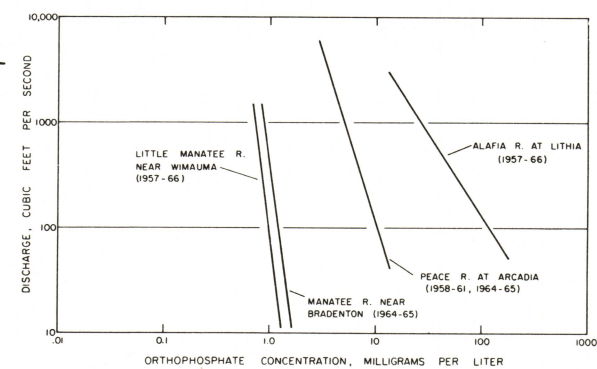


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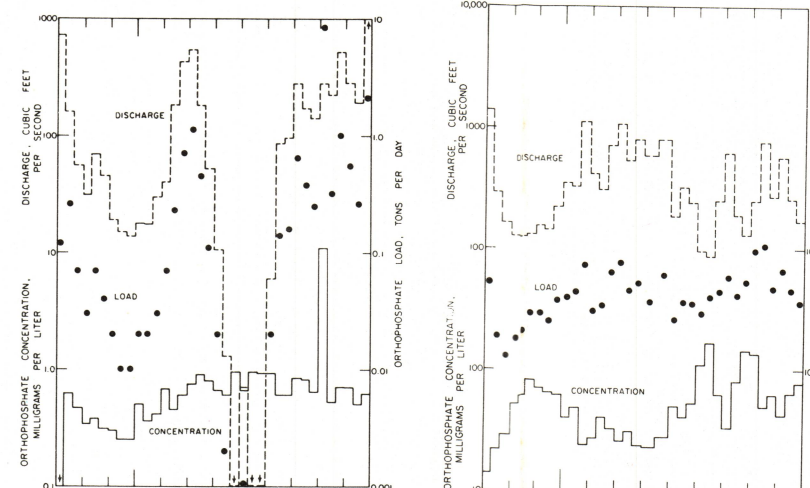


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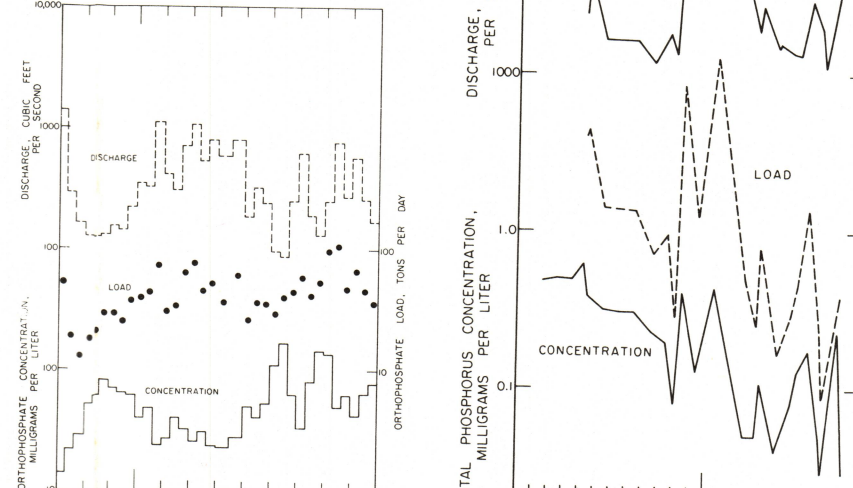


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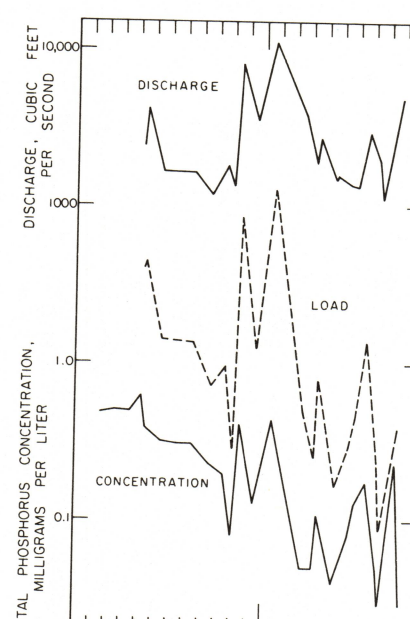


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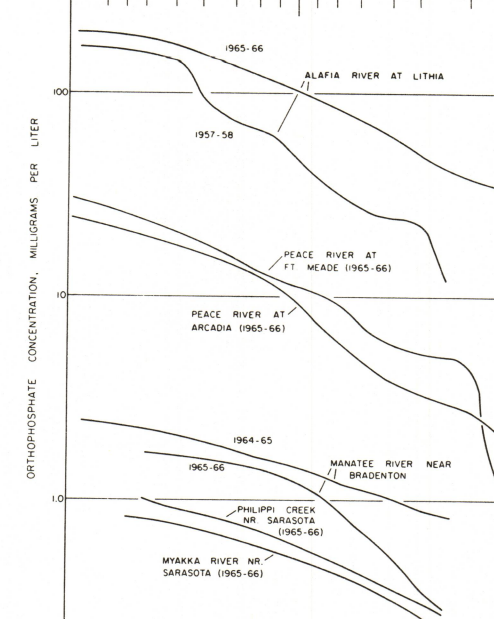
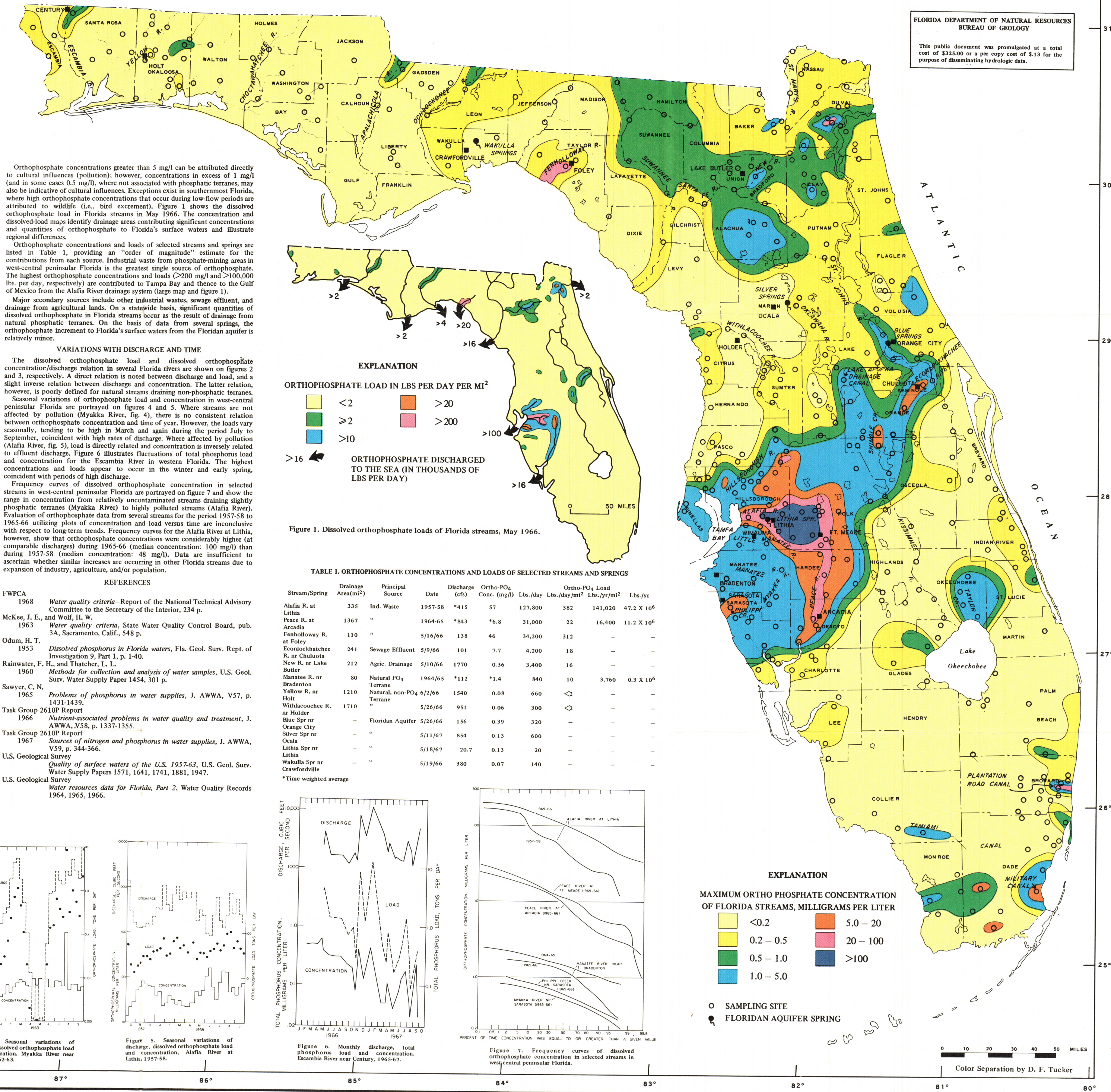


Figure 7. Frequency curves of dissolved orthophosphate concentration in selected streams in west-central peninsular Florida.



EXPLANATION

ORTHOPHOSPHATE LOAD IN LBS PER DAY PER MI²

ORTHOPHOSPHATE DISCHARGED TO THE SEA (IN THOUSANDS OF LBS PER DAY)

Figure 1. Dissolved orthophosphate loads of Florida streams, May 1966.

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Wakulla Spr nr Crawfordville	—	"	5/19/66	380	0.07	140	—	—	—

*Time weighted average

EXPLANATION

MAXIMUM ORTHO PHOSPHATE CONCENTRATION OF FLORIDA STREAMS, MILLIGRAMS PER LITER

<0.2
0.2 - 0.5
0.5 - 1.0
1.0 - 5.0
5.0 - 20
20 - 100
>100

○ SAMPLING SITE
● FLORIDAN AQUIFER SPRING

0 10 20 30 40 50 MILES

Color Separation by D. F. Tucker