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CHANGES IN SELECTED WATER QUALITY PARAMETERS AS INFLUENCED BY LAND USE PATTERNS IN THE ESPIRITU SANTO DRAINAGE BASIN

DECEMBER , 1975

Elvira Cuevas and Richard G. Clements
Terrestrial Ecology Division

OPERATED BY UNIVERSITY OF PUERTO RICO UNDER CONTRACT
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ABSTRACT

Bi-weekly measurements and samples were taken on the surface waters of the Espiritu Santo river and its tributaries Quebrada Grande, Quebrada Jiménez, and Quebrada Sonadora. The parameters studied were temperature, dissolved oxygen (DO), pH, free carbon dioxide (CO_2), salinity, and the concentrations of sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), and chloride (Cl). The results indicated a general increase in the values of all the parameters measured, from higher to lower elevations with the exception of DO which decreased slightly and was found to be near saturation at all times. CO_2 ranged within the normal values for natural surface waters as were the pH values which ranged from 6.5 to 8.2 with a modal value of 7.0. The concentration of Na, K, Ca, Mg, and Cl were found to be below or near the accepted for drinking water standards. Significant differences were found between each river or tributary for the concentration of the elements mentioned above. No marked seasonal variabilities were observed during the period studied except for the temperature of the water which reflected the lowering of air temperatures during the winter months.

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Introduction

Water resources are a determinant in the management and effective use of an area. The quantity and the quality of the water available in an area will influence and will be influenced by land utilization and conservational practices and controls. Rivers and lakes throughout the world are being used continuously for different purposes such as recreation, fishing, electricity, public supply, irrigation, sewage disposal, etc. Wise management and utilization of a water resource will prevent to a large extent many destructive effects on both a short termed and a long termed basis. The maintenance of a good quality of water throughout a system will help in the prevention of long term effects which could impair future utilization of the water not only by man but by other organisms in the ecosystem.

Water quality indices such as temperature, pH, dissolved oxygen, CO_2, and nutrients will determine the capacity of a system to maintain a healthy community and its capability for reestablishment in case of damage to the ecosystem structure.

Temperature is a prime regulator of natural processes within the aquatic environment. It largely affects the rate of metabolism and activity on all organisms. Acting directly or indirectly in combination with other quality constituents, it affects chemical reaction rates, enzyme structures and molecular movement and exchange within membranes in the external and internal cellular environment.

The solubility of gases including oxygen varies inversely with the temperature in the water. In fresh water the solubility of atmospheric oxygen is decreased by about 55% as the temperature rises from 0°C (32°F) to 40°C (104°F) under one atmosphere of pressure (760 mm Hg)(MacKenthum, 1969).

Dissolved oxygen is very important in the aquatic environment. In appropriate concentrations it is essential to sustain life and to sustain species reproduction, vigor, and the development of populations. At reduced dissolved oxygen levels many organisms undergo stress that make them less able to sustain their populations. Oxygen enters the water by absorption directly from the atmosphere or by plant photosynthesis, and is removed by respiration of organisms and by decomposition. Oxygen derived from the atmosphere may be from direct diffusion or by surface water agitation which may also release dissolved oxygen under conditions of supersaturation.

pH, a measure of hydrogen ion concentration, varies over a wide range in natural waters. Natural waters having a low pH contain very little bicarbonate or else contain high concentrations of free carbon dioxide or organic acids. Values of pH in most of the streams of the United States ranges from 6.5 to 8.5 (MacKenthum, 1969). Bogart (1964) reported pH values ranging from 6.8 to 8.1 for periodic stations on streams in Puerto Rico.

The productivity of an aquatic ecosystem is determined by the availability of nutrients. These nutrients can be divided into two categories: macronutrients and micronutrients. Macronutrients include carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), sulfur (S), potassium (K), magnesium (Mg), calcium (Ca), (except for algae where it is a micronutrient), and sodium (Na). Micronutrients include iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), molybdenum (Mo), vanadium (V), boron (B), chloride (Cl), cobalt (Co), and silicon (Si). The role of the major and minor elements in the biological system has been discussed by Smith (1966), Odum (1971), and MacKenthum (1969), among others.

Past Research

Puerto Rico's river system have been partially investigated by the United States Geological Survey (U.S.G.S.), Water Resources Division. Stream flow has been emphasized in the past few years with some chemical studies performed on an infrequent basis during 1958 to 1971 (Water Resources Data for P.R., U.S.G.S. 1950-1972). One of the first attempts to present an overview of the water resources of the island including some aspects of the quality of the water was that of Bogart (1964). At that time measurements of some water quality variables were strictly related to feasibility of water use for human consumption, agriculture, and hydroelectric power supply. Since then there has been an increase in the demand of water for industrial purposes.

The Water Resources Research Institute in Mayaguez has compiled a bibliography of the information published to date pertinent to the water resources situation in Puerto Rico (Vázquez et. al, 1970). They reviewed and reported around 300 titles and included abstracts on each. The work was further separated by subject matter into the following categories: 1) Nature of water; 2) Water cycle; 3) Water supply augmentation and conservation; 4) Water quantity management and control; 5) Water quality management and protection; 6) Water resources and planning; 7) Resources data; 8) Engineering works; and 9) Man power, grants and facilities. The earliest work reported under water quality management and protection was in 1941. The major thrust on water quality studies began in the mid 1960's with most of the work reported dealing with sanitary conditions of major streams, lakes, and coastal waters. Few of the works reported have dealt directly with base studies of rivers, lakes and lagoons. They have dealt primarily with human related problems such as sanitary conditions or water availability for public consumption. (Vázquez et. al., 1970). Some of the basic studies published to date from reservoirs and lagoons are those of Candelas (1964) and Ruíz de Reyes (1971).

Candelas determined some physical and chemical parameters of eight lakes, seven of them reservoirs. The results showed that the maximum temperature recorded was 31°C and the minimum 22°C. No extensive thermal stratification was noted. pH ranged from 7.0 to 8.0 and dissolved oxygen concentrations ranged from 0.2 to 11.25 mg/l. Dissolved oxygen was found to be present from the surface to the bottom. No free CO_2 was found on the surface of any of the lakes.

Ruíz de Reyes conducted an ecological study of the Tortuguero Lagoon located on the north coast. The results showed that salinity fluctuated between 1,530 and 2,620 mg/l with dissolved oxygen values ranging between 4.28 and 5.67 mg/l. Temperature varied between 24°C and 31°C during the period studied. No noticeable thermal stratification or any anoxic areas were found in the lagoon.

There have been no ecological studies published to date of the rivers and streams of Puerto Rico. Due to severe demands for land usage and water consumption it has become pertiment to study rivers as part of a dynamic ecosystem in which interdependency is vital for continuity of the biota. Studying a definable unit of land, such as a watershed, provides a unifying concept in the evaluation of a system because its output reflects the integration of all its related factors and its subordinated ecosystems. It must also take into consideration the impacts brought about by political and socio-economic decisions.

A watershed has been defined as a system in dynamic equilibrium and a definable unit of land on which all water flows to a common outlet and is derived from, consists of, and is characterized by a host of powerful interacting factors which vary over time, over their natural range, and with respect to each other (Black and Leonard 1968). Odum (1971) has described it as a minimum unit to be considered when man's activities in his surroundings will determine or greatly affect the quality of its environment.

While many suitable watersheds could be found for this type of study, the Espiritu Santo drainage basin was selected because a broad data base already exists for the upper reaches of the area. Since 1963 the Terrestrial Ecology Program of the Puerto Rico Nuclear Center has conducted extensive studies on the ecology of the Luquillo Experimental Forest. Many of the results for the period 1963 to 1968 are summarized in Odum (1970). Stream flow measurements have been monitored by the USGS in the Espiritu Santo river from 1960 to the present.

General Description of the Drainage Basin

The Espiritu Santo basin located in the northeastern part of Puerto Rico drains the northwestern slopes of the Luquillo Mountains and flows northward into the Atlantic Ocean. With a drainage area of 20.6 Km^2 it presents a diversity of ecosystems ranging from forested areas to mangrove communities. Its main river, the Espiritu Santo, originates at approximately 1,000 meters elevation and falls to sea level over a distance of 20 kilometers. The main tributaries are the Quebrada Sonadora, Quebrada Jiménez and Quebrada Grande, all originating at the base of El Yunque rock. Some of the characteristics of the system are presented below in table 1.

Table 1. Characteristics of the Espiritu Santo Basin

Main Stream	Length Km		Ave. Grade %		Drainage Area Km^2
Espiritu Santo		19.5		5.1	20.6
1000 M to 50 M elev.	8.9		10.6		-
50 M to Sea Level	10.6		0.47		-
Tributaries					
Quebrada Sonadora		3.8		21.0	1.5
Quebrada Grande		6.4		13.6	1.9
Quebrada Jiménez		7.5		12.6	3.9

Above 200 meters four distinct types of forest are recognized: Dwarf or Mossy Forest, the Sierra Palm Forest, the Colorado Forest and the Tabonuco Forest (Cook and Gleason, 1972, Wadsworth, 1961; Ewel and Whitmore, 1973). Between 100 meters to 200 meters elevation the middle watershed includes cultivated land, pasture land and transitional forest. The lower watershed or coastal plain area includes pasture land, sugar cane fields, abandoned fields, minor crops, coconut plantations, and the estuary bounded by mangrove communities of Rhizophora mangle L., Laguncularia racemosa L. Guertn., and Avicenia nitida, Jacq.

Human use of the middle watershed zone consists mostly of residence, agriculture and recreation. Agricultural land is mainly devoted to minor crops like plantains and bananas. A large area of the land is now abandoned or being zoned for small lots from 1/2 acre to 5 acres. There are many intermittent streams that drain the land on the middle watershed. In this area the african snail Biomphalaria glabrata, the vector for Schistosomiasis, is present.

The lower watershed comprises the flat lowlands of the coastal plain which extend landward for approximately five kilometers. Rio Grande, the major town, is located on the coastal plain about 0.5 kilometers west of the Espiritu Santo River. The terrestrial system was dominated at one time by sugar cane but today it is almost equally occupied by sugar cane, pastures, minor crops and coconuts. The flood plains to the west of Rio Grande are now being developed as urban areas utilizing now a large land area formerly devoted to agriculture.

For approximately two kilometers inland from the coast line the red mangrove *Rhizophora mangle* flanks both sides of the river. Behind the red mangrove, well established stands of *Laguncularia racemosa* are found. To the east of the river, extensive areas of mangroves have been removed and the land drained and filled for tourism development construction purposes. Due to the low elevation of the coastal plain, drainage is necessary for crop production. The interface system is comprised of both natural and man made drainage ways about which very little is known.

The Soil Conservation Service (1968) has described five major soil associations for the area: (1) Swamp-Marshes, (2) Coloso-Toa-Bajura, (3) Caguabo-Múcara-Naranjito, (4) Los Guineos-Humatas-Lirios, and (5) The Rain Forest Association. Of these five associations, the last three occupy the most extensive area within the watershed studied.

The geology of this area was described by Seiders (1961) and presented in the USGS geologic maps of the El Yunque Quadrangle and the Rio Grande Quadrangle. The predominant rocks are the instrusive and stratified rocks. The first are quartz diorite and the second are chiefly of marine origin such as the Hato Puerto formation. In the lower reaches of the watershed, alluvial deposits and terrace deposits are also found. The weathering process of these rocks will define to a certain extent the chemical composition of the stream waters.

Land use patterns also influence the quantity and quality of water. In 1972 an inventory of the island resources was compiled by the Department of Natural Resources of the Commonwealth of Puerto Rico. Through this agency it was possible to obtain the land use inventory for the year 1972 for the municipality of Rio Grande, in which the Espiritu Santo Watershed is located. Based on this inventory, 98.42% of the total acreage is in use as residential areas, water resources and wetlands, forest and agriculture. Of this 98.42%, 51.70% was forested acreage, 35.46% was devoted to agriculture, 6.14% of the area were water resources and wetlands, and 5.12% was residential. (See Appendix Table 1).

Although such a small percentage of the total area is used for housing purposes 52.25% of the consumption from Rio Grande's municipal water supply in February, 1974 was used for residential water and sewage. Although 0.19% of the total municipality area is used for industry, the water consumed by the latter for the same month was 37.82% of the total consumption. (See Appendix Table 2).

These numbers concern only the town of Rio Grande which obtains its water from Lake Carraízo. The "barrios", geographical areas within the municipality, obtain their water from Quebrada Jiménez and Quebrada Grande, Espiritu Santo inside the forest and Zarzal (west branch of Quebrada Jiménez). Monthly estimates given by the Water and Sewage Authority indicate that out of 21,293,000 gallons of water pumped from these streams, 11.2% is taken from a common outlet of Quebrada Jiménez and Quebrada Grande, and 87.63% is taken from the Espiritu Santo River. This water is mainly utilized for residential purposes within the rural zone. (Appendix Table 3).

A population census taken in April 1, 1970 in the Rio Grande municipality indicated a relative increase of 27.8% from 1960 to 1970 (Table 2). This relative increase was almost ninefold from the relative increases for the years 1940-1950 and 1950-1960 which were 3.3% and 3.5% respectively. The recent large increase reflects the urban sprawl that has occurred around the town of Rio Grande.

Table 2. Population Census from the Town of Rio Grande, Puerto Rico for the Years 1940 to 1970

Population Census, April 1st.				Increase or Decrease					
				Absolute			Relative (%)		
1940	1950	1960	1970	40-50	50-60	60-70	40-50	50-60	60-70
16116	16651	17244	22032	535	582	4799	3.3	3.5	27.8

An investigation was carried out on several selected water quality parameters in the river system at the upper and middle portions of the watershed. The lower portion of the watershed was not included in the study, since the attendant problems associated with the study of estuarine conditions were beyond the scope of this investigation.

The objectives of the study were: 1) to evaluate the changes in selected water quality variables as influenced by the existing land use patterns of the area, and (2) to evaluate the gradation of these variables from high elevations to near sea level.

Methods

To evaluate the influence of land use patterns on selected water quality parameters, ten sampling stations were established along the Espiritu Santo river and its tributaries Quebrada Sonadora, Quebrada Grande, and Quebrada Jiménez. These streams originate in the upper reaches of the Luquillo Experimental forest and flow through forested areas and grassland areas with the exception of Quebrada Sonadora that enters the Espiritu Santo inside the forest. The upper reaches of the Espiritu Santo river and the Quebrada Sonadora drain northwestern slopes while Quebrada Grande and Quebrada Jiménez drain the northern slopes of the Luquillo mountains.

Two stations were located on each tributary, one in the forested area and on in the grassland area. Because the Quebrada Sonadora meets the main stream inside the forest, the stations were respectively located on the east and west branches of the stream to determine the input of each branch to the system. Four sampling stations were located on the Espiritu Santo river: inside the forest, at the boundary between forest and grassland, onthe grassland-area, and at the uppermost part of the estuary. The latter station reflected the salt water input into the river system.

The location of each station was selected to evaluate the influence of vegetation types upon selected physical and chemicals parameters over a period of six months. Sampling and measurements were done on a bi-weekly basis. Measurements were taken in situ and surface water samples collected from each station in plyethylene bottles were taken to the laboratory for chemical analysis.

The parameters to be studied were: dissolved oxygen, pH, free carbon dioxide, chloride (Cl), salinity as NaCl, and elemental concentrations of calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K). Following are the methods and/or instruments used for the determination of the parameters mentioned above.

Temperature and Dissolved oxygen: In situ determinations made with YSI Dissolved Oxygen Meter, Model 51A using a YSI 5718 Oxygen-Temperature probe.

pH: Orion Specific Ion Meter, model 404 with a combination pH glass and calomel reference electrode. In situ.

Free CO_2: Titrimetric Methods for Free Carbon Dioxide as stated in Standard Methods for the Examination of Water and Wastewater 13th. Editon, 1971. In situ.

Chloride: Orion Specific Ion Meter, model 404, using model 94-17 Solid State Chloride Electrode in combination with the Ionanalyzer Double Junction Reference Electrode, model 90-02.

Salinity (as NaCl): ppm Cl x 1.65 = ppm NaCl, as stated in Standard Methods for the Examination of Water and Wastewater, 13th edition 1971.

Chemical analyses for Ca, Mg, Na and K: Atomic Absorption Spectrophotometry. Information on rainfall for the period of study was obtained from the daily rainfall records of the area taken and maintained at the El Verde Field Station located on Highway 186, Km. 19.3. It is the only station that maintains daily rainfall records on the northern slopes of the Luquillo Experimental Forest. There are no available records for the lowland area.

The results obtained from field measurements and laboratory analyses were transferred to IBM cards for data processing and statistical analyses.

Results and Discussion

The Espiritu Santo basin and the tributaries along with the station location and identification numbers are shown in Figure 1. The description and site characteristics of each station are summarized in Table 3.

For study purposes the watershed was divided in two areas: forest and grassland. The forest is defined as a considerable area of land covered with a heavy growth of trees; in our case a tropical rain forest with a precipitation ranging from 75 inches to 150 inches per year (Odum, 1970).

Grassland is defined as the area which has been cleared for agricultural or housing purposes and in which the vegetation is composed of grasses and the trees are limited to stream valleys or are widely scattered.

The system is then defined as the river basin which flows through forest and grassland until it reaches the uppermost part of the estuary and flows into the ocean. The system in itself shows the influence of the existing vegetation types in a composite manner.

The data were analyzed statistically utilizing analysis of variance, single way classification, Duncan's New Multiple Range Test to separate means, and T-tests were applicable. Stations values are grouped in various combinations for data analysis as shown in Table 4.

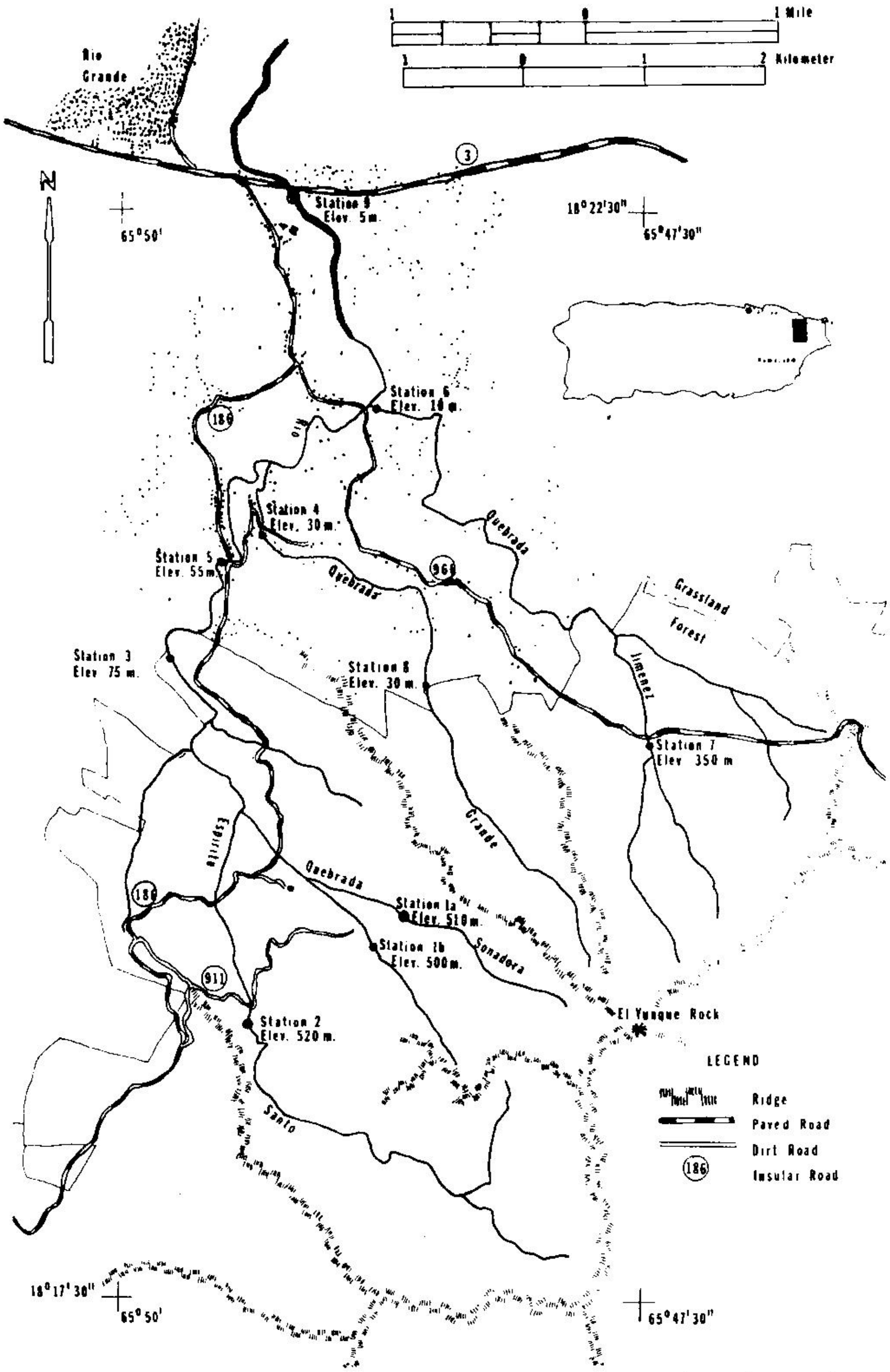

Figure 1: Espiritu Santo Drainage Basin: Stations' Location, Elevation, and Identification Numbers.

Table 3. Site Description, Elevation, and Location of Selected Sampling Stations on the Espiritu Santo Drainage Basin.

Station Number	River	Vegetation Type	Elevation	Site Description
1a	Quebrada Sonadora	Forest	510 m	East branch of the Sonadora inside the forest, 100 m from dead end of road 911. Pool, rocky bottom, shaded.
1b	Quebrada Sonadora	Forest	500 m	West branch of the Sonadora inside the forest, 9 meters south of the road 911. Pool, rocky bottom, shaded.
2	Espiritu Santo	Forest	520 m	Espiritu Santo inside the forest, 100 m south of bridge on road 911. Pool, rocky bottom, open.
3	Espiritu Santo	Boundary	75 m	Espiritu Santo after junction with Sonadora, beside Girl Scouts camp on road 186. Riffle with rocky bottom, open area. Boundary between forest and grassland.
4	Quebrada Grande	Grassland	30 m	Quebrada Grande, 15 meters south of bridge Parcelas Dávila, road 903. Riffle, rocky bottom, very shallow. Open area.
5	Espiritu Santo	Grassland	55 m	Espiritu Santo, 15 meters west of bridge road 186. Riffle, rock slab, open area.
6	Quebrada Jiménez	Grassland	10 m	Quebrada Jiménez, 25 meters from junction with the Espiritu Santo on bridge road 966. Riffle rocky bottom, open area.
7	Quebrada Jiménez	Forest	350 m	Quebrada Jiménez inside the forest, 50 meters south of bridge road 966. Shaded pool with rocky bottom.
8	Quebrada Grande	Forest	110 m	Quebrada Grande inside the forest, located below the waterfalls. Open area, riffle with rocky bottom.
9	Espiritu Santo	Uppermost part of the estuary	5 m	Espiritu Santo river, 50 meters south of bridge on road 3 to Luquillo. Open area rocky bottom covered with silt, debris and litter.

Table 4. Combinations of Data for Statistical Analysis

Combination	N	1a	1b	2	3	4	5	6	7	8	9
					Station Numbers						
All Stations	10	X	X	X	X	X	X	X	X	X	X
All Stations except upper estuary	9	X	X	X	X	X	X	X	X	X	
Forest	6	X	X	X	X				X	X	
Forest w/o boundary	5	X	X	X					X	X	
Grassland	3					X	X	X			
Grassland inc. boundary	4				X	X	X	X			

Each variable will be discussed separately, first in terms of the overall system, then in terms of the system excluding the upper estuary, and finally as forested versus grassland areas as a function of time.

Temperature

The bi-weekly water temperatures for the selected sampling stations of the Espiritu Santo watershed are presented in Appendix Table 4. Mean station values ranged from 19.1°C $\pm$ 0.8 inside the forested zone (Sta. 2) to 24.0°C $\pm$ 0.5 in the uppermost part of the estuary (Sta. 9) (Table 5). During the period of study, average minimum and maximum water temperature occurred in mid-January and late October, respectively. The data suggest that average minimum water temperature

Table 5. Average Values for the Variables Measured at Selected Stations of the Espiritu Santo Drainage Basin.*

River	Vegetation Type	Temperature °C	DO	Free CO_2	Average Concentration mg/1 Salinity	Sodium	Potassium	Calcium	Magnesium	Chloride
Quebrada Sonadora	Forest east branch	19.5e	8.5a	2.06c	23.85c	4.98cd	0.29de	0.90e	1.81d	14.45d
Quebrada Sonadora	Forest west branch	19.2e	8.7a	2.04c	22.57c	4.63d	0.26efg	0.86e	1.54de	13.68d
Quebrada Grande	Forest	22.0bcd	8.5a	2.34b	38.82b	7.02b	0.24g	1.28bc	3.12b	19.89bc
Quebrada Grande	Grassland	23.0abc	8.6a	3.52a	38.84a	8.91a	0.43a	2.21a	5.05a	21.73ab
Quebrada Jiménez	Forest	20.4e	8.5a	2.02c	27.82bc	5.76e	0.28ef	1.18bcd	2.25c	16.86c
Quebrada Jiménez	Grassland	23.6a	8.3a	2.62b	40.05a	9.00a	0.41ab	2.18a	4.80a	24.27a
Espiritu Santo	Forest	19.1e	8.7a	2.40b	23.12c	5.32c	0.40ab	0.88e	1.46e	14.01d
Espiritu Santo	Boundary	22.1bcd	8.5a	2.29b	26.60c	6.19b	0.32cd	1.15cd	2.42c	16.12d
Espiritu Santo	Grassland	23.0ab	8.6a	2.44b	28.38bc	6.56b	0.35c	1.31b	2.89b	17.20c
Grand Mean		21.3	8.5	2.41	29.34	6.49	0.33	1.33	2.82	17.58
$S\bar{X}$		0.6	0.0	0.15	2.18	0.53	0.02	0.17	0.44	1.22

*Values followed by a common letter designation do not significantly differ at the 0.05 probability level according to Duncan's New Multiple Range Test.

in the forested areas occurred about two weeks after the minimum temperature in the grassland areas (mid-January versus the end of January). Temperature ranges during the study period varied depending upon station location, elevation and type of vegetative cover. The minimum range of 3.3°C was found at Station 1a (510 m elevation, forest cover) while the maximum of 6.5°C occurred at Station 9 (5 m elevation, grassland area). Generally, the mean temperature of the water flowing from the forested areas was 3°C lower than the grassland (open) areas (See Figure 2). Temperature differences were found to be significant at the 0.05 and the 0.01 level when the data were combined as grassland versus forest for the entire system and t-tests were performed. (See Table 6). Tests performed on the data for each river system showed no significant differences between forest and grassland stations for the Quebrada Grande. However, the data for the Espiritu Santo river and the Quebrada Jiménez were significantly different when tested. (See Tables 7,8,9 and 10). The differences may be due to vegetative cover, elevation and reduced insolation at the higher elevation due to cloud cover or a combination of these factors.

The effect of elevation on air temperature gradients in the Luquillo National Forest was measured by Jagels (1963). Working from the El Verde area to the El Yunque peak, he measured air temperatures at five locations and reported values of 25°C at 360 M, 24.7°C at 428 M, 23.1°C at 567 M and 21.4°C at 636 M. This is a difference of 3.4°C over an altitudinal change of approximately 275 M. Odum (1970) reported that temperatures at the forest floor were 0.5 to 1.1°C lower

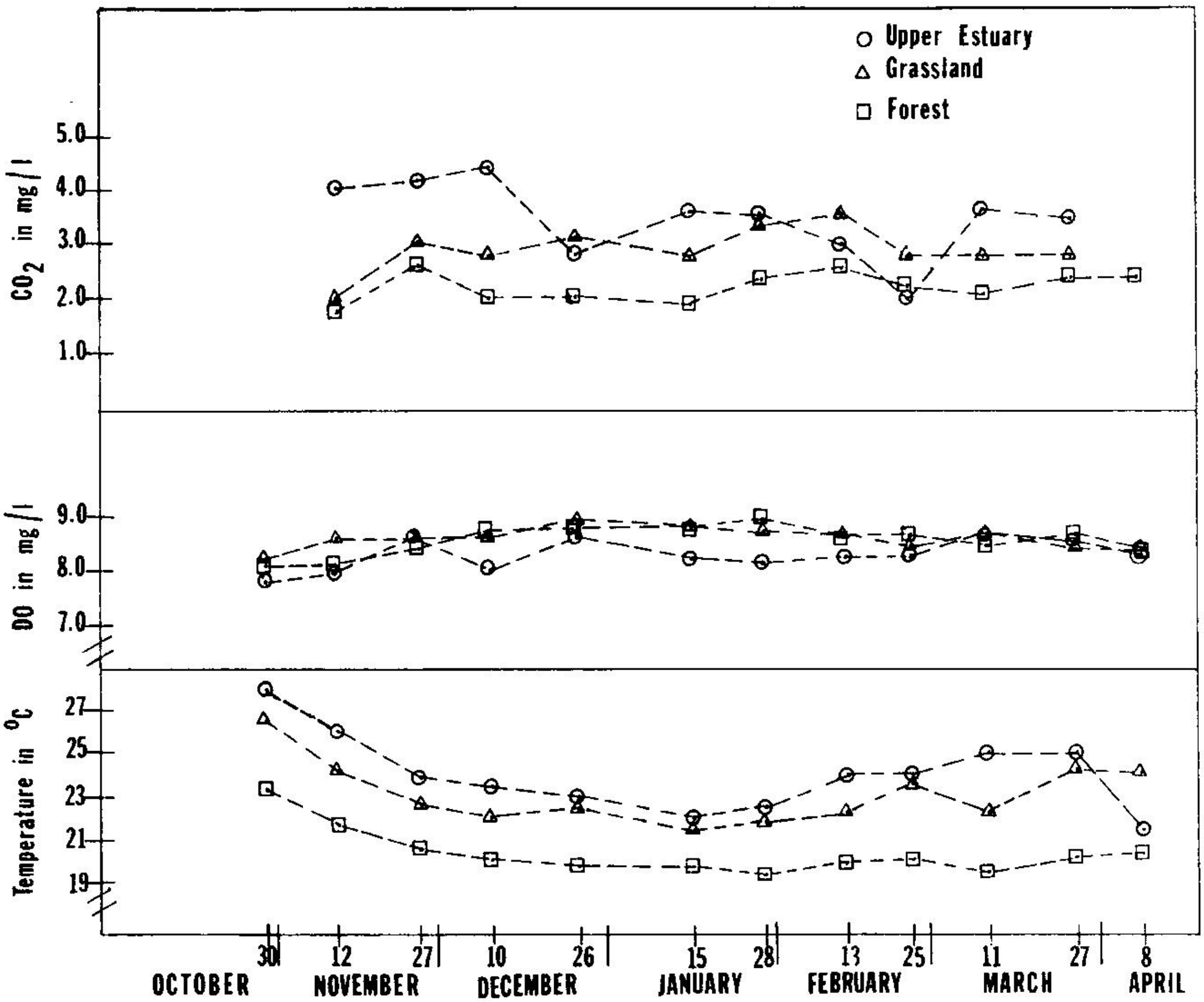

Figure 2 : Composite of Vegetation Types for Temperature, Dissolved Oxygen (DO), and Free Carbon Dioxide (CO_2) in the Espiritu Santo Drainage Basin.

Table 6. t-test and Levels of Significance for Forested Versus Grassland Stations in the Espiritu Santo Drainage Basin.

		df	t	$t_{0.05}$	Level of Significance
Temperature	1)*	7	-3.3960	2.365	**
	2)*	7	-4.3021	"	**
Dissolved Oxygen	1)	7	0.7207	"	NS
	2)	7	0.9650	"	NS
Free Carbon Dioxide	1)	7	-2.7722	"	**
	2)	7	-2.1045	"	NS
Salinity	1)	7	-2.8740	"	**
	2)	7	-1.9774	"	NS
Sodium	1)	7	-3.4010	"	**
	2)	7	-2.6278	"	**
Potassium	1)	7	-2.6857	"	**
	2)	7	-2.2446	"	NS
Calcium	1)	7	-3.8718	"	**
	2)	7	-2.6102	"	**
Magnesium	1)	7	-3.6807	"	**
	2)	7	-2.5889	"	**
Chloride	1)	7	-2.6861	"	**
	2)	7	-1.8918	"	NS

1) forest versus grassland means
2) forest minus boundary station versus grassland plus boundary station means

** Highly significant
NS Not significant

Table 7. t-tests and Levels of Significance for Forested versus Grassland Station, Forest versus Boundary Station, and Boundary versus Grassland Station in the Espiritu Santo River.

Variable	Combination	df	t	t 0.05	Level of Significance
Temperature	F vs G	22	-7.1746	2.074	**
	F vs B	22	-5.4133	2.074	**
	B vs G	22	-1.5078	2.074	NS
Dissolved Oxygen	F vs G	22	0.1428	2.074	NS
	F vs B	22	1.6729	2.074	NS
	B vs G	22	-1.7301	2.074	NS
Free Carbon Dioxide	F vs G	19	-0.3261	2.093	NS
	F vs B	19	0.6658	2.093	NS
	B vs G	18	-0.8106	2.101	NS
Salinity	F vs G	20	-1.8500	2.086	NS
	F vs B	20	-1.3609	2.086	NS
	B vs G	20	-0.7736	2.086	NS
Sodium	F vs G	22	-8.5055	2.074	**
	F vs B	22	-7.5529	2.074	**
	B vs G	22	-2.2213	2.074	*
Potassium	F vs G	22	6.7901	2.074	**
	F vs B	22	10.3950	2.074	**
	B vs G	22	-3.6049	2.074	**
Calcium	F vs G	22	-8.3486	2.074	**
	F vs B	22	-6.8778	2.074	**
	B vs G	22	-2.7210	2.074	*
Magnesium	F vs G	22	-11.6800	2.074	**
	F vs B	22	-10.1281	2.074	**
	B vs G	22	3.0962	2.074	**
Chloride	F vs G	20	-1.8498	2.086	NS
	F vs B	20	-1.3615	2.086	NS
	B vs G	20	-0.7728	2.086	NS

F = Forest B = Boundary G = Grassland

NS = Not Significant * Significant ** Highly Significant

Table 8. t-test and Levels of Significance for Forested versus Grassland Stations in the Quebrada Grande Tributary.

Variable	df	t	$t_{0.05}$	Level of Significance
Temperature	21	-1.9386	2.080	NS
Dissolved Oxygen	21	-1.0692	2.080	NS
Free Carbon Dioxide	18	-4.5887	2.101	**
Salinity	19	-2.2490	2.093	*
Sodium	21	-6.2321	2.080	**
Potassium	21	-7.1610	2.080	**
Calcium	21	-8.8771	2.080	**
Magnesium	21	-7.2783	2.080	**
Chloride	19	0.7370	2.093	NS

Table 9. t-test and Levels of Significance for Forested versus Grassland Stations in the Quebrada Jiménez Tributary.

Variable	df	t	$t_{0.05}$	Level of Significance
Temperature	22	-5.8710	2.074	**
Dissolved Oxygen	22	1.0448	2.074	NS
Free Carbon Dioxide	18	-2.3017	2.101	*
Salinity	20	-4.2045	2.086	**
Sodium	20	-12.2916	2.086	**
Potassium	207	-10.5250	2.086	**
Calcium	20	-15.0240	2.086	**
Magnesium	20	-11.1405	2.086	**
Chloride	20	4.202	2.086	**

NS = Not Significant   * Significant   ** Highly Significant

Table 10. t- Test and Levels of Significance for East Branch versus West Branch Station in the Quebrada Sonadora Tributary.

Variables	df	t	$t_{0.05}$	Level of Significance
Temperature	22	0.6861	2.074	NS
Dissolved Oxygen	22	-1.1760	2.074	NS
Free Carbon Dioxide	20	-0.1547	2.086	NS
Salinity	20	0.3960	2.086	NS
Sodium	22	4.3159	2.074	**
Potassium	22	3.8142	2.074	**
Calcium	22	1.9698	2.074	NS
Magnesium	22	8.5386	2.074	**
Chloride	20	0.3959	2.086	NS

NS = Not Significant

* = Significant

** = Highly Significant

than at the canopy level in the Tabonuco Forest (elevation, approximately 500 M). The vegetation cover of the forest would in turn reduce the heating of the soil resulting in a lower soil temperature. The subsequent infiltration of rainfall and percolation through the cooler temperature regime of the soil profile could result in the lowering of soil water temperatures before its release as flow.

The data in Appendix Table 4 were subjected to an analysis of variance, single way classification, to test for differences among stations and also across sampling dates. The results showed significant differences among station means at the 0.05 level. Those stations that differ significantly from other are presented in Table 11. Temperature variations became statistically significant when analyzed across sampling dates. Figure 3 shows a lowering in temperature throughout time which coincided with the cooler months of November, December and January. Mean temperatures ranged from 20.2°C ± 0.5 to 22.6°C ± 0.5. Although the difference between the average is only 2.4°C, the differences over time are statistically significant. (See Table 11).

Dissolved Oxygen

The dissolved oxygen values obtained throughout the study period were found to be near saturation at all times (See Appendix Table 5 and 26 Mean DO concentration values per station ranged from 8.2 mg/1 + 0.1 at the upper estuary to 8.7 ± 0.1 mg/1. (See Table 5). The differences among stations were found to be nonsignificant at the 0.05 level. Within this narrow range a gradient from forested to grassland was observed with the

Table 11. Summary of Results of F Tests from Analysis of Variance, Single Way Classification, for all Possible Combinations of the Data for the Variables Studied at Selected Stations of the Espiritu Santo Drainage Basin. (See Appendix Tables 14-25).

Treatment: Time
Replicas : Stations

Variable	Stations 1a-8	Forest: Forest	Forest: w/o sta. 3	Grass-land	Grassland with sta. 3
Salinity	**	**	**	NS	NS
Free CO_2	NS	*	*	NS	NS
Ca^{++}	NS	NS	NS	NS	NS
Mg^{++}	NS	NS	NS	NS	NS
Na^+	NS	NS	NS	NS	NS
K^+	NS	NS	NS	NS	NS
Cl^-	*	**	**	*	*
Temperature	**	*	*	**	**
DO	**	**	**	NS	NS

Treatment: Stations
Replicas : Time

Variable	Stations 1a-8	Forest: Forest	Forest: w/o sta. 3	Grass-land	Grassland with sta. 3
Salinity	**	**	**	**	**
Free CO_2	**	NS	*	**	**
Ca^{++}	**	**	*	**	**
Mg^{++}	**	**	**	**	**
Na^+	**	**	**	**	**
K^+	**	**	**	**	**
Cl^-	**	**	**	**	**
Temperature	**	**	**	NS	NS
DO	NS	NS	NS	*	NS

* significant difference
** highly significant
NS not significant

highest DO concentrations inside the forest and the lowest concentrations in the grassland areas.

Within the grassland area Quebrada Jiménez (Sta. 6) varied significantly from the other two stations. This station is located at a lower elevation than the other two grassland stations and its mean temperature for the period studied was the highest of the three. When station 3 was included in the grassland values, no significant differences were found between stations. This is due to the fact that the DO values for station3 fall intermediate between the values for the other sampling stations thus eliminating any sharp differences between them.

Dissolved oxygen concentrations fluctuated throughout the sampling period. These fluctuations were found to differ significantly at the 0.05 level except within the grassland system (See Table 11). The increase and decrease in concentrations coincided with the periods of decrease and increase in temperature during the period studied (See Figure 3). Low water temperatures in the forested areas along with the steep stream gradients give rise to constant and maximum aeration which is probably responsible for the high DO values found in the streams. A t-test performed on the data for each river system showed no significant differences between forest and grassland stations for the same river (Tables 7,8,9,10).

<u>Carbon Dioxide</u>

The bi-weekly values for free carbon dioxide are presented in Appendix Table 6. The values encountered fall within the normal range for surface waters which normally contain less than 10 mg/l CO_2 (Standard

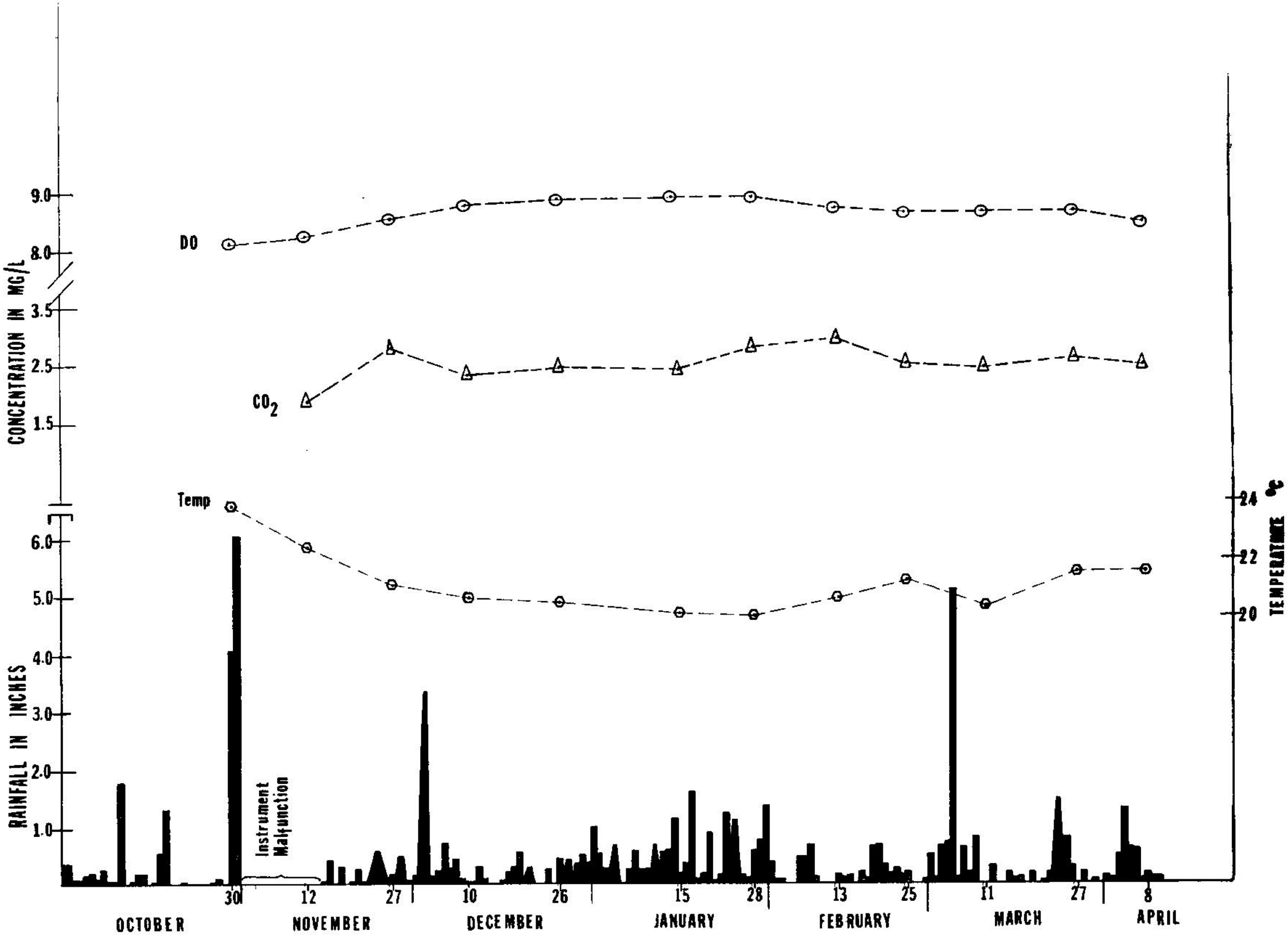

Figure 3: Summary of Mean Values for Temperature, Dissolved Oxygen (DO), and Free Carbon Dioxide (CO_2) across Time. All stations combined not including the upper most part of the estuary.

Methods for the Examination of Water and Wastewater, 1971). Mean values ranged from 2.04 mg/l in Quebrada Sonadora (forest) to 3.52 mg/l in Quebrada Grande (grassland). The overall mean concentration for the entire system, excluding Sta. 9, was 2.41 ± 0.15 mg/l. The highest observed values were recorded at Station 4 (3.52 ± 0.21 mg/l) and Station 9 (3.44 ± 0.22 mg/l)(See Table 5).

Mean values among stations were found to differ significantly at the 0.05 level (Table 11). Station means were separated using Duncan's Multiple Range Test. The mean for station 4 was found to be different from all other stations 1a, 1b, and 7. Although the difference in these values might have a statistical significance, we cannot draw any conclusions at this moment. The inputs from respiration and chemical reactions to the aquatic system could be considered minimal. The main source of CO_2 to the water could be the surface aeration caused by the steep gradients and in turn the constant turbulence and turnover of the system.

When stations were separated according to vegetation cover, i.e. forest vs. grassland, the means from the grassland stations were found to differ significantly from the forest stations utilizing the t-test (See Table 6). However, CO_2 determination in the field is highly subjective depending upon light conditions and color interpretation. The lowest values in Appendix Table 6 belong to areas heavily shaded, whereas the highest values belong to open areas. Errors in reading due to this difference in light intensity could be the reason for the variation encountered in the system.

pH

Out of a total of 119 observations in Appendix Table 7, 83% of the values fell between pH 6.6 and 7.4 with a modal value of 7.0. Sixty four percent of the values were of pH 7 or lower. Based of this data there seems to be no apparent trend for the period studied. Further studies will provide more information on the acidity of the river system.

Data reported by USGS (Report 1973) from 1968 to 1972 for the Espiritu Santo River ranged from 6.2 to 8.6 with 84% of the observations falling between pH 6.7 and 7.5. 87% of the values were of pH 7.5 or lower. This information gives similar results for pH values as the ones obtained in this study. In general, pH values seems to be more acid in the forested areas and more alkaline at the lower reaches of the river; no statistical analyses were carried out to test this hypothesis.

Elemental Concentrations

Elemental concentration in the overall system is influenced by soil types, rock weathering, rainfall, dryfall, salt spray, and vegetation types. Salt water intrusion at the uppermost part of the estuary also provides another source of input to the river system. Cintrón (personal communication) mapped the salt water intrusion for the Espiritu Santo estuary and estimated that the salt water wedge extends about five kilometers from the estuary into the fresh water system. Soil and rock weathering provide the major supply of ions to natural waters (Gorham, 1961) with the concentration of the dissolved salts related to the parent material varying with rocks types (Miller, 1961; Bogart, 1964). Seiders (1971) described the rock formations for the Gurabo and El Yunque quadrangles and presented some data on oxides found in the different rock formations.

USGS data are available for the period of 1968 to 1972 for two locations on the Espiritu Santo river (USGS Report, 1973, Part 2A). USGS Station 00638 is equivalent to station 2 of the study while the second station was located approximately 50 meters upstream from the confluence of the Quebrada Jiménez with the Espiritu Santo. These measurements were taken on a sporadic basis of approximately two to eight times per year. When averaged over a five year period the data gave approximate average values for the concentration in mg/l of Na, K, Ca, Mg, and Cl of 5.5, 0.4, 4.0, 1.7 and 7.9 respectively for station one and 6.6, 0.37, 6.1, 3.8 and 9.33 respectively for station two.

In general the average values are similar to those found in the current study with the exception of Ca and Cl. These differences might be due to analytical methods in which the sensitivity of the measurements could vary according to the techniques utilized. The USGS values for Ca are almost two to three times higher than the values found in the current study. The values reported by Clements and Colón (1972) on the Ca content of the Quebrada Sonadora and Quebrada Grande for the period of 1971 to 1973 are in agreement with those found in the current study.

The results of the chemical analyses for Ca, Mg, Na, K, and Cl are presented in Appendix Tables 8, 9, 10, 11 and 12. Average elemental concentrations showed a marked increased in station 9 (uppermost part of the estuary) with values of 88.14 ± 23.0 mg/l Na, 3.29 ± 0.8 mg/l K, 2.34 ± 0.2 mg/l Ca, 14.86 ± 3.3 mg/l Mg, and 34.27 ± 97.83 mg/l Cl as compared to the average concentration for the other stations taken together which were 6.46 ± 0.1, 0.33 ± 0.0, 1.32 ± 0.2, 2.79 ± 0.1, and 17.58 ± 1.22 respectively.

A significant difference was found among station's means for the concentration of Na, K, Mg, and Cl. Table 5 presents the average values per station and also which stations differ from others according to the New Duncan's Multiple Range Test. Table 12 presents a summary of the results presented according to vegetation types which suggests a gradient from the lowest concentrations in the forested area, intermediate concentrations in the grassland areas, and the highest concentrations at the uppermost part of the estuary. The wide fluctuation encountered in the uppermost part of the estuary reflects the salt water intrusion in the area.

Table 12. Summary of the Results for Sodium, Potassium, Calcium, Magnesium, and Chloride in Stream Water According to Vegetation Types. (Concentration is given in mg/l).

Vegetation Type	Sodium	Potassium	Calcium	Magnesium	Chloride
Forest	5.62 ± 0.06	0.30 ± 0.00	1.04 ± 0.01	2.08 ± 0.04	15.75 ± 0.96
Grassland	8.18 ± 0.22	0.39 ± 0.00	1.88 ± 0.07	4.20 ± 0.20	21.07 ± 1.36
Upper Estuary	88.14 ±23.03	3.29 ± 0.84	2.34 ± 0.23	14.86 ±3.33	34.27 ±97.83

Small differences appear to exist from east to west with the eastermost stations having higher elemental concentrations than the westernmost stations. Differences in geologic substrate and soil types can produce this type of variation in adjacent areas. The effect of orographic rain can also influence elemental variation in an area. In forested ecosystems, rainfall is a source of nutrient elements (Odum, 1970, Clements and Colón, 1974). In the Luquillo mountains, the eastern part of the sierra gets the highest amount of rainfall per year (Wadsworth, 1951). Form this we can speculate that the easternmost side of the sierra will receive a larger input of nutrients in the rainfall which coupled with soil and geological input will increase the absolute stream elemental content of Cl and Na which in this area are primarily of atmospheric origin. Future research will be required to assess the elemental variability of the streams in the Luquillo mountains and to correlate it, if possible, with the sources mentioned before. t-tests on the data for each stream showed significant differences between the forest stations and the grassland stations (Table 7-10). No significant differences were found at the 0.05 level for the concentration of Na, K, Ca, and Mg when the data were tested as a function of time (See Figure 4). Clements and Colón (1973) monitored the Quebrada Sonadora and Quebrada Grande (Sta. 4) for the period of 1971 to 1973. No significant variations across time were found although there were differences in concentration between the two sampling sites. Chloride concentrations in the streams fluctuated significantly across time (See Figure 4). Odum (1970) related the chloride content in the system to

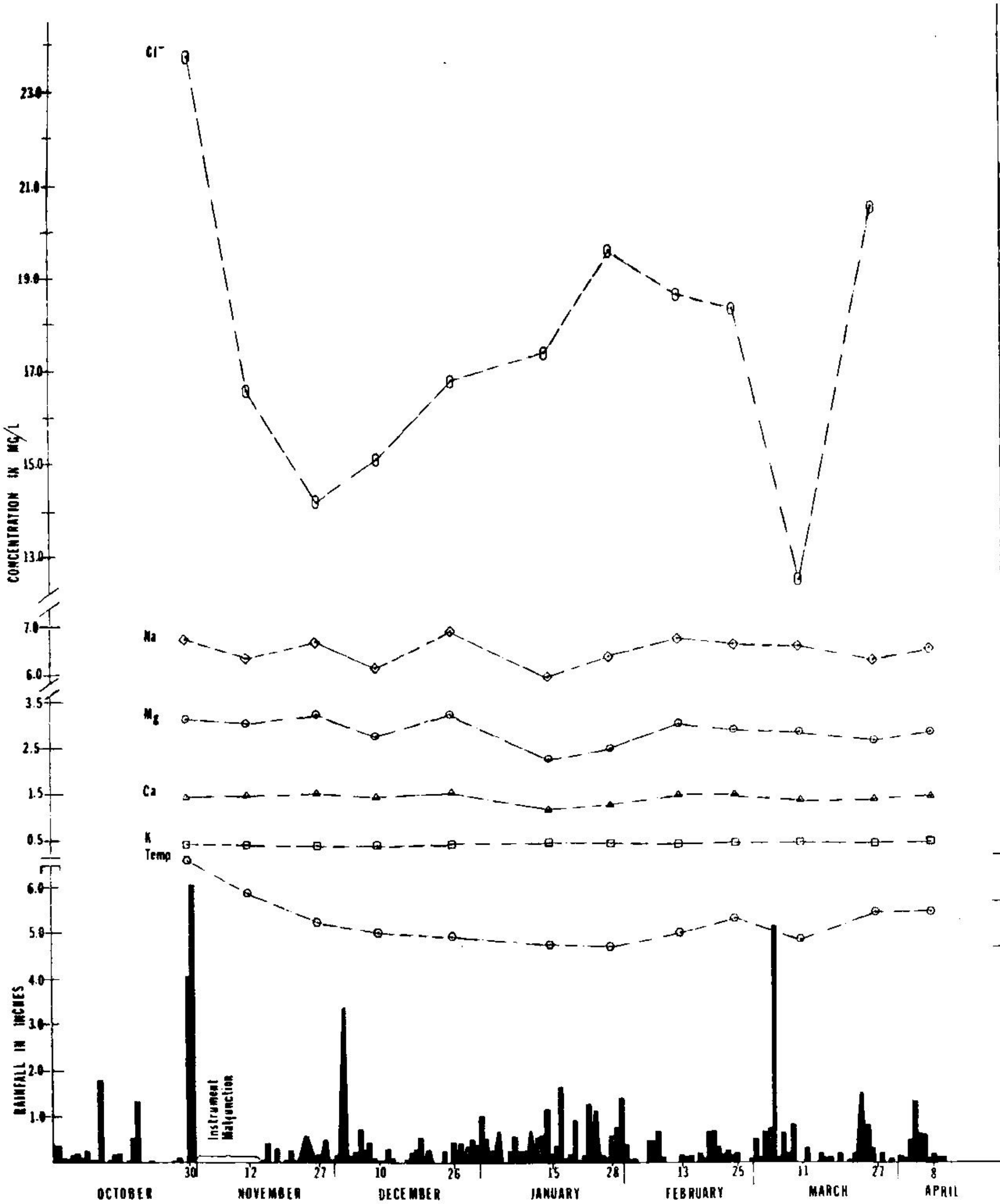

Figure 4: Summary of Mean Values for the Concentrations of Sodium(Na), Potassium(K), Calcium(Ca), Magnesium(Mg), and Chloride(Cl^-) across Time. All stations combined not including the upper most part of the estuary.

processes of exchange at the sea surface with wind controlling the amount of spray released into the rising air that passes the Luquillo mountains. Gorham (1961), has also related the fluctuations of chloride concentration in time with the concentrating and diluting effects of dry and wet weather. No seasonal variations were observed during the period studied.

Salinity

Salinity values were computed by measuring the chloride concentration in the stream water and expressing it as sodium chloride according to the formula mg/l NaCl = 1.65 X mg/l Cl^- given in Standard Methods for the Examination of Water and Wastewater, 13th Edition (1971). The data for the period studied gives evidence of a salinity gradient with the lowest concentrations in the forest area, intermediate concentrations in the grassland areas, and the highest concentrations in the uppermost part of the estuary. The relationships between station location, elevation and salinity values are presented in Figure 5. The data also suggest a salinity gradient from east to west with the easternmost stations having a higher salinity concentration. Salinity values for station 9 fluctuated widely from a low of 38.28 mg/l NaCl to a high of 1419 mg/l reflecting the tidal influence at this station and also the influence from river discharge from the mountains. In periods of heavy and/or continuous rains when the river discharge is increased, surface water samples will reflect the elemental concentration of the rivers in the mountains. During base flow conditions it will tend to reflect not only the fresh water concentration but also the mixing of the salt water inflow during high tide (Appendix Table 13).

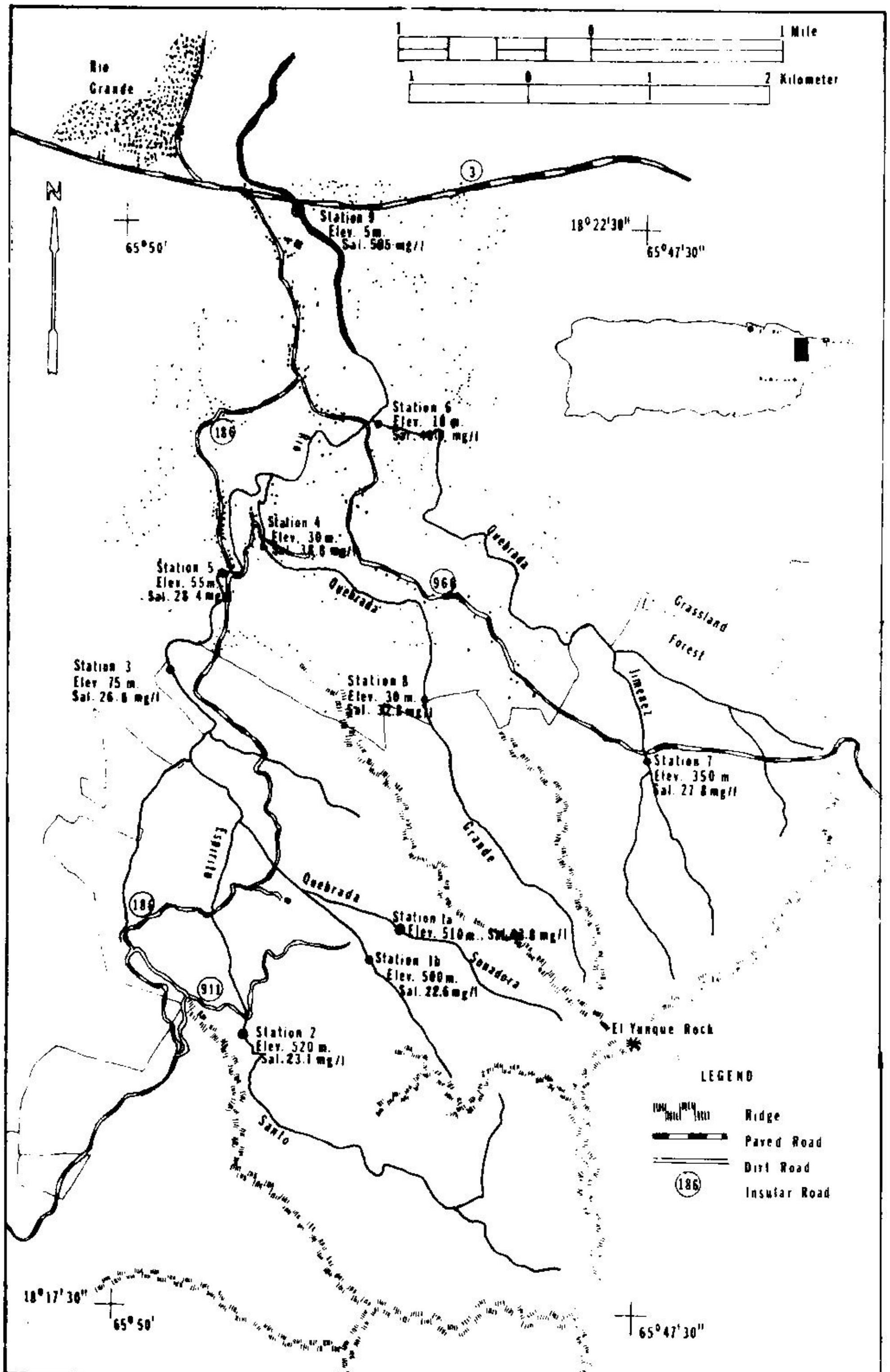

Figure 5: Mean Salinity Values per Station in the Espiritu Santo Drainage Basin.

To eliminate the effect of tidal fluctuations, the data from station 9 were excluded from the statistical analysis. Significant differences were found among stations which depended upon the station location within the drainage area (See Table 11 and Figure 5). Table 5 gives the mean salinity values for each station. These values ranged from 22.57 mg/l in the west branch of the Quebrada Sonadora (Sta. 1.b) to 40.05 mg/l at Quebrada Jiménez, grassland (Sta. 6). Using Duncan's Multiple Range Test to separate means, station 4 and 6 were found to be similar but significantly different from all the other stations. Salinity values for stations la, lb, 2, and 3 were not significantly different but varied significantly from station 7 (forest). Mean values for station 5 (grassland), 7 and 8 (forest) were similar ranging intermediately with station la, lb, 2 and 3 (forest). These differences indicate a possible salinity gradient across the system which could be determined by elevation, land use, elemental concentration in rainfall, wind, geology, and soils.

Summary

There was a general increase in the values of all the parameters measured from higher to lower elevations with the exception of dissolved oxygen (DO) that decreased slightly. DO values were found to be near saturation at all times. Free carbon dioxide (CO_2) concentrations ranged within the normal values for natural surface waters as were the pH values that ranged from 6.5 to 8.2 with a modal value of 7.0. The values for the concentration of sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), and chloride (Cl) were found to be below or near the accepted for drinking water standards (See Appendix Table 7).

Each river or tributary differed significantly from the others in the concentration of the elements mentioned above. These differences were maintained throughout the time period during which the measurements were made. No marked seasonal variabilities were observed except for water temperature which reflected the lowering of air temperatures during the winter months.

Based on the results obtained for the concentration of elements, the Espiritu Santo drainage basin appears to be in steady state conditions in which no time dependent variations occur within the aquatic system. This seems to agree with the results of Johnson (1969-1971) who showed a constancy of the chemical concentration of selected ions for the Hubbard Brook streams during the period studied. Stream flow measurements will determine the total elemental discharge which will vary depending upon base flow or high flow conditions.

Rapid turnover of the water keeps the system under constant renewal. This characteristic makes it difficult for possible health hazards to take hold and thrive. Any modification of land use patterns that could modify the flow rates of the streams making them flow slower could result in the creation of optimum habitats for the liver parasite, *Schistosoma mansoni*, a health hazard for man.

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Appendix

Appendix Table 1. Land Use Inventory for the Municipality of Rio Grande, Puerto Rico according to the data furnished by the Department of Natural Resources, 1972.

Land Use Category	Acreage	Total Acreage	Percent of Total
Communications			
Power Substation	1.26		
Radio Towers	8.79	10.05	0.02
Transportation	0.00	0.00	0.00
Non-productive			
Sand-Coastal	106.22	106.22	0.27
Outdoor recreation-all types	222.35	222.35	0.56
Public facilities-all types	111.24	111.24	0.28
Commercial		86.1	0.22
Urban-downtown	9.43		
Commercial-strip	68.51		
Hotels	8.16		
Industrial		74.78	0.19
Light-non-pollutant	28.91		
Heavy-pollutant	16.33		
Industrial Park	29.54		
Residential-Urban		1001.26	2.26
Light density	1.88		
Medium density	151.48		
Heavy density	275.31		
Slum	6.28		
Unconstructed within urban			
Area	10.05		
Under construction	556.26		
Residential-Rural		1129.51	2.86
Light density	320.56		
Medium density	774.38		
Slum	2.51		
Strip	32.06		

Cont. Table 1

Land Use Category	Acreage	Total Acreage	Percent of Acreage
Water Resources and Wetlands		2419.73	6.14
Rivers, Streams (width 50'+)	98.05		
Embayed, protected	215.59		
Natural fresh water pond less than 1 acre	4.40		
Mangrove swamps	1585.84		
Shrub, bushy wetland	20.74		
Saltwater marsh	139.54		
Freshwater marsh	359.53		
Forest Use		20392.90	51.70
Fine, woody growth	6281.80		
Solid crown cover	1325.62		
Light, scattered crown	88.63		
Public Forest	12696.85		
Agriculture		13985.97	35.46
Sugar Cane	631.70		
Coconut groves	1064.14		
Grazing	11899.21		
Floriculture	6.28		
Coffee	6.91		
Intensive commercial crops	64.73		
Small holder (planted)	67.88		
Citrus plantation	6.28		
Banana plantation	94.28		
Inactive	119.42		
Active	25.14		
TOTAL		39540.11	

Appendix Table 2. Consumptive Water Use for the Municipality of Rio Grande for the Month of February, 1974. Source of Water-Lake Carraízo. Data from Records of P.R. Aqueducts and Sewers Authority.

Use Category	February, 1974 Cubic Meters	Gallons	Percent of Total
Residential Water	158,159	41,753,976	35.67
Residential Water plus sewage	77,979	20,586,456	17.58
Water estimated	2,626	693,264	0.59
Public fountains	1,008	266,112	0.23
Commercial Water	21,243	5,608,152	4.79
Commercial Water plus sewage	9,363	2,471,832	2.11
Estimated Water	1,778	469,392	0.40
Water plus sewage	272	71,808	0.06
Fire hydrants	3,268	862,752	1.65
Industry	7,312	1,930.368	1.65
Industrial water plus sewage	160,378	42,339,792	
TOTAL	443,386	117,053,904	

Appendix Table 3. Consumptive Use of Water taken from Freshwater Sources within the Municipality of Rio Grande for the Fiscal Year 1972-1973.

Source of Freshwater	Daily Estimate*	Monthly Estimate	Yearly Estimate
Quebrada Jiménez and Quebrada Grande	79,000 gal.	2,400,000 gal.	28,800,000 gal.
Espiritu Santo	622,000 gal.	18,660,000 gal.	227,000,000 gal.
Zarzal - Tributary of Quebrada Jiménez	110,000 gal.	330,000 gal.	40,000,000 gal.
TOTAL	811,000 gal.	21,293,000 gal.	295,800,000 gal.

* Data from records of P.R. Aqueducts and Sewers Authority.

Appendix
Table 4. Bi-weekly Temperature Trends in °C at Selected Stations in the Espiritu Santo Watershed.

Sample Date	Station 1a	Station 1b	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8	Station 9**	$\bar{X}$ 1a-8	$S\bar{X}$
10/30/73	21.8	21.4	22.0	25.2	26.0	26.0	27.4	23.0	24.0	28.0	24.1	0.7
11/12/73	21.0	21.0	21.0	23.0	24.0	24.0	25.0	22.0	* -	26.0	22.6	0.5
11/27/73	20.0	19.8	19.5	21.5	22.0	23.0	23.0	21.0	22.1	23.9	21.3	0.4
12/10/73	19.8	19.3	18.8	21.0	22.0	22.2	22.5	20.7	21.7	23.5	20.9	0.5
12/26/73	19.0	19.0	18.5	21.0	22.0	22.5	23.0	20.0	21.0	23.0	20.7	0.5
1/16/74	19.2	18.9	18.9	20.5	21.5	21.0	22.0	20.0	21.0	22.0	20.3	0.4
1/29/74	19.0	18.5	18.0	21.0	21.5	21.5	22.5	19.5	10.5	22.5	20.2	0.5
2/13/74	19.0	18.0	18.0	21.0	22.0	23.0	22.0	20.0	24.0	24.0	20.8	0.7
2/25/74	19.0	19.0	19.0	22.5	24.0	23.0	24.0	20.0	22.0	24.0	21.4	0.4
3/11/74	18.5	18.0	18.0	21.5	22.0	21.5	24.0	19.0	22.0	25.0	20.5	0.7
3/27/74	19.0	19.0	19.0	23.0	25.0	24.0	24.0	20.0	22.0	25.0	21.7	0.8
4/8/74	19.0	19.0	19.0	24.0	24.5	24.0	24.0	20.0	21.5	21.5	21.7	0.8
$\bar{X}$	19.5	19.2	19.1	22.1	23.0	23.0	23.6	20.4	22.0	24.0	21.3	0.6
$S\bar{X}$	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.5		

*Sample not taken because of high water and hazardous conditions.
**Upper most part of the estuary, not included in mean values for the watershed.

Appendix
Table 5. Bi-weekly Dissolved Oxygen Trends in mg/1 at Selected Stations in the Espiritu Santo Watershed.

Sample Date	Station 1a	Station 1b	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8	Station 9**	$\bar{X}$ 1a-8	$S\bar{X}$
10/30/73	7.9	8.2	8.2	7.9	8.4	8.3	7.8	8.4	8.0	7.8	8.1	0.0
11/12/73	8.2	8.5	8.0	7.9	8.3	9.0	8.4	7.6	* -	8.0	8.2	0.1
11/27/73	8.4	8.6	8.5	8.4	8.8	8.5	8.5	8.1	8.4	8.6	8.5	0.0
12/10/73	8.9	8.7	8.6	8.8	8.3	8.7	8.8	8.7	8.7	8.0	8.7	0.0
12/26/73	8.4	10.0	8.7	8.6	9.8	8.6	8.3	8.8.	8.4	8.6	8.8	0.2
1/16/74	8.4	8.8	9.1	8.4	8.9	9.0	8.4	9.3	8.5	8.2	8.8	0.1
1/29/74	8.8	8.9	9.1	8.8	8.8	9.0	8.4	9.1	8.5	8.1	8.8	0.0
2/13/74	8.6	8.8	8.8	9.1	9.0	8.5	8.4	8.2	8.4	8.2	8.6	0.1
2/25/74	8.6	8.0	8.0	8.7	8.2	8.6	8.3	8.5	9.0	8.2	8.5	0.1
3/11/74	8.6	8.6	8.9	8.0	8.5	8.6	8.6	8.4	8.2	8.6	8.5	0.0
3/27/74	8.4	8.5	8.7	8.5	8.5	8.6	7.9	8.5	8.8	8.4	8.5	0.0
4/8/74	8.4	8.3	8.6	7.8	8.3	8.4	8.3	8.4	8.4	8.2	8.3	0.0
$\bar{X}$	8.5	8.7	8.7	8.5	8.6	8.6	8.3	8.5	8.5	8.2	8.5	0.0
$S\bar{X}$	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	

*Sample not taken because of high water and hazardous conditions.
**Upper most part of the estuary, not included in mean values for the watershed.

Appendix
Table 6. Bi-weekly Free Carbon Dioxide Measurements in PPM at Selected Stations in the Espiritu Santo Watershed.

Sample Date	Station 1a	Station 1b	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8	Station 9**	$\bar{X}$ 1a-8	$\bar{SX}$
10/30/73	***-	-	-	-	-	-	-	-	-	-	-	-
11/12/73	2.00	1.75	2.00	2.00	3.00	2.00	1.00	1.00	* -	4.00	1.84	0.2
11/27/73	2.24	1.98	2.49	3.43	4.35	2.29	2.44	2.31	2.99	4.16	1.72	0.2
12/10/73	2.00	1.60	2.15	1.60	3.50	2.60	2.20	2.00	2.65	4.40	2.26	0.2
12/26/73	1.54	1.98	2.49	2.49	3.67	2.60	3.00	1.89	1.69	2.79	2.37	0.2
1/16/74	2.18	1.89	2.49	1.89	3.08	2.40	! -	1.98	1.78	3.59	2.21	0.2
1/29/74	2.24	2.18	2.40	2.29	4.58	2.40	3.00	2.29	2.49	3.48	2.65	0.2
2/13/74	2.29	2.24	2.88	2.29	3.88	3.38	3.19	2.18	3.08	2.99	2.82	0.2
2/25/74	2.34	1.78	2.49	2.38	3.48	2.18	2.49	2.18	1.89	1.98	2.36	0.2
3/11/74	1.78	1.89	1.98	2.29	2.68	2.09	3.39	1.89	2.49	3.60	2.28	0.2
3/27/74	2.10	2.30	2.40	2.20	2.80	2.50	2.90	2.80	2.00	3.40	2.44	0.1
4/8/74	2.00	2.90	2.60	! -	-	-	-	1.70	2.30	-	2.30	0.2
$\bar{X}$	2.06	2.04	2.40	2.29	3.52	2.44	2.62	2.02	2.34	3.44	2.38	0.1
$\bar{SX}$	0.07	0.11	0.10	0.15	0.21	0.12	0.24	0.13	0.16	0.22		

*Samples not taken because of high water and hazardous conditions.
**Upper most part of the estuary, not included in mean values for the watershed.
***Measurements did not begin until 11/12/73.
!No measurement.

Appendix
Table 7. Bi-weekly pH measurements at Selected Stations in the Espiritu Santo Watershed.

Sample Date	Station 1a	Station 1b	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8	Station 9
10/30/73	7.9	8.2	8.0	8.0	7.75	6.9	7.1	7.0	7.3	7.3
11/12/73	6.5	6.6	6.5	7.1	7.3	7.0	8.0	6.3	* -	7.0
11/27/73	6.85	7.0	7.5	6.7	7.1	7.0	7.2	6.45	6.8	6.4
12/10/73	7.0	6.95	7.2	6.6	6.7	6.85	6.95	6.95	6.6	6.65
12/26/73	7.1	6.9	7.1	6.8	7.0	7.1	7.2	6.9	7.2	6.2
1/16/74	6.95	7.0	6.75	7.05	6.75	7.3	7.3	7.15	7.2	7.7
1/29/74	7.1	6.9	6.7	7.1	7.0	7.1	7.1	7.1	7.1	6.9
2/13/74	7.15	7.0	7.1	7.2	7.3	6.85	7.1	7.0	7.2	6.8
2/25/74	6.6	6.8	6.9	7.0	6.9	7.0	7.1	7.0	6.9	7.0
3/11/74	6.6	7.2	6.7	6.3	7.2	6.9	6.85	7.1	6.8	7.1
3/27/74	6.5	6.4	6.6	6.8	6.9	6.8	6.6	6.6	6.4	6.75
4/8/74	6.6	6.65	6.5	6.7	6.7	6.8	6.5	6.8	6.7	6.8

*Sample not taken because of high water and hazardous conditions.

Appendix
Table 8. Bi-weekly Sodium Levels in PPM at Selected Stations in the Espiritu Santo Watershed.

Sample Date	Station 1a	Station 1b	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8	Station 9	$\bar{X}$ 1a-8	$S\bar{X}$
10/30/73	5.03	4.52	5.40	6.50	9.84	6.93	10.01	5.83	6.79	183.14	6.76	0.7
11/12/73	4.70	4.28	5.26	6.24	9.20	6.64	9.19	5.51	* -	171.72	6.38	0.7
11/27/73	4.81	4.43	5.43	6.55	9.82	6.98	9.60	5.63	7.10	206.31	6.71	0.6
12/10/73	4.67	4.40	5.01	5.70	8.47	6.23	8.58	5.46	6.64	66.85	6.13	0.5
12/26/73	4.92	4.75	5.74	6.41	9.76	7.21	10.39	5.77	7.07	194.89	6.89	0.7
1/16/74	5.31	4.87	5.29	5.61	6.86	5.68	7.40	5.80	6.39	7.98	5.91	0.3
1/29/74	5.03	4.60	5.06	5.64	7.86	5.97	*** -	*** -	8.31	10.72	6.07	0.6
2/13/74	5.28	4.84	5.46	6.33	9.14	6.90	9.43	5.94	7.18	74.93	6.72	0.5
2/25/74	4.98	4.81	5.38	6.33	9.49	6.75	8.76	5.83	7.07	17.53	6.60	0.5
3/11/74	4.98	[illegible].66	5.35	6.50	9.01	6.66	9.05	5.83	6.95	92.61	6.55	0.5
3/27/74	4.90	4.60	5.12	6.21	8.42	6.12	8.15	5.83	6.87	11.32	6.25	0.4
4/8/74	5.14	4.81	5.40	6.24	[illegible].01	6.61	8.44	5.97	6.90	19.90	6.50	0.5
$\bar{X}$	4.98	4.63	5.32	6.19	8.91	6.56	9.00	5.76	7.02	88.14	6.46	0.1
$S\bar{X}$	0.06	0.06	0.06	0.10	0.26	0.13	0.26	0.05	0.15	23.03		

*Sample not taken because of high water and hazardous conditions.
**Upper most part of the estuary, not included in mean values for the watershed.
***Sample contaminated.

Appendix

Table 9. Bi-weekly Potassium Levels in PPM at Selected Stations in the Espiritu Santo Watershed.

Sample Date	Station 1a	Station 1b	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8	Station 9**	$\bar{X}$ 1a-8	$S\bar{X}$
10/30/73	0.32	0.27	0.43	0.34	0.42	0.37	0.47	0.32	0.25	6.46	0.35	0.02
11/12/73	0.28	0.25	0.41	0.32	0.41	0.36	0.44	0.28	* -	6.32	0.34	0.02
11/27/73	0.26	0.24	0.41	0.33	0.38	0.35	0.40	0.28	0.20	8.40	0.32	0.02
12/10/73	0.25	0.25	0.38	0.29	0.37	0.33	0.38	0.27	0.23	2.74	0.31	0.02
12/26/74	0.28	0.26	0.42	0.32	0.40	0.37	0.46	0.28	0.20	6.88	0.33	0.03
1/16/74	0.30	0.29	0.37	0.35	0.65	0.36	0.35	0.28	0.25	0.44	0.36	0.04
1/29/74	0.30	0.26	0.36	0.29	0.38	0.32	***-	***-	0.33	0.62	0.32	0.01
2/13/74	0.30	0.24	0.39	0.30	0.37	0.31	0.41	0.27	0.20	2.94	0.31	0.02
2/25/74	0.27	0.26	0.39	0.32	0.36	0.36	0.42	0.27	0.20	0.83	0.32	0.02
3/11/74	0.30	0.28	0.42	0.37	0.42	0.31	0.41	0.28	0.25	2.07	0.34	0.02
3/27/74	0.26	0.26	0.41	0.28	0.46	0.37	0.35	0.29	0.24	0.68	0.32	0.02
4/8/74	0.33	0.27	0.44	0.31	0.51	0.36	0.41	0.29	0.25	1.15	0.35	0.03

*Sample not taken because of high water and hazardous conditions.
**Sample contaminated.
***Upper most part of the estuary, not included in mean values for the watershed.

Appendix
Table 10. Bi-weekly Calcium Levels in PPM at Selected Stations in the Espiritu Santo Watershed.

Sample Date	Station 1a	Station 1b	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8	Station 9**	$\bar{X}$ 1a-8	$S\bar{X}$
10/30/73	0.92	0.89	0.89	1.26	2.41	1.43	2.34	1.22	1.14	3.26	1.39	0.2
11/12/73	0.92	0.91	0.91	1.23	2.32	1.43	2.31	1.20	* -	3.07	1.40	0.2
11/27/73	0.90	0.89	0.94	1.30	2.50	1.52	2.38	1.24	1.33	3.57	1.44	0.2
12/10/73	0.90	0.89	0.96	1.19	2.18	1.35	2.16	1.19	1.21	2.18	1.34	0.2
12/26/73	0.85	0.87	0.89	1.19	2.57	1.44	2.45	1.20	1.38	3.36	1.43	0.2
1/16/74	0.90	0.82	0.76	0.87	1.44	0.99	1.70	1.17	1.09	1.29	1.08	0.1
1/29/74	0.87	0.82	0.73	0.99	1.96	1.03	*** -	*** -	1.74	1.74	1.16	0.2
2/13/74	0.87	0.87	0.87	1.19	2.39	1.35	2.38	1.22	1.26	2.34	1.38	0.2
2/25/74	0.96	0.91	0.94	1.16	2.27	1.43	2.11	1.17	1.31	2.11	1.36	0.2
3/11/74	0.78	0.78	0.81	1.11	2.15	1.32	2.07	1.10	1.16	1.94	1.25	0.2
3/27/74	1.01	0.87	0.92	1.14	1.99	1.19	2.06	1.12	1.23	1.43	1.28	0.2
4/8/74	0.92	0.81	0.91	1.21	2.31	1.28	2.06	1.20	1.18	1.70	1.32	0.2
$\bar{X}$	0.90	0.86	0.88	1.15	2.21	1.31	2.18	1.18	1.28	2.34	1.32	0.2
$S\bar{X}$	0.01	0.01	0.02	0.03	0.09	0.05	0.06	0.01	0.05	0.23	0.03	

*Sample not taken because of high water and hazardous conditions.
**Upper most part of the estuary, not included in mean values for the watershed.
***Sample contaminated.

Appendix

Table 11. Bi-weekly Magnesium Levels in PPM at Selected Stations in the Espiritu Santo Watershed.

Sample Date	Station 1a	Station 1b	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8	Station 9**	$\bar{X}$ 1a-8	$S\bar{X}$
10/30/73	1.97	1.61	1.47	2.80	5.79	3.42	5.34	2.39	2.97	28.12	3.08	0.5
11/12/73	1.88	1.58	1.50	2.62	5.67	3.15	5.17	2.25	* -	25.51	2.98	0.6
11/27/73	1.88	1.59	1.56	2.84	5.98	3.33	5.58	2.41	3.41	33.33	3.18	0.5
12/10/73	1.76	1.54	1.50	2.36	4.83	2.80	4.44	2.17	2.92	11.18	2.70	0.4
12/26/73	1.90	1.60	1.56	2.65	5.90	3.21	5.98	2.39	3.29	29.68	3.16	0.6
1/16/74	1.73	1.42	1.25	1.75	3.25	1.97	3.34	2.04	2.64	2.32	2.15	0.2
1/29/74	1.65	1.44	1.32	2.01	4.08	2.39	*** -	***-	3.99	4.01	2.41	0.4
2/13/74	1.84	1.56	1.50	2.58	5.46	3.09	5.16	2.30	3.08	13.00	2.95	0.5
2/25/74	1.83	1.58	1.49	2.44	5.00	3.03	4.60	2.19	3.12	5.32	2.81	0.4
3/11/74	1.71	1.48	1.47	2.48	5.06	2.89	4.72	2.17	2.94	17.30	2.77	0.4
3/27/74	1.78	1.47	1.42	2.22	4.50	2.62	4.04	2.16	2.96	3.75	2.57	0.4
4/8/74	1.81	1.56	1.49	2.35	5.07	2.80	4.40	2.31	3.02	4.79	2.76	0.4
$\bar{X}$	1.81	1.54	1.46	2.42	5.05	2.89	4.80	2.25	3.12	14.86	2.79	0.1
$S\bar{X}$	0.02	0.02	0.02	0.09	0.23	0.12	0.23	0.04	0.11	3.33		

*Sample not taken because of high water and hazardous conditions.

**Upper most part of the estuary, not included in mean values for the watershed.

***Sample contaminated.

Appendix
Table 12. Bi-weekly Chloride Measurements in PPM at Selected Station in the Espiritu Santo Watershed.

Sample Date	Station 1a	Station 1b	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8	Station 9**	$\bar{X}$ 1a-8	$S\bar{X}$
10/30/73	20.0	20.1	17.5	20.5	31.0	25.3	36.8	14.0	28.0	760	23.68	2.40
11/12/73	13.5	13.2	13.5	16.0	22.1	17.5	19.5	14.2	* -	550	16.19	1.16
11/27/73	13.0	12.9	12.8	15.0	3.65	11.5	24.0	16.5	18.0	730	14.15	1.83
12/10/73	13.5	12.3	13.0	14.4	19.0	15.5	18.1	14.3	16.1	206	15.13	0.76
12/26/73	14.0	12.3	13.0	14.9	25.0	13.5	23.3	16.5	18.8	860	16.81	1.54
1/15/74	14.0	14.2	14.5	14.0	20.8	13.9	23.0	19.0	23.5	232	17.43	1.38
1/28/74	18.5	17.5	18.3	17.5	22.0	19.0	18.8	20.0	25.0	40	19.62	0.82
2/13/74	16.5	14.5	15.0	18.0	24.5	18.5	24.0	17.5	19.0	330	18.61	1.18
2/25/74	16.0	15.0	16.0	16.0	24.0	18.0	25.0	16.0	19.0	60	18.33	1.24
3/11/74	2.0	2.5	2.5	11.0	22.0	16.5	23.5	18.5	14.0	180	12.50	2.83
3/27/74	18.0	16.0	18.0	20.0	25.0	20.0	31.0	19.0	17.5	28	20.50	1.56
4/8/74	*** -	-	-	-	-	-	-	-	-	-	-	-
$\bar{X}$	14.45	13.68	14.01	16.12	21.73	17.2	24.27	16.86	19.89	3427	17.58	1.22
$S\bar{X}$	1.43	1.33	1.31	0.83	2.04	1.13	1.64	0.64	1.36	9783		

*Sample not taken because of high water and hazardous conditions.
**Instrument malfunction.
***Upper most of the estuary, not included in mean values for the watershed.

Appendix
Table 13. Bi-weekly Salinity Measurements in PPM NaCl at Selected Stations in the Espiritu Santo Watershed.

Sample Date	Station 1a	Station 1b	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8	Station 9**	$\bar{X}$ 1a-8	$S\bar{X}$
10/30/73	33.00	33.16	28.88	33.82	51.13	41.74	60.72	23.10	46.20	1254.00	39.08	3.96
11/12/73	22.28	21.78	22.28	26.40	36.46	28.88	32.18	23.43	* -	907.50	26.71	1.91
11/27/73	21.45	21.28	21.12	24.75	38.84	18.98	39.60	27.22	29.70	1204.50	26.99	2.56
12/10/73	22.28	20.30	21.45	23.76	31.35	25.58	29.86	23.60	26.56	339.90	24.97	1.25
12/26/73	23.10	20.30	21.45	24.58	41.25	22.28	38.44	27.22	31.02	1419.00	27.74	2.54
1/16/74	23.10	23.43	23.92	23.10	34.32	22.94	37.95	31.35	38.78	38.28	28.76	2.27
1/29/74	30.52	28.88	30.20	28.88	36.30	31.35	31.02	33.00	41.25	66.00	32.38	1.34
2/13/74	27.22	23.92	24.75	29.70	40.42	30.52	39.60	28.88	31.35	544.50	30.71	1.94
2/25/74	26.40	24.75	26.40	26.40	39.60	29.70	41.25	26.40	31.35	99.00	30.25	2.04
3/11/74	3.30	4.12	4.12	18.15	36.30	27.22	38.78	30.52	23.10	297.00	20.61	4.68
3/27/74	29.70	26.4	29.70	33.00	41.25	33.00	51.15	31.35	28.88	46.20	33.83	2.57
4/8/74	*** -	-	-	-	-	-	-	-	-	-	-	-
$\bar{X}$	23.85	22.57	24.12	26.60	38.84	28.38	40.05	27.82	32.82	565.08	29.34	2.18
$S\bar{X}$	2.36	2.19	2.16	1.37	1.70	1.86	2.71	1.05	2.24	161.41		

*Sample not taken because of high water and hazardous conditions.
**Upper most part of the estuary, not included in mean values for the watershed.
***Instrument malfunction.

Appendix
Table 14. Analysis of Variance, Single Way Classification. Results from the Variables Tested in Time at all Stations.

Variable	Source	df	Mean Square	F	F_{005}
Temperature	Date	11	12.7693		
	Error	108	4.0390	3.162	1.89
Dissolved Oxygen	Dates	11	0.4499		
	Error	108	0.1051	4.279	1.89
Carbon Dioxide	Dates	9	0.5794		
	Error	90	0.4773	1.214	2.00
Salinity	Dates	10	29299.8906		
	Error	99	54768.4340	0.535	1.95
Sodium	Dates	11	663.4934		
	Error	108	1249.6182	0.531	1.89
Potassium	Dates	11	0.8421		
	Error	108	1.6579	0.508	1.89
Calcium	Dates	11	0.2549		
	Error	108	0.4011	0.636	1.89
Magnesium	Dates	11	18.9949		
	Error	108	27.8354	0.682	1.89
Chloride	Dates	10	10616.95		
	Error	99	20146.40	0.52	1.95

Appendix
Table 15. Analysis of Variance, Single Way Classification. Results from the Variables Tested in Time at Stations 1a-8.

Variable	Source	df	Mean Square	F	$F_{0.05}$
Temperature	Dates	11	10.7930		
	Error	96	3.5818	3.013	1.90
Dissolved	Dates	11	0.4525		
Oxygen	Error	96	0.1003	4.511	1.90
Carbon	Dates	9	0.6604		
Dioxide	Error	80	0.3508	1.882	2.02
Salinity	Dates	10	210.8241		
	Error	88	62.9772	3.348	1.96
Sodium	Dates	11	0.7309		
	Error	96	2.6795	0.273	1.90
Potassium	Dates	11	0.0026		
	Error	96	0.0060	0.438	1.90
Calcium	Dates	11	0.0862		
	Error	96	0.2855	0.302	1.90
Magnesium	Dates	11	0.7463		
	Error	96	1.8419	0.405	1.90
Chloride	Dates	10	87.09		
	Error	88	23.88	3.64	1.96

Appendix
Table 16. Analysis of Variance, Single Way Classification. Results from the Variables Tested in Time at Forested Stations.

Variable	Source	df	Mean Square	F	$F_{0.05}$
Temperature	Dates	11	5.8688		
	Error	60	2.2089	3.013	1.73
Dissolved Oxygen	Dates	11	0.3798		
	Error	60	0.1009	3.763	1.73
Carbon Dioxide	Dates	9	0.3285		
	Error	50	0.1275	2.576	2.08
Salinity	Dates	10	161.2696		
	Error	55	29.8998	5.394	2.01
Sodium	Dates	11	0.1249		
	Error	60	0.8206	0.152	1.73
Postassium	Dates	11	0.0012		
	Error	60	0.0038	0.328	1.73
Calcium	Dates	11	0.0138		
	Error	60	0.0409	0.337	1.73
Magnesium	Dates	11	0.0926		
	Error	60	0.4247	0.218	1.73
Chloride	Dates	10	59.21		
	Error	55	10.98	5.39	2.01

Appendix
Table 17. Analysis of Variance, Single Way Classification. Results from the Variables Tested in Time at Forested Stations not including Station 3.

Variable	Source	df	Mean Square	F	$F_{0.05}$
Temperature	Dates	11	4.6986		
	Error	48	1.6848	2.789	2.00
Dissolved Oxygen	Dates	11	0.2842		
	Error	48	0.1030	2.759	2.00
Carbon Dioxide	Dates	9	0.2584		
	Error	40	0.1200	2.153	2.12
Salinity	Dates	10	148.0231		
	Error	44	35.6115	4.043	2.06
Sodium	Dates	11	0.1138		
	Error	48	0.9150	0.124	2.00
Potassium	Dates	11	0.0011		
	Error	48	0.0045	0.246	2.00
Calcium	Dates	11	0.0094		
	Error	48	0.0452	0.209	2.00
Magnesium	Dates	11	0.0488		
	Error	48	0.4864	0.100	2.00
Chloride	Dates	10	54.34		
	Error	44	13.08	4.15	2.06

Appendix
Table 18. Analysis of Variance, Single Way Classification. Results from the Variables Tested in Time at Grassland Stations.

Variable	Source	df	Mean Square	F	$F_{0.05}$
Temperature	Dates	11	6.0268		
	Error	24	0.4208	14.321	2.21
Dissolved Oxygen	Dates	11	0.1336		
	Error	24	0.1225	1.091	2.21
Carbon Dioxide	Dates	9	0.5056		
	Error	20	0.5498	0.920	2.39
Salinity	Dates	10	112.6466		
	Error	22	55.8093	2.018	2.30
Sodium	Dates	11	1.4252		
	Error	24	2.0280	0.703	2.21
Potassium	Dates	11	0.0024		
	Error	24	0.2704	0.516	2.21
Calcium	Dates	11	0.1394		
	Error	24	0.2704	0.516	2.21
Magnesium	Dates	11	1.1740		
	Error	24	1.4668	0.800	2.21
Chloride	Dates	10	61.31		
	Error	22	25.51	2.40	2.30

Appendix
Table 19. Analysis of Variance, Single Way Classification. Results from the Variables Tested in Time at Grassland Stations including Station 3.

Variable	Source	df	Mean Square	F	$F_{0.05}$
Temperature	Dates	11	8.0374		
	Error	36	0.6171	13.025	2.07
Dissolved Oxygen	Dates	11	0.2066		
	Error	36	0.1189	1.738	2.07
Carbon Dioxide	Dates	9	0.5389		
	Error	30	0.5071	1.063	2.21
Salinity	Dates	10	120.3441		
	Error	33	62.1371	1.937	2.13
Sodium	Dates	11	1.3903		
	Error	36	2.3650	0.588	2.07
Potassium	Dates	11	0.0025		
	Error	36	0.0047	0.525	2.07
Calcium	Dates	11	0.1430		
	Error	36	0.3234	0.442	2.07
Magnesium	Dates	11	1.1931		
	Error	36	1.8319	0.651	2.07
Chloride	Dates	10	60.27		
	Error	33	25.27	2.107	2.13

Appendix
Table 20. Analysis of Variance, One Way Classification. Results from the Variables Tested at all Stations.

Variables	Source	df	Mean Square	F	$F_{0.05}$
Temperature	Location	9	42.1667		
	Error	110	1.7925	23.52	1.99
Dissolved Oxygen	Location	9	0.2619		
	Error	110	0.1266	2.068	1.99
Carbon Dioxide	Location	9	2.9634		
	Error	90	0.2389	12.40	2.01
Salinity	Location	9	316138.8750		
	Error	100	28698.2390	11.02	2.00
Sodium	Location	9	8026.8438		
	Error	110	636.50	12.61	1.99
Potassium	Location	9	10.5935		
	Error	110	0.8452	12.53	1.99
Calcium	Location	9	4.0946		
	Error	110	0.0842	48.63	1.99
Magnesium	Location	9	192.6614		
	Error	110	13.4650	14.31	1.99
Chloride	Location	9	116242.44		
	Error	100	10544.81	11.02	2.00

Appendix
Table 21. Analysis of Variance, One Way Classification. Results from the Variables Tested at Stations 1a-8.

Variables	Source	df	Mean Square	F	$F_{0.05}$
Temperature	Location	8	37.6433		
	Error	99	1.6306	23.085	2.05
Dissolved Oxygen	Location	8	0.1783		
	Error	99	0.1331	1.340	2.05
Carbon Dioxide	Location	8	2.1334		
	Error	81	0.2091	10.201	2.08
Salinity	Location	8	470.8450		
	Error	90	43.1497	10.912	2.07
Sodium	Location	8	30.2180		
	Error	99	0.2377	127.143	2.05
Potassium	Location	8	0.0585		
	Error	99	0.0014	42.575	2.05
Calcium	Location	8	3.2454		
	Error	99	0.0242	134.108	2.05
Magnesium	Location	8	20.9504		
	Error	99	0.1760	119.036	2.05
Chloride	Location	8	138.56		
	Error	90	15.698	8.83	2.07

Appendix
Table 22. Analysis of Variance, Single Way Classification. Results from the Variables Tested at Forested Stations.

Variables	Source	df	Mean Square	F	$F_{0.05}$
Temperature	Location	5	21.8129		
	Error	66	1.3337	16.351	2.36
Dissolved Oxygen	Location	5	0.1316		
	Error	66	0.1444	0.911	2.36
Carbon Dioxide	Location	5	0.3055		
	Error	54	0.4363	2.113	2.39
Salinity	Location	5	164.4679		
	Error	60	40.5807	4.053	2.37
Sodium	Location	5	9.0847		
	Error	66	0.0786	115.58	2.36
Potassium	Location	5	0.0404		
	Error	66	0.0006	67.32	2.36
Calcium	Location	5	0.4016		
	Error	66	0.0091	44.13	2.36
Magnesium	Location	5	4.7583		
	Error	66	0.0411	115.77	2.36
Chloride	Location	5	60.4218		
	Error	60	14.9041	4.054	2.37

Appendix
Table 23 Analysis of Variance, Single Way Classification. Results from the Variables Tested at Forested Stations not including Station 3.

Variables	Source	df	Mean Square	F	$F_{0.05}$
Temperature	Location	4	16.9131		
	Error	55	1.1801	14.33	2.55
Dissolved	Location	4	0.1119		
Oxygen	Error	55	0.1375	0.814	2.55
Carbon	Location	4	0.3487		
Dioxide	Error	45	0.1273	2.739	2.59
Salinity	Location	4	204.8720		
	Error	50	44.5529	4.59	2.57
Sodium	Location	4	10.3196		
	Error	55	0.0707	145.96	2.55
Potassium	Location	4	0.0490		
	Error	55	0.0006	81.67	2.55
Calcium	Location	4	0.4573		
	Error	55	0.0291	56.46	2.55
Magnesium	Location	4	5.5705		
	Error	55	0.0291	191.43	2.55
Chloride	Location	4	75.2652		
	Error	50	16.3625	4.600	2.57

Appendix
Table 24. Analysis of Variance, Single Way Classification. Results from the Variables Tested at Grassland Stations.

Variables	Source	df	Mean Square	F	$F_{0.05}$
Temperature	Location	2	1.4936		
	Error	33	2.2245	0.671	2.29
Dissolved Oxygen	Location	2	0.3803		
	Error	33	0.1106	3.438	2.29
Carbon Dioxide	Location	2	3.2067		
	Error	27	0.3383	9.478	3.35
Salinity	Location	2	452.8159		
	Error	30	48.2880	9.377	3.32
Sodium	Location	2	23.0022		
	Error	33	0.5559	41.38	2.29
Potassium	Location	2	0.0211		
	Error	33	0.0029	7.27	2.29
Calcium	Location	2	3.1140		
	Error	33	0.0544	57.24	2.29
Magnesium	Location	2	16.7006		
	Error	33	0.4459	37.45	2.29
Chloride	Location	2	194.3313		
	Error	30	37.2297	5.22	3.32

Appendix
Table 25. Analysis of Variance, Single Way Classification. Results from the Variables Tested at Grassland Stations including Station 3.

Variables	Source	df	Mean Square	F	$F_{0.05}$
Temperature	Location	3	4.6994		
	Error	44	2.1938	2.142	2.82
Dissolved Oxygen	Location	3	0.3114		
	Error	44	0.1277	2.439	2.82
Carbon Dioxide	Location	3	2.9510		
	Error	36	0.3114	9.477	2.86
Salinity	Location	3	532.7090		
	Error	40	41.3959	12.869	2.84
Sodium	Location	3	26.9315		
	Error	44	0.4463	60.341	2.82
Potassium	Location	3	0.0316		
	Error	44	0.0024	13.430	2.82
Calcium	Location	3	3.7548		
	Error	44	0.0443	84.700	2.82
Magnesium	Location	3	21.0830		
	Error	44	0.3596	58.623	2.82
Chloride	Location	3	161.5138		
	Error	40	24.2042	6.673	2.84

Appendix

Table 27. Drinking Water Standards for the United States and Europe. Taken from the Encyclopedia of Geochemistry and Environmental Sciences, Volume IVA. Van Nostrand Reinhold Company, New York, 1972. Page 320.

Determination	USPHS	WHO	Rational Limit (McKee)
	Bacterial		
Coliform bacteria, per 100 ml	1.0	0.05a 1.0b	
	Physical		
Turbidity, silica scale units	5	-	
Color, cobalt scale units	15	-	
Odor, maximum threshold number	3	-	
	Chemical (mg/liter)		
Alky benzene sulfonate	0.5	-	
Ammonia	-	0.5a	
Arsenic	0.05c	0.2a,b	0.05
Barium	1.0c	-	
Cadmium	0.01c	0.5a	
Calcium	-	200b	200
Carbon chloroform extract	0.2		
Chloride	250	350a	500
Chromium (hexavalent)	0.05c	0.05a,b	
Copper	1.0	3.0a	1.0
Cyanide	0.2	0.1a,b	
Fluoride	1.6.3.4c	1.5a	1.5
Iron	0.3	1.0b	1.0
Lead	0.05c	0.1a,b	0.1
Magnesium	-	125a	125
Magnesium + sodium sulfate	-	1000b	
Manganese	0.05	0.1a	0.1
Nitrate, as NO_3	45	50a	
Phenolic compounds	0.001	0.001a	
(Potassium)			500d
Selenium	0.01c	0.05a,b	0.05
Silver	0.05c	-	
(Sodium)			500d
Sulfate	250	250a	
(Sulfur)			500d
Total Solids	500	1500	
Zinc	5.0	5.0a	5.0
	Radiological (pc/liter)		
Radium-226	3c	-	
Alpha emitters	-	1a,b	
Strontium-90	10c	-	
Beta Emitters	1000c	10a,b	

a WHO European Standards of 1961.
b WHO International Standards of 1958.
c Mandatory, Others are recommended by USPHS
d Does not appear as such in original list.

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