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C.2COLOR OF WATER IN FLORIDA STREAMS
AND CANALSby
Matthew I. KaufmanPrepared by
UNITED STATES GEOLOGICAL SURVEY
in cooperation with the
BUREAU OF GEOLOGY
FLORIDA DEPARTMENT OF NATURAL RESOURCES
TALLAHASSEE, FLORIDA
1969

INTRODUCTION

A knowledge of the occurrence and distribution of color in surface waters, from natural as well as man-influenced sources, is important to the understanding and management of the quality aspects of Florida's water resources. The color of water is significant for both domestic and industrial uses and is also related to productivity and trace metal concentration in aqueous environments. Regional differences of color in surface waters exist which can be related in part to natural decomposition of organic matter and in part to industrial and agricultural influences. The occurrence and distribution of color in Florida streams and canals is described herein, including sources, significance, regional distributions and chemical associations, seasonal variations, and the relations of color to streamflow.

SOURCES, NATURE, AND SIGNIFICANCE OF COLOR

Natural waters exhibiting a yellow to brown color are common throughout many parts of the world. Waters of this type are often referred to as swamp, humus, or colored water (Christman and Ghassemi, 1966). The color may be of organic or mineral origin. Organic sources include humic materials (decaying vegetation, tannins, peat), aquatic plants, etc. Inorganic sources are metallic substances such as iron and manganese compounds, chemicals, and dyes. Numerous industries discharge materials that contribute to the color of water, including pulp and paper, textile, and refineries. Agricultural drainage and returned irrigation water also contribute to color of water (FWPCA, 1968; McKee and Wolf, 1963).

According to the Research Committee Report (1966), the effectiveness of decomposition of organics in contributing to water color depends on the quantity of material undergoing decomposition and the rate of decomposition. In tropical and subtropical regions, the quantity of vegetation is abundant and the rate of decomposition is high; thus rivers in the southeastern U.S., Central America, and northern South America are highly colored. Black and Christman (1963a) noted a linear relation between total organic matter and color value of water. The organic macromolecules are similar to soil organics and the aqueous extracts of wood, soil, and vegetation at various stages of growth and decay (Res. Comm. Rept., 1966; Christman and Ghassemi, 1966).

Most of the organic matter in naturally colored surface waters consists of simple to complex mixtures of nonvolatile polymeric hydroxy carboxylic acids (Lamar and Goertitz, 1966; Lamar, 1968). Many of these acids color the water yellow to brown, influence the pH of some stream waters, and account for the acidic properties of organic color. These organic acids exist in water as negatively charged colloidal sols which exert a holding action for a number of metallic ions such as iron and manganese. This holding action has been referred to as adsorption, bonding, complexation, and chelation. The negative charge has been attributed by Black and Christman (1963b) to ionization of the carboxyl and aromatic hydroxyl groups.

Color values are determined by the comparison method (Rainwater and Thatcher, 1960). One standard color unit is produced by a solution containing 1 mg/l (milligram per liter) platinum and 0.25 mg/l cobalt. The color of a water sample is compared with that of glass discs calibrated to correspond with colors on the platinum-cobalt scale.

Both soil and water humics are capable of stimulating the growth of algae. Thus water color plays a significant role in maintaining high primary productivity in aquatic environments. The relation between water color and productivity involves trace metal stabilization by the humics. In some instances, however, where humics are highly concentrated they may severely limit organic productivity because of absorption and reduction of photosynthetically active light (Res. Comm. Rept., 1966). According to FWPCA (1968), color in excess of 50 units may limit photosynthesis and have a deleterious effect upon aquatic life, particularly phytoplankton and the benthos. Slack and Feltz (1968) noted that organic loading of a stream (due to natural leaching and decomposition) contributed to dissolved oxygen depletion and that water color was inversely related to dissolved oxygen and directly related to iron and manganese concentrations. Low dissolved oxygen or anoxic conditions resulting from decaying vegetation are favorable for the reduction of iron to the soluble ferrous species (Lamar, 1968).

Color is esthetically undesirable in waters used for domestic purposes and may dull clothes and stain fixtures. The 1962 USPHS Drinking Water Standards limit the color of acceptable water to 15 units. Most Florida streams exceed these limits most of the time and would require treatment for removal of the color. Color is undesirable in water for a number of industrial uses, with limits ranging from 0-100 units (McKee and Wolf, 1963). Humic-derived color is also significant in other aspects of hydrology. There is a possible role of humics in corrosion (lead in particular is rendered soluble by water humics) and they may interfere with coagulation of other constituents of natural waters, particularly with procedures involving colorimetric analyses (Res. Comm. Rept., 1966).

REGIONAL DISTRIBUTION AND CHEMICAL ASSOCIATIONS

The distribution of maximum color values in Florida streams and canals is shown on the large map. The values are time as well as space related and tend to coincide with periods of high flow. The regional distributions and interpretations are generalized based on data from the early 1940's through 1966 and local variations may be expected to exist. Waters exhibiting considerable color include those in northcentral and northeast Florida (associated in part with drainage from Okefenokee Swamp in southeast Georgia), coastal areas east of the St. Johns River, parts of central and eastcentral peninsular Florida, and those waters in the environs of Lake Okechobee. Frequency curves of color in Florida streams, utilizing streams and periods of record considered representative of the region.

Excluding streams affected by industrial and agricultural influences, most of the highly colored streams in Florida have low specific conductance, are soft, acidic (low pH) and contain appreciable iron. They are weakly buffered and thus potentially corrosive. The color in these waters is in general derived from the

natural decomposition of organic matter. The low pH relates to carbon dioxide and organic acids produced during decomposition. The low conductance relates in part to dilution coincident with periods of increased streamflow and in part to many of the substances in solution being non-conductors. An inverse relation between color and specific conductance is exhibited by some streams (figure 2). Although no consistent statewide relation between color intensity and iron concentration exists, some individual streams exhibit a direct relation (figure 3). Lamar (1968) reported that filtration of natural surface waters through 0.1 μ and 0.01 μ millipore filters removed progressively greater amounts of iron and organic color. He concluded that a relationship existed between iron concentration, pH, and the particle size of the organic colloidal sols.

Waters with high color in the environs of Lake Okechobee have high specific conductance, are hard, generally alkaline and contain considerable sulfate, nitrate, chloride, and at times iron. The color is derived from the leaching of organic soils that accompanies drainage and irrigation of agricultural lands. Color in the Okechobee area tends to increase with increasing mineralization (Hillsboro Canal, figure 2), in contrast to many of Florida's streams. The pumping of drainage and irrigation waters into the canal at times results in reversal of flow direction from the normal situation in which water drains from Lake Okechobee toward the Atlantic Ocean.

Several streams in the state receive paper mill wastes and the receiving waters then become highly colored, soft, alkaline, and highly mineralized. Selected chemical characteristics of waters with high color are given in Table 2, noting regional differences and environmental controls and emphasizing that properties of a given colored water depend on its source.

VARIATIONS WITH DISCHARGE AND TIME

Streams, particularly those subject to large fluctuations in runoff, show considerable variation in color. In general, increased color is observed immediately following rainfall due to the initial flush of decayed organic matter into the stream, with high color tending to coincide with periods of high flow (figure 4). The effects of dilution with increased discharge following the initial flush, as well as seasonal variations, contribute to the observed scatter.

Seasonal variations of color and pertinent correlations and interrelations are portrayed in figures 5 and 6. Fluctuations in color values are concomitant with fluctuations in discharge, irrespective of time of year, and are associated with variations in iron concentration, specific conductance, and pH. These relations are typical of those occurring in many of Florida's streams. In southeast Florida, as a result of the leaching of organic soils that accompanies drainage of water from agricultural lands, increased color values relate directly to increased specific conductance and at times to nitrate concentration (figure 7). The latter relation is especially evident during October and late June to early July when peaks of nitrate concentration are associated with rapidly increasing color values.

Seasonal variations of color in a number of Florida streams and canals are summarized in table 3. Maximum color values predominate during July through October, coincident with the period of active decomposition and leaching of organic matter and the flushing action of high rainfall and runoff. Minimum values tend to occur in May and June associated with the period of plant growth, little rainfall, and low flow) and also in December (associated with the period when vegetation is dormant).

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Chemical Characteristics Typical of Representative Waters with High Color

Stream/Canal	Date	Color Pt-Co Units	pH	Iron (Fe) as CaCO ₃ μ moles at 25°C	Hardness Spec. Cond., μ moles at 25°C	Chemical Type	Remarks
Withlacooches R. nr. Eva	9/22/64	540	4.4	0.60	8	Ca-Mg-Na-Cl	Swamp drainage
Welaunee Cr. nr. Wacissa	5/3/56	500	4.4	1.5	15	Ca-Mg-Na-Cl	Swamp drainage
Cow Cr. nr. Maytown	9/2/65	800	4.6	0.55	12	Na-Cl	Swamp drainage
Moatline Cr. nr. St. Augustine	8/11-20/57	560	6.2	0.45	28	Ca-Mg-Na-Cl	Swamp drainage + ground water inflow
New R. nr. Lake Butler	7/15-20/57	460	6.2	0.60	38	Ca-Mg-HCO ₃	Agric. drainage + ground water inflow
Indian Prairie Canal nr. Okechobee	7/18/55	520	6.0	1.7	91	Ca-SO ₄	Agric. drainage
West Palm Beach Canal at Canal Pt.	6/23/54	480	7.2	0.30	519	Ca-HCO ₃	Agric. drainage + organic soil leaching; high SO ₄
Fenholloway R. at Foley	5/16/66	1400	8.2	0.23	96	Na-Cl-HCO ₃	Receives paper mill effluent

TABLE 3
Occurrences of Maximum and Minimum Color Values in Selected Florida Streams and Canals by Months

Stream/Canal	Number of Occurrences	
	Maximum Color	Minimum Color
January	0	8
February	2	5
March	8	4
April	7	4
May	3	17
June	10	11
July	23	1
August	21	0
September	24	1
October	19	1
November	5	3
December	1	10

36 stations on 32 different streams and canals during the period 1950-67. Maximum and minimum values occurred more than once in the year at many stations.

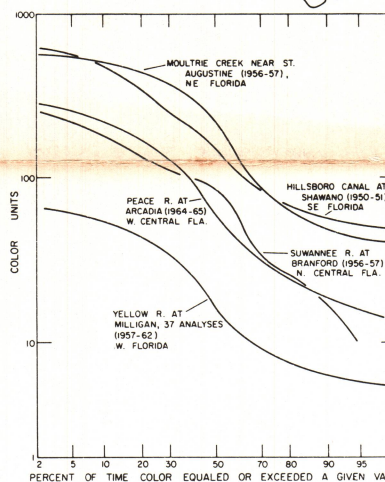


Figure 1. Frequency curves of color in selected Florida streams.

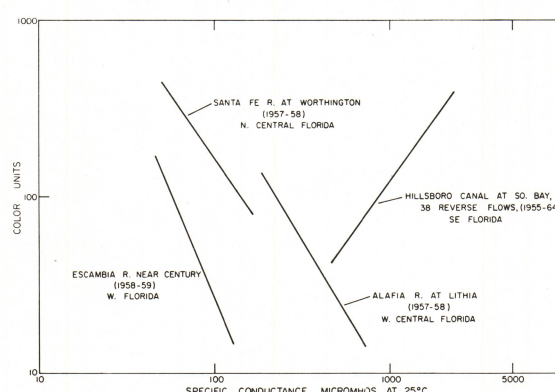


Figure 2. Relation of color values to specific conductance in selected Florida streams and canals.

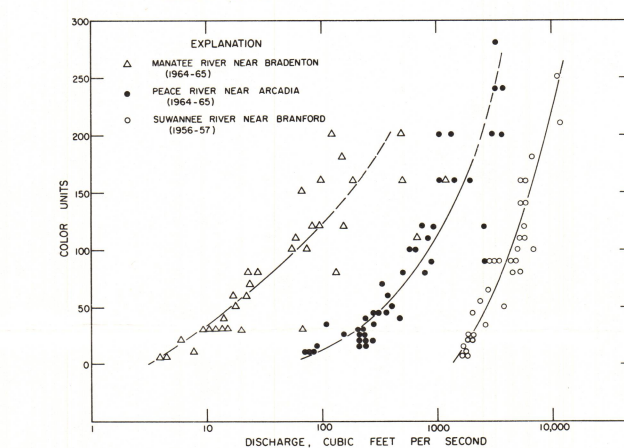


Figure 4. Relation of color values to discharge in three streams in N. Central and W. Central Florida.

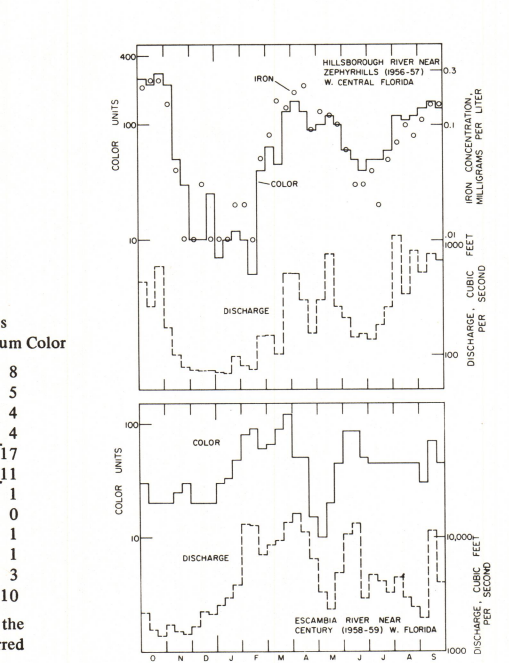


Figure 5. Seasonal variations of color, discharge, and iron concentration in two Florida streams.

TABLE 1
Regional Comparisons of Color in Selected Florida Streams and Canals

Region	Number of Streams/Canals Utilized	Color, Pt-Co Units	
		Mean	Range
Western Florida	5	25	0-120
No. Cent. Florida	4	150	5-360
No. East Florida	3	200	5-560
East Cent. Florida	3	110	30-260
West Cent. Florida	8	90	5-280
So. East Florida	5	140	37-560

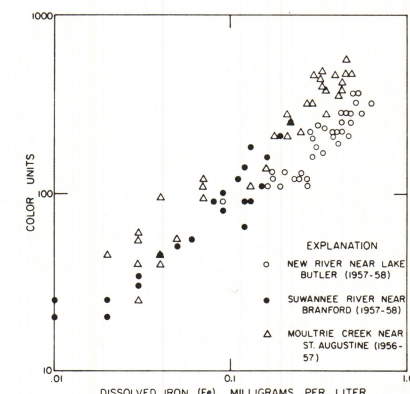


Figure 3. Relation of color values to the dissolved iron concentration in three streams in N. Central and NE Florida.

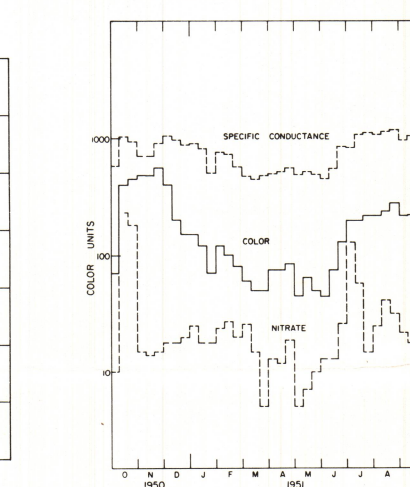


Figure 7. Seasonal variations of specific conductance, color, and nitrate concentration, Hillsboro Canal at Shawano, SE Florida, 1950-51.

EXPLANATION
MAXIMUM COLOR OF WATER IN FLORIDA STREAMS
(COLOR UNITS, PLATINUM-COBALT SCALE)

<100	300 - 400
100 - 200	400 - 500
200 - 300	>500

WATER QUALITY DATA STATIONS, FLORIDA STREAMS
U. S. GEOLOGICAL SURVEY 1940 - 66

- Minimum of 4 yrs. bimonthly, or at least 20 complete analyses, all flow conditions.
- Minimum of 2 yrs. semi-annual, or at least 5 complete analyses, all flow conditions.
- Annual, 1 to 4 complete analyses, generally represents low flow conditions.
- △ Daily specific conductance station, minimum record 1 yr.

0 10 20 30 40 50 MILES

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Excluding streams affected by industrial and agricultural influences, most of the highly colored streams in Florida have low specific conductance, are soft, acidic (low pH) and contain appreciable iron. They are weakly buffered and thus potentially corrosive. The color in these waters is in general derived from the

natural decomposition of organic matter. The low pH relates to carbon dioxide and organic acids produced during decomposition. The low conductance relates in part to dilution coincident with periods of increased streamflow and in part to many of the substances in solution being non-conductors. An inverse relation between color and specific conductance is exhibited by some streams (figure 2). Although no consistent statewide relation between color intensity and iron concentration exists, some individual streams exhibit a direct relation (figure 3). Lamar (1968) reported that filtration of natural surface waters through 0.1 μ and 0.01 μ millipore filters removed progressively greater amounts of iron and organic color. He concluded that a relationship existed between iron concentration, pH, and the particle size of the organic colloidal solids.

Waters with high color in the environs of Lake Okeechobee have high specific conductance, are hard, generally alkaline and contain considerable sulfate, nitrate, chloride, and at times iron. The color is derived from the leaching of organic soils that accompanies drainage and irrigation of agricultural lands. Color in the Okeechobee area tends to increase with increasing mineralization (Hillsboro Canal, figure 2), in contrast to many of Florida's streams. The pumpage of drainage and irrigation waters into the canal at times results in reversal of flow direction from the normal situation in which water drains from Lake Okeechobee toward the Atlantic Ocean.

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Seasonal variations of color and pertinent correlations and interrelations are portrayed in figures 5 and 6. Fluctuations in color values are concomitant with fluctuations in discharge, irrespective of time of year, and are associated with variations in iron concentration, specific conductance, and pH. These relations are typical of those occurring in many of Florida's streams. In southeast Florida, as a result of the leaching of organic soils that accompanies drainage of water from agricultural lands, increased color values relate directly to increased specific conductance and at times to nitrate concentration (figure 7). The latter relation is especially evident during October and late June to early July when peaks of nitrate concentration are associated with rapidly increasing color values.

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New R. nr. Lake Butler	10	11
Indian Prairie Canal nr. Okeechobee	23	1
West Palm Beach Canal at Canal Pt.	21	0
Fenholloway R. at Foley	24	1
	19	1
	5	3
	1	10

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Figure 5. Seasonal variations of color, discharge, and iron concentration in two Florida streams.

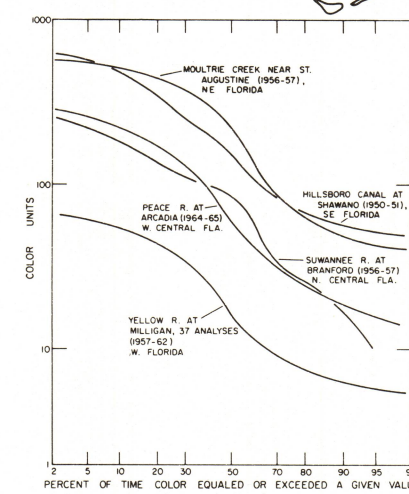


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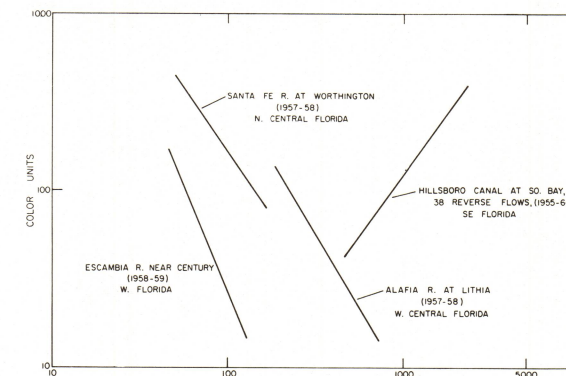


Figure 2. Relation of color values to specific conductance in selected Florida streams and canals.

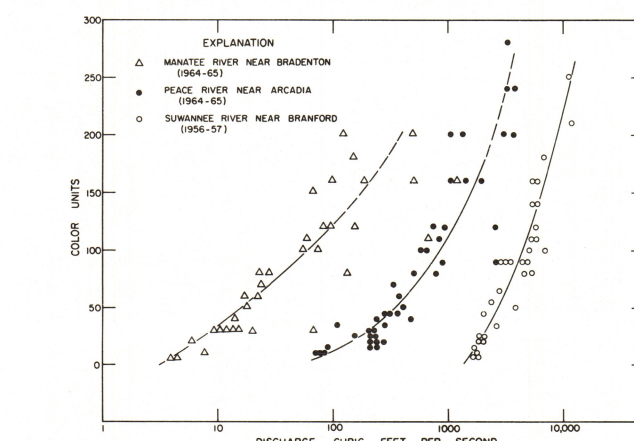


Figure 4. Relation of color values to discharge in three streams in N. Central and W. Central Florida.

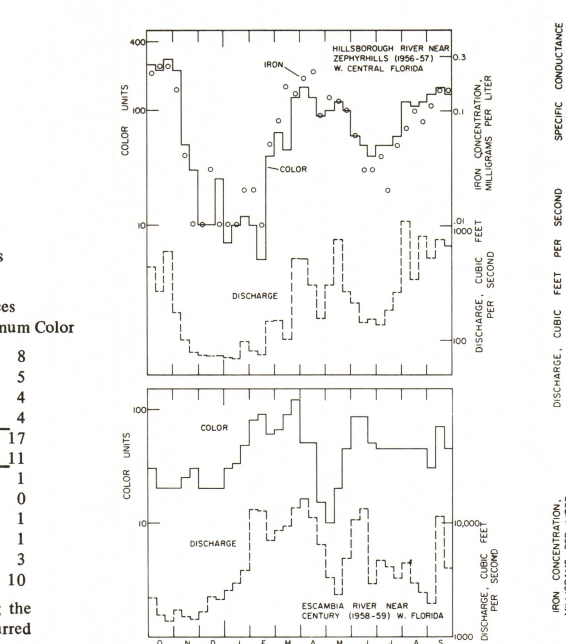


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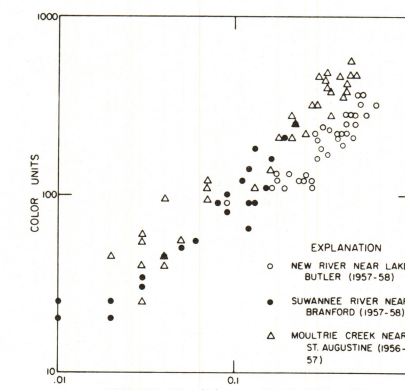


Figure 3. Relation of color values to the dissolved iron concentration in three streams in N. Central and NE Florida.

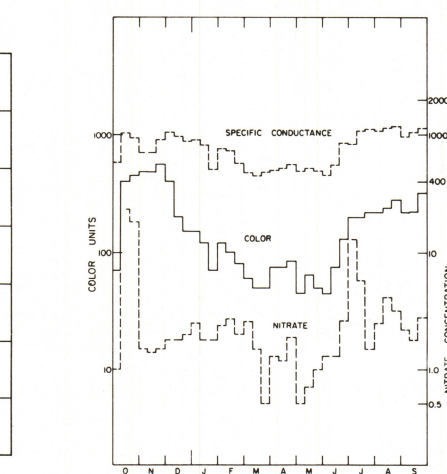


Figure 7. Seasonal variations of specific conductance, color, and nitrate concentration, Hillsboro Canal at Shawano, SE Florida, 1950-51.

EXPLANATION
MAXIMUM COLOR OF WATER IN FLORIDA STREAMS
(COLOR UNITS, PLATINUM - COBALT SCALE)

<100	300 - 400
100 - 200	400 - 500
200 - 300	>500

WATER QUALITY DATA STATIONS, FLORIDA STREAMS
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- Minimum of 4 yrs. bimonthly, or at least 20 complete analyses, all flow conditions.
- Minimum of 2 yrs. semi-annual, or at least 5 complete analyses, all flow conditions.
- Annual, 1 to 4 complete analyses, generally represents low flow conditions.
- Daily specific conductance station, minimum record 1 yr.

0 10 20 30 40 50 MILES