PUERTO RICO NUCLEAR CENTER 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 NO. (40.1)1899 FOR US ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION ---Page Break--- QUALITY PARAMETERS AS INFLUENCED BY CHANGES IN SELECTED WATER QUALITY AND LAND USE PATTERNS IN THE ESPIRITU SANTO DRAINAGE BASIN ELVIRA CUEVAS AND RICHARD G. CLEMENTS DIVISION OF TERRESTRIAL ECOLOGY DECEMBER 1975 PUERTO RICO NUCLEAR CENTER OPERATED BY THE UNIVERSITY OF PUERTO RICO FOR THE ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION ---Page Break---

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. pH 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 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. ---Page Break---

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sewage disposal, etc. Wise management and utilization of a water resource will prevent to a large extent many destructive effects on both a short-term and long-term 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, 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. ---Page Break--- ‘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 59% as the temperature rises from 0°C (32°F) to 100°C (212°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 air-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 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 range from 6.5 to 8.5 (MacKenthun, 1969). Bogart (1964) reported pH values ranging from 6.8 to 8.1 for periodic stations for 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 Saith (1966), Odum (1971), and MacKenthun (1969), among others. Past Research Puerto Rico's river system has 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 1972 (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 Rovart (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 for water for industrial purposes. The Water Resources Research Institute in Mayagüez has compiled a bibliography of the information published to date pertinent to the water resources.

situation in Puerto Rico (Véequex et al. gro). 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) Resource data; 8) Engineering works; and 9) Manpower, grants and facilities. The earliest work reported under water quality management and protection was in 1971. The major thrust on water quality studies began in the mid-1960s 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 (Azquer et al., 1970). Some of the basic studies published to date from reservoirs and lagoons are those of Candelas (1969) and Rufz de Reyes (year). 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 CO2 was found on the surface of any of the lakes. Rufz 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 on the rivers and streams of Puerto Rico indicate that due to severe demands for land usage and water consumption, it has become pertinent to study rivers as part of a dynamic ecosystem in which interdependency is vital for the 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. It 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) 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 Biology 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 1962 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 northern slopes of the Luquillo Mountains and flows northward into the Atlantic Ocean. With a drainage area of 20.6 km², 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 2. Table 1. Characteristics of the Espiritu Santo Basin Main Stream Espiritu Santo 19.5 5a 20.6 Two W to 50M eter. 6.9 10.6 * SOM to Sea level 10.6 O.h7 2 Tributaries Quebrada Sonadora 38 ao as Quebrada Grande au ie x3 ‘Quebrada Jiménez 13 1216 3.9 ---Page Break--- 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; Evel and Wattmore, 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. Gaertn., and Avicennia nitida, Jacq. Land 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 ‘urban areas utilizing now a large land area formerly devoted to agriculture. ---Page Break--- For approximately two kilometers inland from the coastline ‘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-Hiicara-Narenjite, (4) Lor Guineo-Humatas-Tirtos, 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 the 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 intrusive 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 ---Page Break--- 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, 98.10% of

the total acreage ie in use as residential areas, water resources and wetlands, forest and agriculture. Of this 98.4%, 51.70% was forested acreage, 35.4% was devoted to agriculture, 6.1% 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 Carraizo. The "barrios," geographical areas within the municipality, obtain their water from Quebrada Jiménez and Quebrada Grande, Espiritu Santo inside the forest and Zarcal (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, 11.24% is taken from a common outlet of Quebrada Jiménez and Quebrada Grande, and 87.636% is taken from the Espiritu Santo River. This water is mainly utilized for residential purposes within the rural zone. (Appendix Table 3). ---Page Break--- 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 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. Absolute, Relative (Ugo _1950__1960_1970 1940-50 1950-60 1960-70 16,126 16,651 17,244 22,032 5,358 582 W199 3,335 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. 20 ---Page Break--- 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 one 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 grass, on the grassland areas, and at the uppermost part of the estuary. The latter station reflected the saltwater input into the river system. The location of each station was selected to evaluate the influence of vegetation types upon selected physical and chemical 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 polyethylene bottles were taken to the laboratory for chemical analysis. ---Page Break--- 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 YBI Dissolved Oxygen Meter, Model SIA using a YSI 5730 Oxygen-Temperature probe. pH: Orion Specific Ion Meter, model 401 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 Edition, Hatton, 1971. In situ. Chloride: Orion Specific Ion Meter, model 940, 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 2.65 = 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. ---Page Break--- The results obtained from field measurements and laboratory analyses were transferred to TIM 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 2. The description and site characteristics of each station are summarized in Table 3. For

For study purposes, the watershed was divided into 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 precipitation ranging from 75 inches to 150 inches per year (Odus, 1910). 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 where applicable. Station values are grouped in various combinations for data analysis as shown in Table I.

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Table II, Combinations of Data for Statistical Analysis

Combination Nia woo 3 7 5 6 7 8 9 ALL Stations

woox X eK x x Kx xX x ALL Stations except upper estuary 9 kX KX Xe XK x x Forest 6 x xxx x x Forest w/o Boundary 5 ox oe x x x Grassland 3 XK x Grassland in boundary 4 xe 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 ± 0.8 inside the forested zone (Sta. 2) to 22.0°C ± 0.5 in the uppermost part of the estuary (Sta. 9) (Table 5). During the period of study, average minimum and maximum water temperatures occurred in mid-January and late October, respectively. The data suggest that average minimum water temperature ---Page Break --- 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 Tuguillo National Forest were 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 360m, 24.7°C at 428m, 23.1°C at 567m, and 21.0°C at 636m. This is a difference of 3.4°C over an altitudinal change of approximately 275m. Odum (1970) reported that temperatures at the forest floor were 0.5 to 1.1°C lower.

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

Variable	t-value	Degrees of Freedom	p-value
Temperature	73.3960	2.365	<0.0001
Dissolved Oxygen	70.9850	18	<0.0001
Free Carbon Dioxide	-2.87	2	0.003
Salinity	-2.87	2	0.003
Sodium	-2.87	2	0.003
Potassium	2.6857	2	0.003
Calcium	3.6807	2	0.003
Magnesium	3.6807	2	0.003
Chloride	2.6862	2	0.003

Forest versus grassland: Highly significant. Not significant.

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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	t-value	p-value
Temperature	7.176	<0.0001
Dissolved Oxygen	1.6729	0.108
Free Carbon Dioxide	0.3261	0.565
Salinity	-1.8500	0.063
Sodium	8.5055	<0.0001
Potassium	6.7901	<0.0001
Calcium	8.386	<0.0001
Magnesium	7.6807	<0.0001

-12.6800 2.074 " PveB 22 "011208 © 2.074 " ByeG 2 310962 BLO " chloride Pye 20 1.8498 2.086 us PveB 20 113615 2.086 us BveG 20 0.728 2.086 18 F = Forest, 1B = Boundary G = Grassland NS = Not Significant, * Significant M Highly Significant a ---Page Break--- 'Table 8, t-test and Levels of Significance for Forested versus Grassland Stations in the Quebrada Grande Tributary. Tre OE Variable ae £ "os Significance 'temperature a -1.9396 2.080 1 Dissolved oxygen a -1.069 2.080 s Free Carbon Dioxide Fry -4.5887 2.101 " Salinity ct 2.2490 2.098 . Sodium a 6.2321 2.080 " Potassium a -1.1610 2.080 " calcium a 8.87 2.080 Magnesium 2 1.2183 2.080 a Chloride - 0.7370 2.093 1s 22 ---Page Break--- 'Table 9. t-test and Levels of Significance for Forested versus Grassland Stations in the Quebrada Jiménez Tributary. . Travel of variable at t 2.05 Significance 'Temperature 22 5.8710 2.0m " Dissolved Oxygen 22 2.0848 2.078 18 Free Carbon Dioxide 8 2.3017 2.101 * Salinity 20 2085, 2.086 " Sodium 20 12.2016 2.086 " Potassium por =10.5250 2.086 " calcium 20 © -18,.0040 2.086 " Magnesium 20 -21.1ho5 2.086 " chloride 20. 4,208 2.086 " WS ©

Not Significant * Significant * Highly Significant 23 ---Page Break--- Table 10, t- Test and Levels of Significance for East Branch versus West Branch Station in the Quebrada Sonadore Tributary. read OF 5 Variables ag. t 0.05 Significance 'Temperature 2 0.6861 2.07s 15 Dissolved Oxygen 22 -1.1760 2.07h 15 Free Carbon Dioxide 20 -0.1547 2.086 15 Salinity 20 0.3960 2.086 Xs Sodium 22 4,z159 2.o7h " Potassium 22 3.812 2.074 " calcium 22 1.9698 207k ns Magnesium 22 8.5386 2.078 " chloride 20 0.3959 2.086 % WS = Not Significant * = Significant + © Highly Significant ---Page Break--- 'than at the canopy level in the Tabomuco Forest (elevation, approximately 500M). '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 1 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 others 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 22.0°C ± 0.5. Although the difference between the averages is only 2.0°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 °C). Mean DO concentration values per station ranged from 8.2 mg/l ± 0.1 at the upper estuary to 8.7 ± 0.2 mg/l. (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 highest DO concentrations inside the forest and the lowest concentrations in the grassland areas. Within the grassland area, Quebrada Jinénex (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 Le

Due to the fact that the DO values for Station 3 fall intermediate between the values for the other sampling stations, this eliminates 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 area, 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 stream. 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).

Carbon Dioxide

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/1. Mean values ranged from 2.04 mg/1 in Quebrada Sonadora (forest) to 3.52 mg/1 in Quebrada Grande (grassland). The overall mean concentration for the entire system, excluding Station 9, was 2.11 ± 0.25 mg/1. The highest observed values were recorded at Station 4 (3.52 ±

0.21 mg/1) and Station 9 (3.44 ± 0.22 mg/1) (See Table 5). Most 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 differences in these values might have 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 GO 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, CO2 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. 29 ---Page Break--- Out of a total of 119 observations in Appendix Table 7, 87% 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 on 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 SIS (Report 1973) from 1968 to 1972 for the Espiritu Santo River ranged from 6.2 to 8.6 with 81% 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 seem to be more acidic in the forested areas and more alkaline at the lower reaches of the rivers. 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. Saltwater intrusion at the uppermost part of the estuary also provides another source of input to the river system. Cintrén (personal communication) mapped the saltwater intrusion for the Espiritu Santo estuary and estimated that the saltwater wedge

extends about five kilometers from the estuary into the fresh water system. Soil and rock weathering provide the major supply of tons to natural waters (Gorham, 1961) with the concentration of the dissolved salts related to the parent material varying with rock 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 2k). 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 Jinéner 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, % 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 Colon (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, Na, K, and Cl are presented in Appendix Tables 9, 10, 11, and 12. Average elemental concentrations showed a marked increase in station 1 (uppermost part of the estuary) with values of 88.14 ± 23.0 mg/L Na, 3.29 ± 0.8 mg/L K, 20.38 ± 0.2 mg/L Ca, 14.86 ±

3.3 mg/L Na, and 3K.27 + 97.89 me/ 1€1 as compared to the average concentration for the other stations taken together which were 6.46 ± 0.1, 0.33 + 0.0, 1.30 ± 0.2, 2.19 ± 0.2, and 17.58 + 1.22 respectively. A significant occurrence was found among stations' means for the concentration of Na, K, Mg, and Cl. Table 5 presents the average values per station and also which stations ranked after others according to the New Duncan's Multiple Range Test. Table 12 presents a summary of the results presented according to vegetation types which suggest 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 saltwater 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 Types Sodium | Potassium | Calcium | Chloride Forest, 0.06 ± 0.40 + 0.00 | 1.04 + 0.02 | 5.75 + 0.96 | 0.22 ± 0.39 + 0.00 | 1.88 + 0.07 | 1.00 + 1.36 | 3.29 + 0.84 | 12.30 + 0.03 | 32 ± 3.27 | 97.83 ---Page Break--- Small differences appear to exist from east to west with the easternmost 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; Clonets and Colén, 197%). In the Luquillo mountains, the eastern part of the sierra gets the highest amount of rainfall per year (Wadsworth, 1951). From 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 inputs, 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 source mentioned before. t-tests on the data for each stream showed significant differences between the forest stations and the grassland stations (Table 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). Clemente and Colén (1973) monitored the Quebrada Sonadora and Quebrada Grande (Sta. 1) 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 processes of exchange at the sea surface with wind controlling the amount of spray released into the rising air that passes the Luquillo mountains. Corban (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 values were computed by measuring the chloride concentration in the stream water and expressing it as sodium chloride according to the formula me/1 NaCl = 1.65 X me/1 Cl" given in Standard Methods for the Examination of Water and Wastewater, 13th Edition (1987). 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 © higher salinity concentration. Salinity values for station 9 fluctuated widely from a low of 38.28 mg/l NaCl to a high of 1019 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). 35 ---Page Break--- ita 5 eae Salinity Values pr Sa 1 Espisite Saale Drainage ---Page Break--- 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 (8. 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.d) to 0.05 mg/l at Quebrada Jiménez, grassland (Sta. 6). Using Duncan's Multiple Range Test to separate means, stations 4 and 6 were found to be similar but significantly different from all the other stations. Salinity values for stations 1a, 1, 2, and 3 were not significantly different but varied significantly from station 7 (forest). Mean values for stations 5 (grassland), 7, and 8 (forest) were similar ranging intermediate with stations 1a, 1b, 2, and 3 (forest). These differences indicate a possible salinity gradient across the system which could be determined by elevation, and 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 nominal 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 drinking water standards (See Appendix Table 7). " ---Page Break--- 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 Fajardo 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 optimal habitats for the liver parasite, Schistosoma mansoni, a health hazard for man. ---Page Break--- LITERATURE CITED American Public Health Association, 1971. Standard Methods for the Examination of Water and Wastewater, 13th Edition. American Public Health Association, N.Y., 874 pp. Departamento de Salud, Censos de Población de Puerto Rico, 1940, 1950, 1960, y 1970. Gobierno de Puerto Rico. Soil Conservation Service, 1968. Soil Survey of the

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O27 Outdoor recreation - all types 202.35, 28.95 0.56 Public facilities - all types m.2h ua 0.28 Commercial 6.1 0.22 Urban - downtown Commercial - strip Motels Industrial 74.78 0.39 Light -

non-pollutant, 28.91 Heavy - pollutant 16.33 Industrial Park 29.51 Residential Urban 1001.26 2.26 Light density 1.88 Medium density 3518 Heavy density 275.31 Medium 6.28 Unconstructed within urban Area, 10.05 Under construction 556.96 Residential - Rural 1229.52 2.86 Light density Medium density Blue Strip ---Page Break--- Cont. Table 1 seen de aT Pca OF Use Category Acreage __Acreage Acreage, Water Resources and Wetlands 219.73 6.14 Rivers, Streams (width 50'+) 8.05 Enclosed, protected 215.59 Natural fresh water pond with less than 1 acre Mangrove swamps 1585.84 Shrub, bushy wetland 20.7% 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, 1269685 Agriculture 13985.97 35.46 Sugar Cane 632.70 Coconut groves 2064625 Grazing 1899.21 Floriculture 6.28 Coffee and Intensive commercial crops 64.73 Small holder (planted) 67.88 Citrus plantation 6.28 Banana plantation 9128 Inactive land Active 25.14 TOTAL 39540.12 SC a3 ---Page Break--- Appendix Table 2. Consumptive Water Use for the Municipality of Rio Grande for the Month of February, 1974. Source of Water - lake Carraizo. Data from Records of P.R. Aqueducts and Sewer Authority. Feb 97 Water 6 — Use Category cubic Meters Gallons Total Residential Water 158,159 4,753,976 35.617 in services T1919 20,586,456 17.58 Water metered 24626 653,264 0.59 Public fountains 1,008 266,12 0.23 Commercial Water 21,23 5,608,350 Lp commercial water 9363 acreage can be evaluated Estimated Water 778 469,390 ok Water plus services are 71,868 0.06 Fire hydrants 3,268 60,752 1.65 Industry 1312 3,930,368 1.65 Other sources 160,378 42,339,792 total 43,386 127,053,908 SSS My ---Page Break--- Appendix Table 3. Consumptive Use of Water taken from Freshwater Sources within the Municipality of Rio Grande for the Fiscal

Year 1972-1973. A total Fei Source of Freshwater Estimated Estimate 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. Zareal - Tributary of Quebrada Jiménez 220,000 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 Sewer Authority.

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eth 2.00 Salinity Dates o —25299.8906 Error 99 SET6B1U3N0 04535 1.95, Sodium Dates a 663.4934 Error 108 1291618252 1.89 Potassium Dates a 0.001, Error 108 16579 0.508 1.89 Calcium Dates a 0.2549 Error 108 0.636 1.89 Magnesium Dates a 28.9949 Error 108 27.8356 0.6 1.89 Chloride Dates 10 10616.95 Error 99 Baile.iio 0.52 1.95 56 ---Page Break--- Appendix Table 15. Analysis of Variance, Single Way Classification. Results from the Variables Tested in Time at Stations 1a-6, Variable Source at. Mean Square __p__<0.05 ‘Temperature Dates 10.7930 Error % 3.5818 3.013 1.90 Dissolved Dates a 0.4525 Oxygen Error % 0.1003 0.541 2.90 Carbon Dates 9 0.6608 Dioxide Error 80 0.3508 1.882 2.08 Salinity Dates 19 210.8241 Error 8 62.772 3.81 Sodium Dates: a 0.7309 Error % 2.6795 0.273 1.90 Potassium Dates a 0.006 Error % 0.010060 0.38 1.90 Calcium Dates a 0.086 Error % 0.2855 0.302 1.90 Magnesium Dates a 0.7463 Error % 1.8819 0.405 1.90 Chloride 20 87.09 88, 23.68 3.64 1.96 ---Page Break--- Appendix Table 16. Analysis of Variance, Single Way Classification, Results from the Variables Tested in Time at Forested Stations. Variable Source of Mean Square F<0.05 Temperature Dates, n 5.0688 Error 6 2289 3.013, 1.73 Dissolved Dates u 0.3798 Oxygen Error % 0.01009 3.76373 Carbon Dates 9 0.3285

Dioxide Error 50 0.576 2.08 Salinity Dates 10 161.2696 Error 55 29.8998 5.398 2.01 Sodium Dates n 0.129 Error 60 0.005. Potassium Dates n 0.0012 Error 6 0.0038 0.388 Calcium Dates a 0.0138 Error 0 0.089 0.33773 Magnesium Dates nu 0.0906 Error 6 0.21873 Chloride Dates a 59.0 Error 55 10.98 5.39 2.01 ---Page Break--- Appendix Table 17. Analysis of Variance, Single Way Classification. From the Variables Tested in Time at Forested Stations not including Station 3. Results Variable Mean Square F<0.05 'Temperature a 2.789 2.00 Dissolved a Oxygen 2.759 2.00 Carbon Dates 9 Dioxide Error 4 2.53 2.12 Salinity Dates 20 Error 4.03 2.06 Sodium Dates a Error 48 1.00 Potassium Dates n Error 1 0.266 2.00 Calcium Dates a Error 1

0.209 2.00 Magnesium Dates a Error 4B 0.100 2.00 chloride Dates 2.0 Error My was 2.06 59 ---Page Break--- Appendix Table 18, Analysis of Variance, Single Way Classification. Results from the Variables Tested in Time at Grassland Stations. Variable Source of Mean Square F 0.05, Temperature Dates = Error 6 23.005 2.07 Dissolved Dates = Oxygen Error 6 1.738 2.07 Carbon Dates 9 Dioxide Error 30 1.063 2.30 Salinity Dates 10 Error 33 2.937 2.30 Sodium Dates = Error 2 0.703 Error Potassium Dates = Error 2 0.516 Error Calcium Dates = Error 2 0.516 Error Magnesium Dates = Error 2 0.800 Error Chloride Dates 10, Error 22 2.0 2.30 ---Page Break--- Appendix Table 19. Analysis of Variance, Single Way Classification. Results from the Variables Tested in Time at Grassland Stations including Station 3. Variable Source of Square F 0.05 Temperature Dates = Error 6 23.005 2.07 Dissolved Dates = Oxygen Error 6 1.738 2.07 Carbon Dates 9 Dioxide Error 30 1.063 2.30 Salinity Dates = Error 33 2.937 2.30 Sodium Dates = Error 6 0.588 2.07 Potassium Dates = Error 6 0.525 2.07 Calcium Dates = Error 6 0.652 2.07 Magnesium Dates = Error 6 0.652 2.07 Chloride Dates 10 Error 33 2.107 2.33 ---Page Break--- Appendix Table 20. Analysis of Variance, One Way Classification. Results from the Variables Tested at all Stations. Variables Source of Mean Square F (0.05) Temperature Location 9 0.1667 Error 1.7925 23.52 1.99 Dissolved Location 9 0.2619 Oxygen Error 0.11266 2.068 1.99 Carbon Location 9 2.9634 Dioxide Error 9 2389 22.40 2.01 Salinity Location 9 326238.8750 Error 109286982390 21.02 2.00 Sodium Location 9 8026.8438 Error 636.50 22.61 2.99 Potassium Location 9 10.5935 Error 0 0.452 12.53 1.99 Calcium Location 9 4.0986 Error 0 0.82 48.63 1.99 Magnesium Location 9 192.6624 Error 31324650 2k. 2.99 Chloride Location 9 1629. bls Error 100 2054.81 2.00 ---Page Break--- Appendix Table 21. Analysis of Variance, One Way Classification, Results from the Variables Tested at Stations 1a-6.

Variables Source of Mean Square e 0.05 'Temperature Location 8 37.6433, Error 9 116306 23.085 205 Dissolved Location 8 0.2783 Oxygen Error 9 011331 1.30 2.05 Carbon Location 8 2.233 Dioxide Error a 0:20 = 10.201 2.08 Salinity Location 70,8450 Error 90 \gialg7 to. 2.07 Sodium Location 8 30.2180 Error 9 0.2377 e713 2.05 Potassium Location 8 0.0585 Error 9 crook = 2575205 Calcium Location 8 3.25 Error ~ Oroei2 134.208 2.05 Magnesium 8 20.9508 9 0.1760 119.036 2.05 Chloride 8 138.56 9 15.698 8.83 2.07 63 ---Page Break--- Appendix Table 22. Analysis of Variance, Single Way Classification. Results from the Variables Tested at Forested Stations. Variables Source of Mean Square EB Fo.05 Temperature location 5 21.8129 Error 6 2.3337 16.3591 2.36 Dissolved Location 5 0.2316 Oxygen Error 6 0.01 2.36 Carbon Location 5 0.3055 Dioxide Error 6 0.4363 232.39 Salinity Location 5 164.679 Error 60 40.5807 4.053 2.37 Sodium Location 5 9.0847 Error 6 0.07 = 115.58 2.6 Potassium Location 5 0.004 Error 6 0.0006 67.32 2.36 Calcium Location 5 0.406 Error 6 0.008 23 2.36 Magnesium Location 5 4.7583 Error 6 0.01 15.77 2.36 Chloride Location 5 60.428 Error 6 1.00 4.058 2.37 ---Page Break--- Appendix Table 23 Analysis of Variance, Single Way Classification. Results from the Variables Tested at Forested Stations not including Station 3. Variables Source of Mean Square? 0.05 Temperature Location 8 26.9131 Error 6 2180. 24.33 2.55 Dissolved Location 8 Oxygen Error 35 0.013375 0.8

2.55 Carbon Location 8 0.3487 Dioxide Error 45 0.013273 2.739 2.59 Salinity Location 8 204.8720 Error 50 0.5529 4.59 2.97 Sodium Location 8 0.3196 Error 5 1.077 5.96 2.95 Potassium Location 8 0.0490 Error 8 0.067 2.95 Calcium Location 8 0.4573 Error 35 0.56 56.46 2.55 Magnesium Location 8 5.5105 Error 55 0.01 2.55 Chloride Location 8 15.0652 Error 50 163625 4.600 2.57 ---Page Break--- Appendix Table 24. Analysis of Variance, Single Way Classification, Results from the Variables Tested at Grassland Station: Variables Source of Mean Square _F Fo.05

‘Temperature Location 2 1.8936 Error 3B 2re2ks 0.6 2.29 Dissolved Location 2 0.3803 oxygen Error 3 011106 34438 2.29 carbon Location 2 3.2067 Dioxide Error 2 013383 9.03.35 Salinity Location B52 8159 Error 30 48.2880 9.3rr 3.32 Sodium Location 2 23.0082 Error 3B 015959 M38 2.29 Potassium Location 2 o.can. Error 33 0.0029 Tet 2.29 Calcium Location 2 3.280 Error 33 Oroshk S72 2.29 Magnesium Location 2 36.7006 Error 3B OLhW59 37.5 2.29 chlorides Location 219.3323, Error 30 31221 5.22 3.38 SEER ---Page Break--- : ‘Appendix Table 95. Analysis of Variance, Single Way Classification, Results from the Variables Tested =t Grassland Stations including : Station 3. . variables Source ar Mean square £ Fo.05 Temperature Location 3 4.699 . Error ub 2.1938 2.ahe 2.82 : Discovered Location 3 o.3a04 Oxygen Error a o.ie77 2.039 2.82 Carbon Location 3 2.9510 Dioxide Error % 0.3314 per 2.86 salinity Location 3 932.7090 Error 0 42,3959 12.869 2.84 Sodium Location 3 26.9935 Error a ont 60.341 2.82 Potassium Location 3 0.0316 Error ais o.00et 33.430 2.82 calcium 3 3.7508 Mi volts 84.700 2.82 Magnesium Location 3 21.0830 Error ais 0.3596 58.603 2.82 chlorides Location 316.5198. Error 40 2h20i2 6.603 2.84 ---Page Break--- 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. Hi Determination was Limit (e.g. Coliform bacteria, per 100 ml Bacterial 1.0 0.058 ap Physical Turbidity, sensitive scale units 3 - Color, cobalt scale units B Odor, maximum threshold number 3 2 Chemical (ng/liter) ‘Any benzene sulfonate 0.5 - Ammonia : dose aromatic 0.28, Barium : cadmium 0.50 calcium 200% 20 carbon chloroform extract Chloride 3500 500 Chromates (hexavalent) 0.050, copper 3.00 10 cyanide 0.1, Fluoride 150 15 ‘iron Lo 19 lead ion, magnesium 1258 325 Magnesium + sodium sulfate 300 Manganese Ota oa Nitrate, as N03 508 Phenol compounds ‘0.0018 (Potassium) 5008 Selenium 0.0le 0.054,’

0.05 Silver 0:05e : Godin) 5008 sulfate 250 2508 (Guiter) 008 Total Solids 500 3500 ine 5.0 5. 5.0 Radiological. (pe/liter) aaium206 3e - Nipba emitters : aasb Strontium-90 360 : Beta Bnltiers 0008 208, a Wi European Standards of 1961. WI International Standards of 1958, © Mandatory, Others are recommended by USPS 4 Does not appear as such in original list. 1m ---Page Break--- wr auoer wat Prepared in connection with work under Contract No. E~{40-1)-1898 Tih the US. Energy Research Development Administration, ERDA retains mene Fane Aue royalty-free license in and to any copyrights covering this paper, with he "aht to authorize others to reproduce all any part of the copyrighted pane” ---Page Break---