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THE IMPACT OF INDUSTRIAL AND ECONOMIC
DEVELOPMENT ON WATER AVAILABILITIES
IN SOUTH PUERTO RICO

Project A-017-PR

by

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...The silent mound slept beneath the sun, hiding the sweet well that through ten thousand years had brought life to so many. Its waters trickled away through subterranean channels until they entered the malignant swamp which extended itself year after year over the no longer fertile ground. How great the desolation was, how crushed and puny the grandeur that had existed here. Even the birds came no more, for the grasses that had grown centuries before now perished in the desiccated air; the mound had become part of a desert.

This land of richness and great orchards. This land where bees had made honey famous before the Bible was composed. These far sweet lands that had gladdened a man's heart and made his wife sing. These sacred valleys where men had wrestled with the concept of God, and with God Himself. These marvelous hills where the baals had stood and the fair girls had danced naked, all slept under dust.

How contradictory it was: the swamps spread, wasting their waters while at the same time the land became desert for want of water...

James A. Michener-The Source,
Fawcett World
Library, New York, 1968, p. 760.

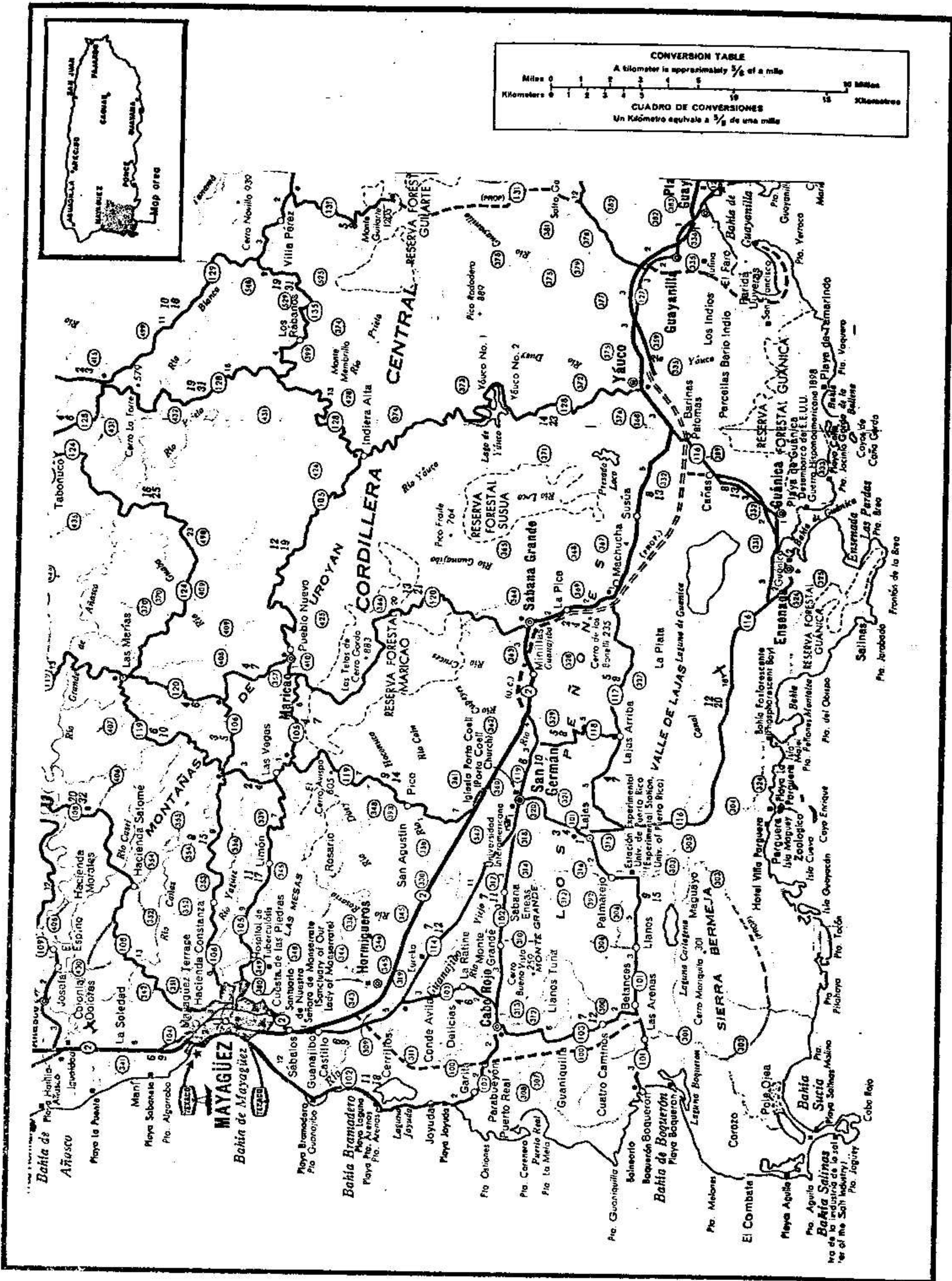


Figure 1 - AREA OF STUDY : Shade

ACKNOWLEDGEMENTS

This writer wishes to take advantage of the opportunity afforded by these few lines to acknowledge the great indebtedness which he feels is due to the many courtesies and kindnesses shown him in the course of gathering the required data for this study from the following governmental agencies: U.S. Geological Survey, U.S. Weather Bureau, U.S. Soil Conservation Service, the Planning Board, Department of Agriculture, the Health Department, the Water Resources Authority, the Aqueduct and Sewer Authority, the State Department, Economic Development Administration, Department of Public Works, the administrative offices of the House of Representatives and the Senate, and many others too lengthy to enumerate. But particular mention should be made of Messrs. Santos M. Visca-sillas, U.S. Department of Agriculture Soil Conservation Service, and Pedro Negroni, Chemical Engineer, Production Division, Aqueduct and Sewer Authority, who had given much of their valuable time and effort in making available filed information. And last but not least, this writer would like to extend his personal appreciation for the kindly understanding Mr. Félix H. Prieto, new Director of the Water Resources Research Institute, has shown of the causes of the failure to finish the report at an earlier date, due to the malicious, wilful and arbitrary incidents instigated by his predecessor, which tended to negate every form of motivation to further proceed with the project.

ABSTRACT

The Impact of Industrial and Economic Development on Water Availabilities in South Puerto Rico is a study consisting of a discussion of four subject areas: the authority and responsibility for water in Puerto Rico, the hydrology of the southwestern part of the Island, the more pertinent socio-economic aspects of life in the region of study, and an analysis of the procedures involved in water production.

A multiplicity of governmental agencies are involved with water, and a legitimate question is raised as to whether or not this condition might not lead to public disagreements. The welfare of the people of Puerto Rico would certainly be jeopardized by such public disagreements amongst its senior officials.

Partly to controvert or eliminate such happenings, it is proposed that a multidimensional or interdisciplinary approach be employed in the planning and execution of expanded water availabilities. Such an approach would insure that the multiple facets of the water problem would be given their due and proper consideration.

And partly to achieve more objectivity in decision making, this paper advocates the exclusion of secondary benefits in any benefit-cost analysis, and the results of such analysis be used in conjunction with the simplex or distribution method of linear programming. Costs could be held at, or close to, the original estimates through the use of the Critical Path Method.

Some of the more relevant socio-economic factors that have a direct bearing on the patterns of water use were examined. Available housing units could be used as a predictor of water requirements. A further refinement of the predictor could be made by using the number of rooms in urbanization type dwellings, or the number of bedrooms in public type dwellings.

The record seems to support the observation that there is ample water supply in the region and in the two cases that might be doubtful, their water requirements are partly being met by independent rural aqueducts.

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I-INTRODUCTION

The word "south" in the title of the proposal referred to a geographic area south of an arbitrarily selected line running from the west to the east. It is an imaginary line located approximately at 18°14' north latitude which purports to divide Puerto Rico into north and south for purposes of the study.

Since undertaking the study, a number of different situations had arisen to force some changes. First, there was the unavailability of information concerning the area first planned to be covered. Secondly, manpower required for the project was not available. Thirdly, some administrative decisions were made arbitrarily which tended to restrict and/or impair completion of the project.

The consequence is that the word "south" has come to mean southwest Puerto Rico. The shaded portion shown in Figure I indicates the region covered in this report. While the area covered has been drastically reduced, the quality of resultant inferences are in no way impaired.

II-AUTHORITY AND RESPONSIBILITY FOR WATER IN PUERTO RICO

Authority over land water in Puerto Rico was first exercised by the Spanish Minister of Foreign Affairs. However, based on the Water Law of June 13, 1879, the authority was later passed on to the Governor General by rural decree on April 5, 1886. The decree took effect after its publication in Puerto Rico some twenty days later.^{1/}

After the Spanish-American War, the Water Law was amended by the passage on March 12, 1903 of an act entitled "Law to Amend the Water Law."^{2/} By the passage of this amendment, the authority over land water in Puerto Rico became vested upon the Commissioner of the Interior, which later became the Secretary of Public Works in conformity with Law Number 6 of July 25, 1952.^{3/} The Public Service Commission was, likewise, invested with the authority to oversee "the proper utilization of public waters for public and special purposes". To give effect to this authority, "public waters" was defined as "waters which flow continuously or discontinuously from lands of the same ownership, springs, and little rivers which flow on their natural beds, and rivers".^{4/}

In Puerto Rico, the responsibility for water is shared by diverse governmental agencies in varying extent and degree. The Planning Board, as the agency established to insure a coordinated, adequate, and economical development has, among other responsibilities, been assigned responsibilities involving water. According to its enabling act^{5/} the Board is required to prepare and adopt a master plan containing its recommendations for the development of Puerto Rico, which includes the location, nature, and general

extensive of waters, flood control, navigation, industrial and domestic uses of water, fishing, recreation, and well being in general.^{6/} From an operational standpoint, however, and when a indepth study involving water is required, the Board itself does not undertake the necessary research. A specialized agency equipped with the pertinent expertise is usually assigned the task, or it may engage private consultants.

One other important responsibility of the Health Department is in establishing classifications and quality standards for surface waters in Puerto Rico.^{7/} Surface waters are to include artificial or natural sources, including water beds, lakes, ponds, still water, water courses and interior channels, springs, irrigation systems, drainage systems, and other bodies of accumulated water.^{8/}

To implement or to give delegated authority greater effect, Law number 109, establishing the Public Service Commission of Puerto Rico, was enacted June 28, 1962.^{9/} Under this legislation, it was envisaged that the Public Service Commission would only have police powers over public waters. This is to say that the Commission's function with respect to public waters would be only to insure that its utilization would be for the good of the general public.^{10/}

The Water Resources Authority of Puerto Rico was first established on May 2, 1941, and since then, the law has undergone a series of amendments. These, however, have had to do with the Authority's corporate structure and obligations.^{11/} But its func-

tioning as a developer of the headwaters of rivers and as a consequent provider of electrical energy dates as far back as July 25, 1925, when Law number 60 was passed for the purpose of developing the headwaters of rivers. In 1927, Law number 60 was superseded by a Joint Resolution (36) of the Legislature of Puerto Rico, which in turn was amended by the law of April 25, 1930. Eight years later this was reenacted by an Act entitled "Law for the Development of the Headwaters of Rivers". A fund for the development of headwaters of rivers was also established by imposing a temporary real estate tax.^{12/}

When the WRA was first founded, it was for the purpose of conserving, developing and utilizing water resources and energy of Puerto Rico "to bring to the people of the Commonwealth, in an economic and abundant manner, benefits accruing from them to promote the general welfare and increase commerce and the well-being of the Authority..." It was invested with the requisite authority to achieve these objectives, including rendering service, sale, or transformation (intercambio) of water or electrical energy.^{13/}

The government agency whose output in services which enter more intimately in the life of every citizen is the Aqueduct and Sewer Authority. It was first established as a public corporation in May, 1945, and since then, its organic act has undergone a series of amendments. The Authority's basic structure and operation, however, remain as those provided in the Act of 1949.^{14/}

The ASA was established for the purpose of providing or helping to provide the people of Puerto Rico an adequate water and sanitary sewer service. To these ends, the Authority was invested

with certain rights and powers, not the least of which is providing additional, apart from improving and extending, water and sewer installations.^{15/}

Prior to the establishment of the ASA, there were antecedent activities. The more significant of these were the Insular Sewer Service established by Law number 16 on November 21, 1941 and the Insular Aqueduct Service founded on April 13, 1942. The latter was a subsidiary organization of the Puerto Rico Water Resources Authority, and organized under the corporate regulations of Puerto Rico.^{16/}

The latest entity that has entered the water control picture is the Environmental Quality Board. Its establishment was in consequence of the Government's declaration of policy to the effect that "it is the continued policy of the Commonwealth Government, including its municipalities, in cooperation with interested public and private organizations, to utilize all practical methods and means, including technical and financial assistance, for the purpose of encouraging and providing for the general welfare, creating and maintaining the conditions under which man and nature can exist in productive harmony and complying with social and economic needs and whatever requirements that may arise with the present and future generations of Puerto Ricans".^{17/} The jurisdiction under this policy would seem to include the totality of man's environment, a fact which could easily make the EQB's operation the most far-reaching of any other governmental instrumentality, including the probability of it becoming a deterrent to other equally as vital activities of the Government.

Under Title II, Article II, of the Act, the EQB was invested

with some thirty-five specific "duties and functions", of which only those of the most far-reaching implications are cited:18/

- (2) "to collect authoritative and relevant information about future conditions and tendencies in the quality of the environment, to analyse and interpret this information in order to determine whether these conditions and tendencies are interfering, or might interfere, with the implementation of the policy stated in Title I of this law...
- (3) "to revise and evaluate government programmes and activities in the light of the policy established in Title I of this law in order to determine up to what point such programmes and activities are contributing to the implementation of the said policy.
- (4) "to develop and recommend to the Governor public policy for encouraging and furthering the betterment of the quality of the environment so as to meet the conservational, social, economic, health and other requirements and goals of the Commonwealth of P.R.;
- (12) "to establish such norms for the purity and quality of the environment as shall be deemed most fitting;
- (22) "to issue orders of execution and non-execution of cessation and of waiving of rights at the discretion of the Board, in order to take the necessary measures for prevention or control...

- (24) "to ask for notification before beginning any construction, installation or establishment possibly detrimental to the environment and to natural resources as these are defined in the bye-laws...
- (25) "to issue provisional orders, after notifying the Planning Board, forbidding the construction of installations whose plans and specifications make clear that they are in violation of the present law and its regulations;
- (26,a) "if the owners or proprietors or their representatives refuse to give such permission, the representative of the Board will offer a sworn declaration to any Judge of the First Instance, spreading upon the record the intention of the Board and requesting right of access to the land, body of water or property;
- (27) "to require any Board, Department, Agency or other State or Municipal organization and the officials and employees of the same to offer the help necessary for the implementation of this law and its provisions".

Summary and Analysis:

It is not very likely that the government's authority over public waters would be questioned. But should there be any lurking doubt, it should be pointed out that sovereignty over Guam, the Philippines, Cuba and Puerto Rico was taken over by the Government of the United States as a result of the Treaty of Paris in 1898. In turn this authority was delegated to

various arms of government under a military regime and later affirmed upon the establishment of civilian government. In the case of Puerto Rico, that authority was reaffirmed in 1917 and again in 1952 by the Constitution upon the establishment of the Commonwealth Government.

Section II showed how water is a responsibility shared amongst seven distinct arms of government: their involvement consisting of policing public waters, accentuating the positive role water plays in economical and industrial development, employing water as an important means of meeting and providing for expanded requirements for electricity, or providing water for stepped-up commercial, industrial, recreative, and domestic needs.

Although no disturbing disagreements or differences of opinion have erupted so as to focus public concern or opprobrium,^{19/} nevertheless all the classic arguments against divided responsibility are present and not so deeply buried under a panoply of administrative harmony.

The scope of the EQB's enabling Act is very broad, and unless it is a forerunner of a drastic change in administrative operation, it is feared that a minimal implementation of the Act might lead to invidious disagreements between the authorities concerned.

One other dysfunction of a divided responsibility is the creation of an operational "no-man's" land. For either an executive is not quite certain whereof his authority begins and ends, or out of fear or consideration for a fellow executive,

he limits his activities-never venturing beyond safe, familiar grounds. The net effect is a service that is either lopsided, falling short of its objectives, uneconomical, or, that a large segment of the population is not being given full consideration or neglected altogether.

FOOTNOTES

Part II-

1. Annotated Laws of Puerto Rico; volume 12, section 501, p. 219.
2. Ibid.
3. Op. cit., p. 220.
4. Op. cit., p. 223.
5. Law No. 213, May 12, 1942, Planning and Budget Law of Puerto Rico, as amended.
6. "The Board will prepare and adopt a regulatory plan which will make clear...the recommendations of the Board for the development of Puerto Rico and which might include the siting, nature and general extension of...waters... flood control, navigation...industrial and domestic use of water, fishing, recreation and general welfare..."
7. Sanitary Regulation No. 129 to establish the classification of and qualitative norms for the surface waters of Puerto Rico, etc.
8. "By surface water is understood any superficial source of water whether natural or artificial, including all running water, lakes, lagoons, dams, watercourses and interior canals, springs, irrigation and drainage systems and any other body or accumulation of water".
9. "Public Service Act of Puerto Rico". Annotated Laws of Puerto Rico, p. 307.
10. "The Comission will have the power of giving public or quasi-public authorization, where the giving of such authorization is not provided for by any other process of law, including the right to use or cross, go under or above, public highways or channels of public or private ends... it will be empowered in the same way to implement the provisions of this law, those of the Water Law and will be responsible besides for water policy". A.L.P.R., p. 317.
11. "Law number 83", May 2, 1941, A.L.P.R., p.85.
12. Ibid.
13. "The Authority is created to conserve, develop and utilize, as well as to help in the conservation, development and use of the sources of water and energy

in Puerto Rico; to make accessible to the inhabitants of the Commonwealth of P.R. in the fullest and most economical way the benefits of these, and to advance by these means the general welfare, prosperity and commerce. The Authority is also conferred with the necessary and convenient rights and powers to carry into effect the above mentioned ends, including...the formulation, adoption, emendation and repealing of those rules and regulations necessary and pertinent to the exercising and carrying out of their powers and duties or for regulating the service, sale or interchange of water or electric energy". A.L.P.R. pp.90-91.

14. "Aqueduct and Sewer Authority Act", A.L.P.R., vol. 22, p.37.
15. "The Authority is created with the purpose of providing and helping to provide the people of Puerto Rico with an adequate water and sewage service and with any other services or facilities necessary to the provision of the same. The Authority will have and will exercise all the rights and powers necessary or expedient to carry into effect the proposed water and sewage installations under its jurisdiction and to provide additional installations of the same kind..." A.L.P.R., pp.42-43.
16. Op. cit., p. 46.
17. Law to establish the public policy of the Commonwealth of Puerto Rico, pp. 1-2.
18. Ibid., pp. 6-10.
19. Such a one that had erupted between the Planning Board and the Highways Authority.

III-GENERAL HYDROLOGY OF THE REGION

Physical Setting:

The area defined for this study is a quadrangle located in the southwestern part of Puerto Rico. Its approximate boundaries are in the north latitude $18^{\circ}17'$; in the east longitude $66^{\circ}45'$; in the south the Caribbean Sea; and in the west the Mona Passage. See Figure 1. Included in the quadrangle are the following cities and towns: Guayanilla, Yauco, Guánica, Sábana Grande, Maricao, Las Marfas, Añasco, Mayaguez, Hormigueros, San Germán, Cabo Rojo and Lajas. The region is approximately one-half the area slated for industrial and economic development.^{1/}

There are four distinctly identifiable areas within the quadrangle; namely the Guayanilla-Yauco Area, the Guánica Area, the Bajura Watershed Area and the Añasco River Watershed Area. The Guayanilla-Yauco area^{2/} forms the easternmost portion of the region, and it includes the foothills, valleys, and coastal plains around such urban areas as Guayanilla and Yauco. To the south is the Caribbean Sea. This particular area receives water and is drained by the Yauco River, Guayanilla River and the Macaná River. The basins of the Yauco and Guayanilla Rivers extend northward to the Cordillera Central and reach altitudes as high as 3,600 feet. The highest part of the shorter Macaná basin has an altitude of 2,900 feet, but most of the basin is in the foothills section. The topography, geology and weather of the three river basins have considerable effect on the quantity, the quality and the variability of water in this section.

The Guánica Area^{3/} adjoins the Guayanilla-Yauco Area,

and like the latter, it is also located in the south coast of Puerto Rico. The Area is approximately five to six miles southwest of the town of Yauco, and it includes the Loco River and tributary basins and a small strip of coast. The area of study is eleven miles long, and its width varies from about one-and-a-half miles in the mountainous section to six miles near the coast.

For ease of description, the Guánica Area may be divided into two sections: the mountains and the plains.

The mountain section includes the Loco River drainage area north of Loco Dam and the entire Cañas River basin. There are steep-sided peaks and ridges, some of which attain altitudes greater than 2,000 feet above mean sea level. Near the headwaters of the Loco River is Pico Fraile, which rises to 2,506 feet above mean sea level. Defined surface drainage is in narrow, deeply incised valleys. The ridges slope downward to about 1,000 feet above mean sea level in the foothills around Loco Lake and the lower Cañas River valley.

The plains section includes the lower Loco River valley below the lake, all of Quebrada Arenas and Susúa basins, and the hills and low lands to the sea. The upper reaches of Quebrada Arenas drain a part of the foothills west of the Cañas River basin. The stream then crosses the lowlying plains of the eastern edge of the Lajas Valley to where it joins the Lajas Valley drainage canal, thence to the lowlying flood plains (about 160 feet above mean sea level) of the Loco River.

The Bajura Watershed Area^{4/} is located in the south

central area of the region under study, and it includes the municipalities of Cabo Rojo, Hormigueros, Mayaguez, Las Marías, Maricao, San Germán and Sábana Grande. It is approximately 18 miles long and 8 miles wide. It is bounded on the north by the areas drained by the Yaguez and Añasco Rivers, on the east by the Yauco River watershed, on the south by the Lajas Valley. The watershed consists of the area drained by the Guanajibo River, its tributaries, and adjacent laterals, which lie between the Guanajibo River outlet and the city of Mayaguez. The topography is irregular, as elevation varies from sea level to 2,897 feet above sea level.

The headwaters of the Guanajibo River originate from the Cordillera Central approximately six miles northeast of Sábana Grande, and flow westward for some 24 miles until it empties into Mayaguez Bay.

The last, but not the least, of the principal areas in the region is the Añasco River Watershed Area.^{5/} The section under study traverses across the whole northern part of the region. It consists of portions of Añasco, Las Marías, Yauco, Maricao and Mayaguez. Geographically, the area is bounded on the north by the watershed of the Culebrinas and the Guajataca; on the east by the headwaters of the Arecibo River; on the south by the Bajura Watershed; and on the west by the Mona Passage. The area encompassed by these boundaries is actually much larger than that included in this study, for it excludes such municipalities as San Sebastián, Lares and Adjuntas.

The headwaters of the Añasco River are located way up

in the Cordillera Central at approximately 3,950 feet above sea level, and flow in a westerly direction for some 46 miles to its mouth in Añasco Bay.

Based on the foregoing descriptions, the physical characteristics of the region of study may be summarized as follows:

1. Seven river systems traverse the area, of which four, namely the Yauco, the Loco, the Guanajibo and the Añasco may be considered the larger river systems. Their headwaters are all situated in the Cordillera Central with varying elevations from 1,000 feet to 3,950 feet above sea level.
2. In the uplands are to be found deep river gorges, with steep gradients. The average fall in feet per mile on the Yauco River is 236; on the Guanajibo 155; and on the Añasco 136.^{6/} Below the dam on the Loco River, the river gradient varies from less than 20 feet to 33 feet per mile.^{7/}
3. Except for a narrow strip of coast in the west and a broad, flat plain southeast and south of San Germán, the region is hilly and blending in the north with high mountains of the Cordillera Central, reaching altitudes as high as 3,900 feet.

Climate:

Puerto Rico is in the belt of the trade winds. It is therefore exposed to considerable air flow that is relatively persistent from the east-northeast. The air from the broad reaches

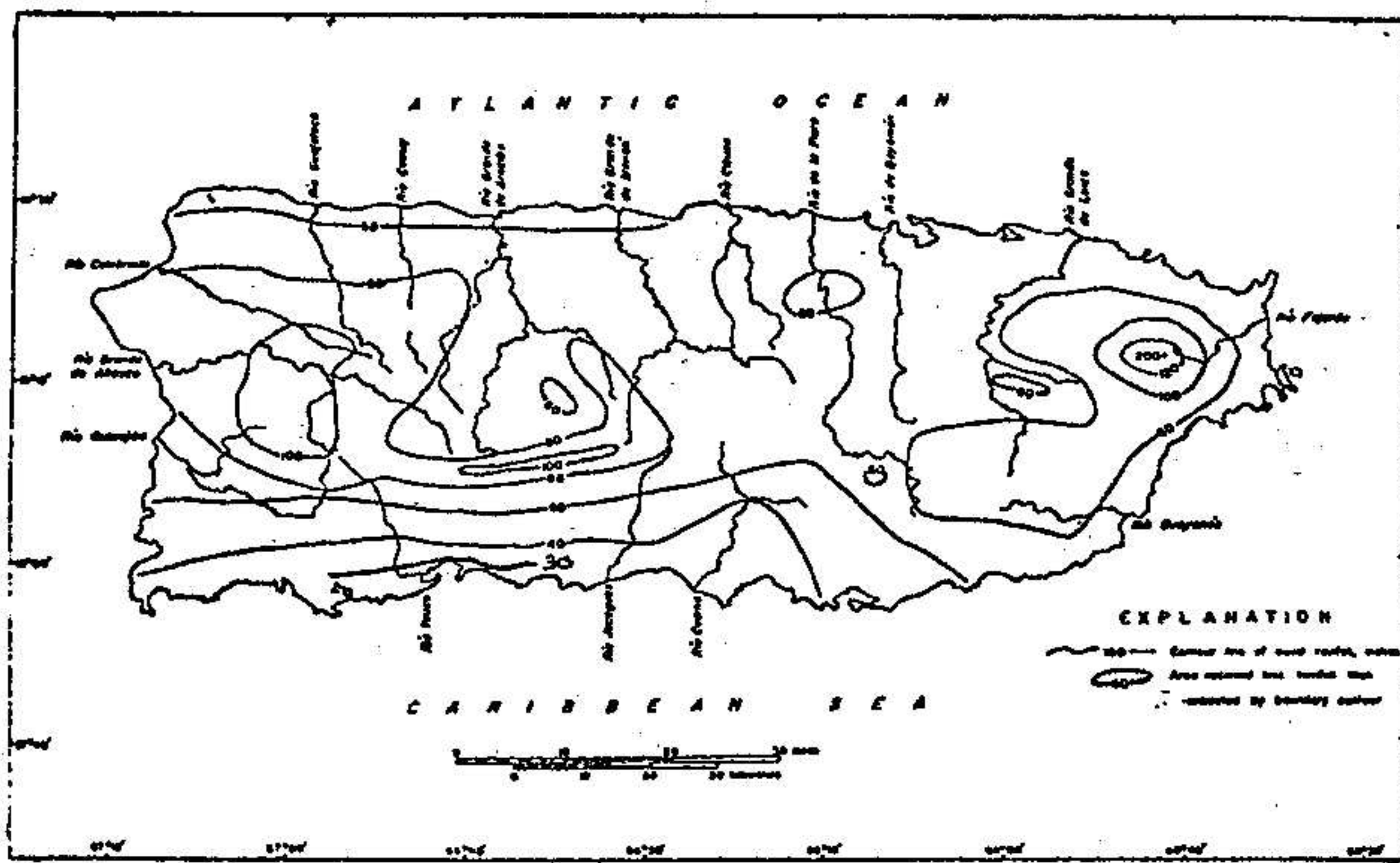


Figure 2, Rain Map of Puerto Rico and of the Region, with the 30-inch Isohyet added (Adopted from USGS)

of the Atlantic Ocean contains much moisture, and as a result of orographic effect (the effect of mountains forcing moist air to higher altitudes resulting in precipitation), much rain falls on the windward side of the mountains. Much less rain falls on the leeward side. (See the annual rainfall map of Puerto Rico) The winter is dry and winter drouths are common, followed by spring rains and a lull in the first part of summer. In the late summer and fall is the wettest period, reaching maximum in September and October.

In the region of study, the climate may be characterized as consisting of both extremes. This is to say that the coastal lowlands are dry, the foothills semi-arid, and the uplands rainy and wet. In the Guayanilla-Yauco section, the climate is hot and moderately dry. In 1961,^{8/} the air temperature in the plains and foothills was reported to have ranged from 56° to 97°F and in the uplands 51° to 82°F.

The climate in the Guánica section represents a variant of the foregoing. In the drainage area of the Loco River, precipitation reaches from 40 inches to 70 inches annually. The northern foothills of this section is semi-arid, whereas the lower part of the Loco River Valley, consisting the largest part of the Guánica area, is described as the most arid in Puerto Rico.^{9/} The average annual rainfall over much of the area is less than 40 inches, and in Ensenada only 30 inches. Evaporation rates are the same as those measured in the Lajas Valley - 70 inches per year.

The climate of this section may be characterized as

warm, wet summers and warm but dry winters. In the Bajura watershed Area, the average annual rainfall is from about 56 inches to 105 inches, while the daily average temperature in San Germán is 79.3°F in the summer and 75.2°F in the winter.^{10/}

In the Añasco River Watershed Area, the climate is pretty much the same as in the preceding Area, except that it is a shade warmer in the summer and winter-the differences are 0.01°F and 0.03°F respectively.^{11/}

Sources of Water:

Precipitation is the principal source of all water for the plains and upland areas of the study region. Part of the rainfall becomes stream run-offs; a good portion is returned to the hydrologic cycle through evapotranspiration and the remainder meanders downstream to the plains to recharge ground-water aquifers. Surface run-offs and water-bearing aquifers are the two sources from which water can be withdrawn under controlled conditions.

Rainfall:

Figure 2, Rain Map of Puerto Rico and the Region^{12/} shows the amount of rainfall on the plains and tributary uplands areas of the region. As can be observed, the amount of rainfall varies with altitude and relief: from a maximum annual average of 100 inches along the Cordillera Central it progressively diminishes toward the south coast to a minimum of 30 inches along a belt

extending from the southeastern to the southwestern part of the region.

Annual rainfall occurrence in the region is two periods: 50 per cent from August through November and only 15 per cent from December through March. This is to say that rainfall is heaviest in August to November and least in January to March.

Annual average rainfall in inches in the Bajura Watershed and the Añasco River Watershed areas is shown in the following table:

	<u>Bajura Watershed</u>	<u>Añasco River Watershed</u>
January	2.1	2.00
February	2.6	2.03
March	3.5	3.68
April	5.6	4.92
May	3.4	8.24
June	4.1	9.81
July	6.0	10.44
August	7.7	10.99
September	8.6	10.79
October	9.4	9.26
November	6.9	5.86
December	3.6	2.59

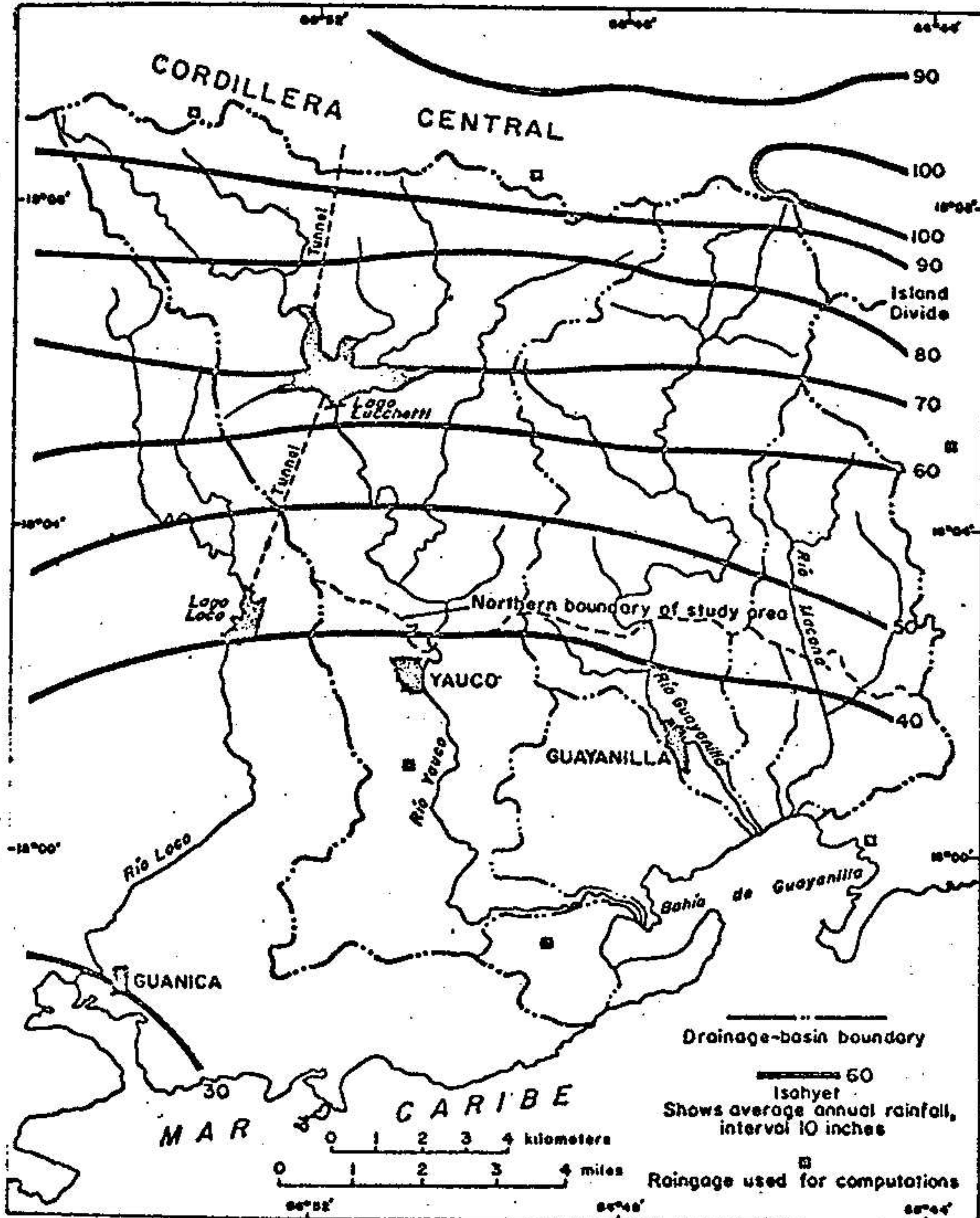


Figure 3, Annual Average Rainfall in the Guayanilla-Yauco Area (inches). Adopted from PRWRA.

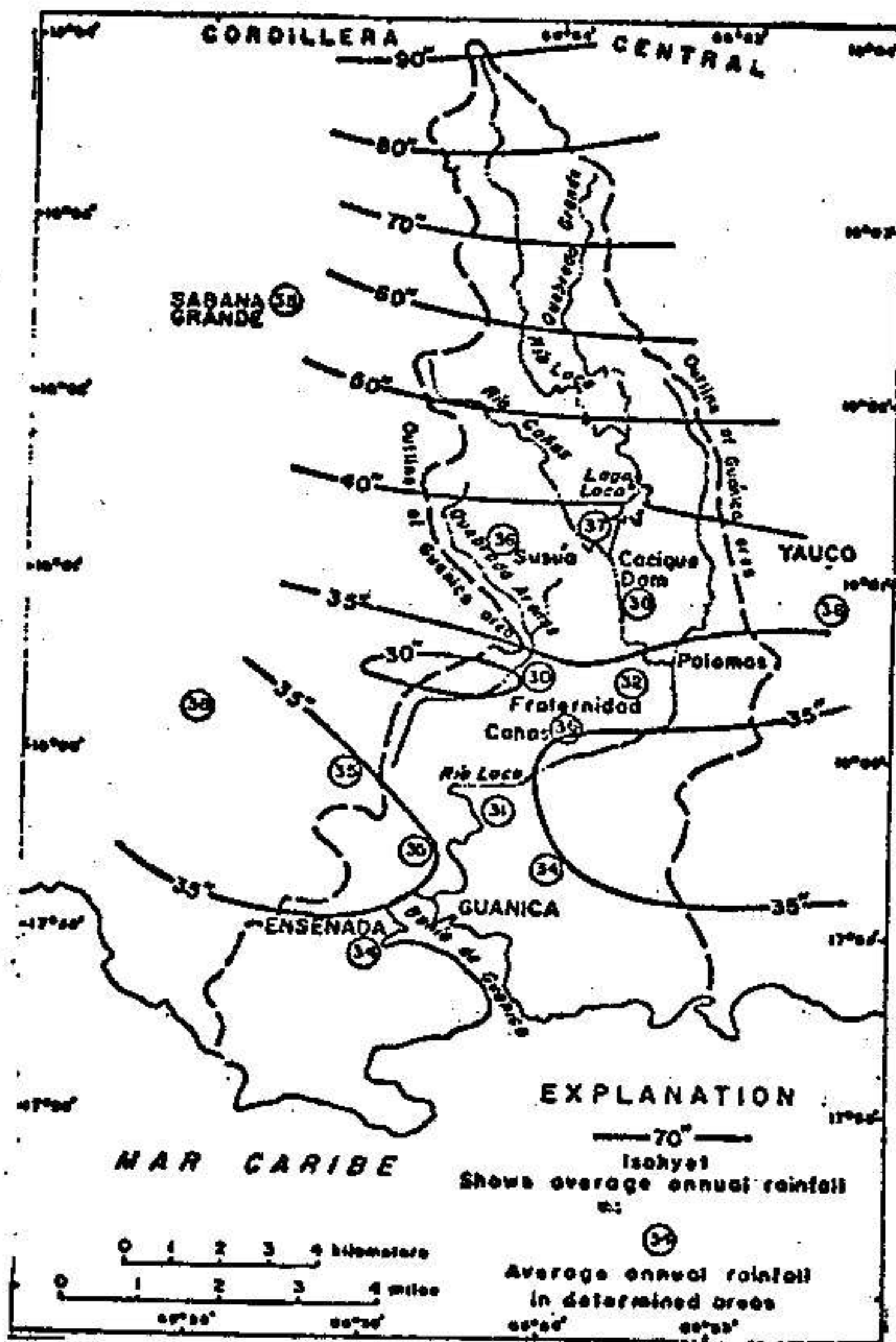


Figure 4, Annual Average Rainfall In the Guánica Area (inches)

Adopted from PRWRA.

On the other hand, the annual average rainfall in inches in the Guayanilla-Yauco and Guánica areas (Figures 3 and 4) is 70 and 60 inches respectively; whereas the 51 year average in Maricao is 104 inches and the 61-year average in Ensenada (Guánica Area) is 30 inches.

In contrast with other tropic areas, rains in Puerto Rico occur with suddenness and intensity. Their duration for the most part is from two to three hours, followed by a bright sunshine thereby making the surrounding atmosphere extremely humid. In other tropic areas rains fall days on end without the sun coming out behind heavily-laden water-bearing clouds, followed by a protracted cool, dry period.

Surface Water:

The region is traversed by several rivers: (Figure 5), namely, the Macaná, the Guayanilla, the Ducey, the Yauco, the Loco, the Guanajibo, the Cruces, the Cupeyes, the Cafn, the Hoconuco, the Duey, the Viejo, the Rosario, the Yaguez, the Cañas, the Casei and the Añasco. However, only the Guayanilla, the Yauco, the Loco, the Guanajibo and the Añasco are considered the principal rivers, with the remainder constituting their tributaries. (Figure 5). Two of these flow west and empty into Mona Passage and, the remainder, south into the Caribbean Sea. The headwaters of these principal river systems are located in the Cordillera Central and it is estimated in the neighborhood of 441 square miles. Toward the south and the west, the average fall in feet per mile is approximately 175.6.^{13/}

Flooding is a common phenomenon in the region. This is mainly due not only to the suddenness and intensity of rains but also to the steep gradients of deep, rocky channels of the upper reaches of the principal river systems.

The occurrence of floods in the various river basins in the region varies. In the Guayanilla-Yauco Area, the Guayanilla River has been known to have 20 rises in three years with an average discharge for the highest day of more than 100 cubic feet per second (cfs) and about 10 rises of an average of 200 cfs. In 1963, the highest daily average discharge was 709 cfs.^{14/} In the Bajura Watershed Area, such floodings have been known to occur from less than one to about five times a year.^{15/} Finally, in the Añasco River Watershed Area, the flood plains get inundated three to four times a year.^{16/}

Damage from floods has been wrought upon communities, homes, commercial enterprises, highways, farms and standing crops and other natural resources.

Less obvious damage has also been wrought; such as silting in the Guayanilla and Mayaguez bays, delays in the re-planting of cane sugar and reduction of the sucrose content of flooded cane crops.

Toward the eastern extremity of the region of study, a more controlled water regimen exists. The special area study, to which reference has been variously made, indicates that the drainage from the Loco River and its tributaries empties into the Loco Lake, where it is supplemented by water from the Luchetti Lake. (See figure 6). Part of the impounded water in the Loco Lake

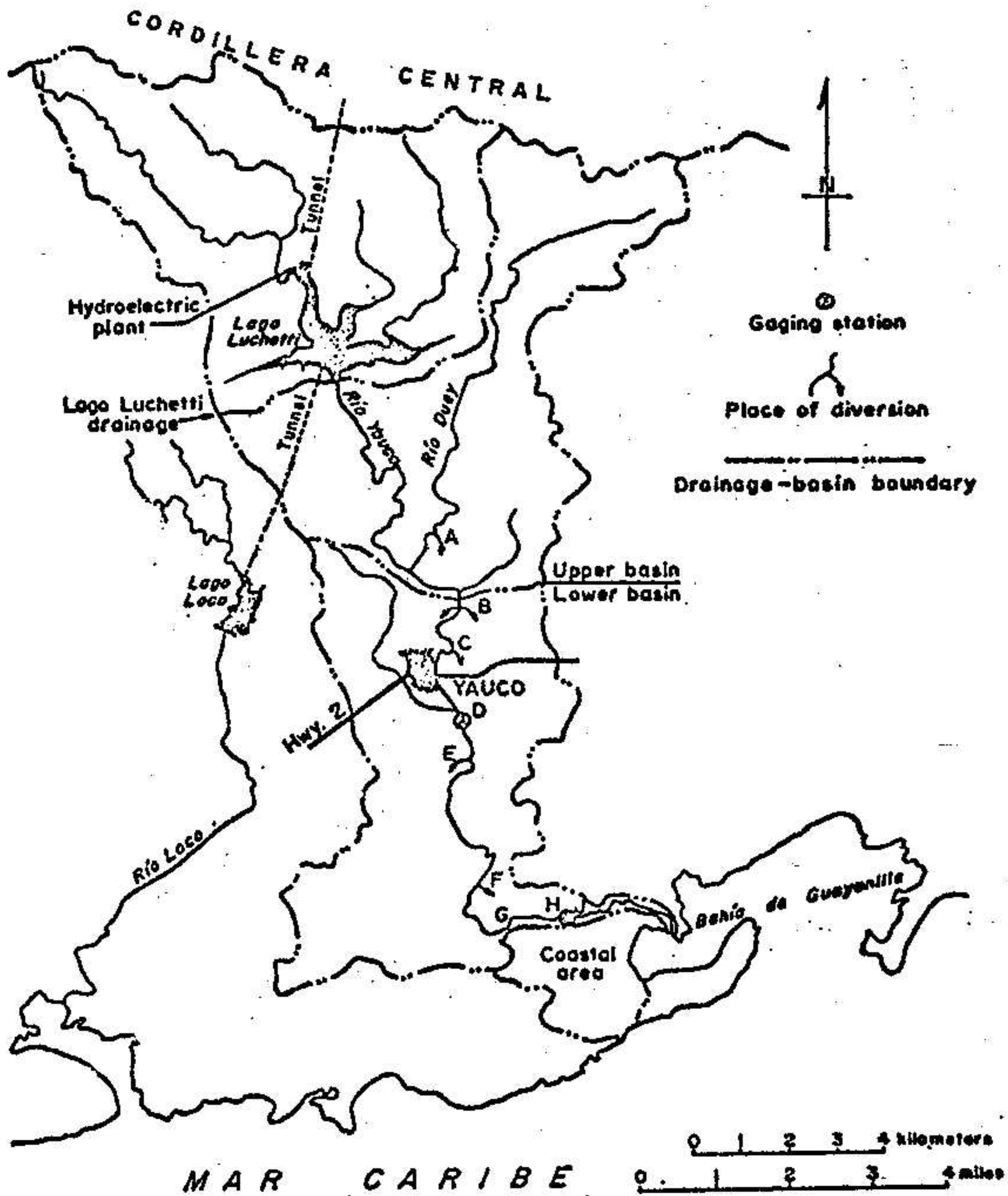
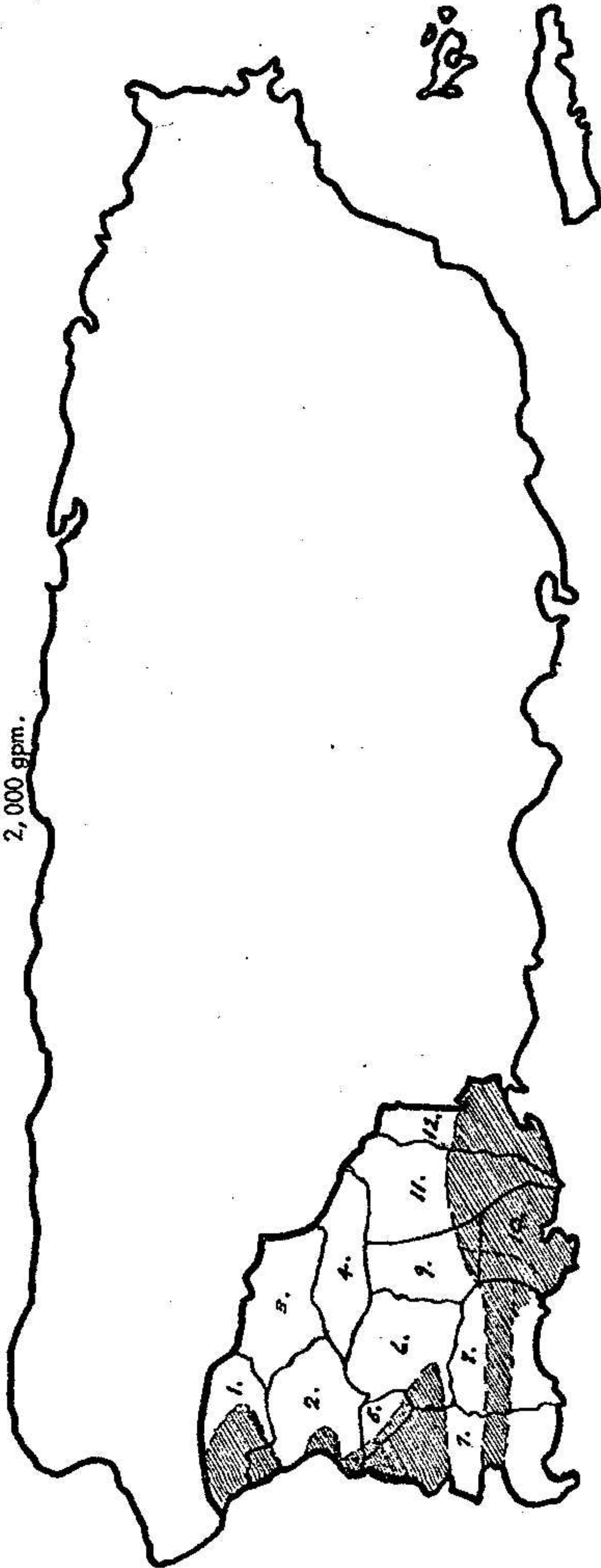


Figure 6, Guayanilla-Yauco Area, illustrating a controlled water regimen (Adopted from USGS)

LEGEND:

Hatch marks indicate areas of underground water development:

- | | | |
|----------------|------------------|---|
| 1- Añasco | 7- Cabo Rojo | Añasco Area : Seven drilled wells, three in use. Additional large supply of fresh ground water lies east of Central Igualdad. |
| 2- Mayaguez | 8- Lajas | Mayaguez Area : Thirty wells recorded, 12 in use. Most wells yield 400 gpm. |
| 3- Las Marías | 9- Sabana Grande | Guanajibo Area : Thirty-five wells recorded, 19 in use. Yields from wells in the alluvium - 0-400 gpm. Yields from wells in limestone - 1, 100 gpm. |
| 4- Maricao | 10- Guánica | Lajas Valley : Sixty-five wells recorded. Yields from 29 wells drilled and tested - 2, 000 gpm. |
| 5- Hormigueros | 11- Yauco | |
| 6- San Germán | 12- Guayanilla | |



GROUND WATER AVAILABILITIES IN THE REGION

- | | |
|-------------------|--|
| Southwest Area : | Sixty-four wells recorded, 39 in use. Shallow wells yield good quality water but likely to go dry during the dry season. |
| Guánica Area : | Forty-six wells recorded, 30 in use. Average yield for 16 wells - 1, 160 gpm. Ten wells exceed 1, 000 gpm and two wells yield 2, 000 gpm. |
| Guayanilla Area : | 107 wells recorded, 66 in use. Average yield of 43 irrigation wells - 1, 160 gpm. Average yield of 32 wells exceeds 1, 000 gpm. Two wells from the above, yield 2, 000 gpm each. |

(Adopted U. S. G. S.)

Figure 7 (a)

is diverted out of the area by means of the Lajas Valley Irrigation Canal and the remainder is released or spills over the dam and flows to the lower valley. Most of the stream flow reaching the lower Loco River valley is absorbed by the alluvium. Only during large scale releases from Loco Dam or during floods does the Loco River flow all the way to Guánica Bay.

Ground Water:

Ground water storage occurs in sub-surface reservoirs known, and previously referred to, as aquifers. These are described as "solid bedrock or loose, unconsolidated material that stores and transmits usable quantities of water". Its prevalence in the region is widespread and, as indicated in Figure 7, data on some 493 wells and springs are available.

Dependence upon ground water in the region is likewise widespread. In the Guayanilla-Yauco, Guánica and until recently, Cabo Rojo areas, ground water has been the principal source of water. In the Añasco River Watershed Area, dependence upon ground water is more confined; that is its use is limited to Central Igualdad, livestock and some domestic use.

Ground water^{17/} in the region is under water-table conditions. This is to say that the water level in a well is approximately the same as that in an aquifer. The literature indicates further that the same conditions obtain where the wells are cased through the alluvium and top the underlying bedrock because ground water moves freely between aquifers.

The surface of the water table somewhat resembles the

land surface because the water table is at higher altitudes in the uplands than in the lowlands. It is higher in the mountains and foothills than in the river valleys. Even in the flat valley that gently slopes toward the Mona Passage and the Caribbean Sea, the water table stands at higher altitudes in the northern than it is in the western and southern parts of the region. The water table, however, is flatter and smoother than land surface because it is deeper beneath the surface in the uplands and closer to it in the lowlands.

Underground reservoirs depend principally upon rainfall, or streams, ditches, and irrigational canals, for replenishing losses through discharges at various points in the lower valleys. Ground water moves freely within, and between, the aquifers; so that at higher points water is discharged to join the main channels of streams only to be absorbed by the alluvium further downstream. Water mobility within the aquifers may be slow, but after alternating as charge and discharge, it eventually reaches the sea. Charges and discharges should balance out over time.

Where the amount of water lost due to evapotranspiration and flood runoffs exceeds rainfall, the deficiency is counterbalanced by surface water moving into the area either through natural flow or being conducted from higher basins.

Summary and Analysis:

1. The topography of the region of study is very irregular-the northern foothills blend with higher peak mountains of the Cordillera Central, rising as much as 3,900 feet above

mean sea level, while the flood plains are to the south and west.

The headwaters of the principal river systems originate in the uplands to the north of the region, often traversing basins of varying widths and lengths until they reach the sea.

2. The climate of the region includes both extremes rainy and wet in the mountains, semi-arid in the foothills and dry in the coastal lowlands. The temperature in these areas range from 51°F to 97°F, and the annual average rainfall varies from 104 inches in the uplands to about 30 inches in the coastal flood plains. This amount of rainfall is much less than that which falls on the wind-ward side due to the formation of rain shadows on the leeward side of the Island. Since precipitation that falls on the earth surface is the principal source of water in the region and it being less could mean a diversion of some rivers in the north to the south to take care of any increased need. The source of water for all uses could still be augmented by a systematic development of ground water resources in the region.

3. Floods are common occurrences in the region. They are mainly due to the suddenness and intensity of rains, plus the fact that the headwaters of the principal river systems are deep, narrow valleys lined with volcanic rocks (Figure 8) with steep gradients averaging 175.6 feet of fall per mile. The effect of hurricanes is also a factor in increasing flood levels and duration of flow.

Elimination of catastrophic effects of floods in the region may be brought about by damming and the use of other water-

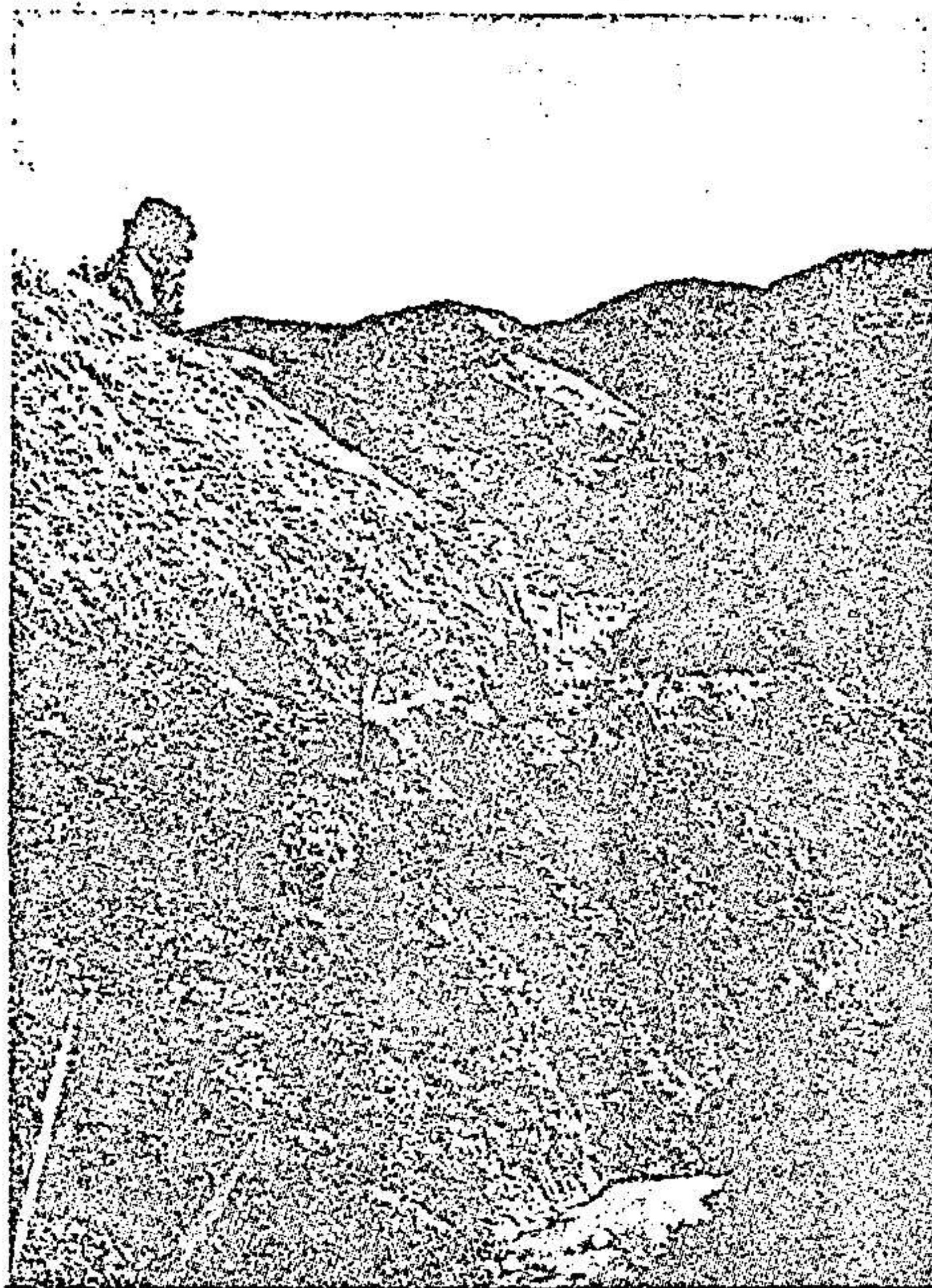


Figure 8, Headwaters of Rivers in the Region.

retention structures, of which the Bajura Watershed Work Plan and the Añasco River Watershed Work Plan are excellent examples tending toward that direction.

FOOTNOTES

Part III-

1. Development Plan for the Southwest Region of Puerto Rico, Puerto Rico Planning Board, Bureau of Master Planning, January 1969.
2. For descriptions and other relevant materials used in this section this writer drew heavily upon James W. Crooks, et al-Water Resources of the Guayanilla-Yauco Area, United States Geological Survey, 1968.
3. For descriptions and other relevant materials used in this section the writer drew heavily upon Neal E. McClymonds-Water Resources of the Guánica Area, United States Geological Survey, 1967.
4. For descriptions and other relevant materials used in this section, this writer drew heavily upon the work plan entitled Bajura Watershed, U. S. Department of Agriculture Soil Conservation Service, October 1961.
5. For descriptions and other relevant materials used in this section, this writer drew liberally upon the Añasco River Watershed Work Plan, U. S. Department of Agriculture Soil Conservation Service, March 1961.
6. Dean B. Bogart, Ted Arnow and James W. Crooks-Water Resources of Puerto Rico, U. S. Geological Survey, 1964, p.11.
7. Neal E. McClymonds, op. cit., pp. 13-14.
8. James W. Crooks, - et al. op. cit., - p.11.
9. Neal E. McClymonds - op. cit., p. 15.
10. Same as footnote 4 above, pp. 7-8.
11. Vid reference in footnote 5, p. 10.
12. Dean B. Bogart, et al - op. cit. p. 68.
13. Ibid., p. 11.
14. James W. Crooks - op. cit., p. 27.
15. Reference is the same as footnote 4, pp. 9-12.
16. See reference in footnote 5, p. 11.
17. Subsequent of the Guánica-Guayanilla Bay Area, U.S. Geological Survey, Survey paper no. 475 B, pp. B 114-116, 1963.

IV-PERTINENT SOCIO-ECONOMIC ASPECTS OF THE REGION

Demography:

Over the ten year period between 1961-1970, preliminary statistics indicate that the population of Puerto Rico had reached a total of 2,754 thousand, as compared with the 2,360 thousand in 1960. This represents an annual average increase of approximately 1.7 percent or almost triple the annual average increase of 0.6 percent for the corresponding period 1951-1960. The overall net increase in population for the Island was 14.5 percent.^{1/}

For the same period in the region, the population amounted to 306.6 thousands, or approximately 11.1 percent of the overall total for Puerto Rico.

Internally the area under study experienced a rather modest increase in population. In absolute terms the 32,383 net increase over the 274.2 thousands for 1960 represents a growth rate of approximately 11.8 percent which is only 2.7 percent short of the Island rate.^{2/}

It should be noted that the foregoing rate of population growth will tend to be accelerated within the decade, as a result of a previously described commitment of the present administration to hasten effectuation of an industrial and economic development plan for the region. In addition there is likewise a proposal to establish a second international airport in the area. However, at present there seems to be a difference of opinion as to the location. But whether the final choice of

Table I indicates that all the municipalities within the region experienced population increases, if only very modestly in two or three instances. While no objective data is available, it is very probable that the population losses of Las Marías and Maricao represent a shift to other municipalities within the region which gained a population increase to the extent of 11.8 per cent. Apart from the excess of births over deaths, there is evidence to support the inference that the net regional population increase was due to population shifts, instigated by the search for economic and cultural betterment. Since the amenities of life in the region and for the whole Island have improved so greatly in the last decade, returnees in substantial numbers from the mainland are being attracted by prospects of a job in industry where the year-round climate is ideal.

Perhaps the most significant development in the shifting of the population in Puerto Rico was the gradual but relentless overwhelming of rural "barrios"* by industrialization and urbanization. Some have already all but disappeared. During the decade of 1961-1970, more than 500 basically rural "barrios" had less population than at any other time. No municipality in the Island was exempted from this change.

Although the rural population grew steadily from 1920 to 1960, the gap between it and its urban counterpart had narrowed significantly each census, since the Bureau of the Census first began dividing the count between rural and urban. In 1920, more

*"Barrios"-One of the districts or wards into which a large town or city is divided.

than one million Puerto Ricans were classified as rural, 72 percent of the Islands's total, as compared to the 42 percent in 1970.^{3/}

In the decade of the 60's, the "barrios" that were fundamentally urban, not only expanded but new ones were also established. Four hundred twenty-two were enlarged whereas one hundred forty were newly created, consisting of one or more urbanizations, the new life style for hundreds of thousands of Puerto Ricans. In the last decennial census for Puerto Rico, urban population was 1,575,491 as compared to the 1,136,542 rural; or, some 400,000 had migrated into the towns and cities throughout the Island and had concentrated in public housing developments and urbanizations.

Table II indicates the population shifts in places of 1,000 inhabitants or more and the percent of change for the years 1970 and 1960.

Table II-Population of Places of 1,000 Inhabitants or More

<u>Places</u>	<u>1970 and 1960</u>		<u>Percent change 1960 to 1970</u>
	<u>1970 Preliminary</u>	<u>1960</u>	
Añasco	4,404	(1)	
Cabo Rojo	7,158	3,086	132.0
Guánica	8,538	4,100	108.2
Guayanilla	5,156	3,067	68.1
Hormigueros	6,428	1,647	290.3
Lajas	3,364	914	268.1
Las Marías	474	511	-7.3
Maricao	1,492	1,475	1.2
Mayaguez	69,485	50,147	38.6
Rincón	1,534	1,094	40.2
Sábana Grande	5,556	3,318	67.5
San Germán	11,319	7,790	45.3
Yauco	12,880	8,996	43.2

(1) Not reported separately in 1960.

Source: U.S. Department of Commerce, Bureau of the Census, Series PC (P1)-53.

Shifts in population in the region show the following pattern:

Añasco: The population rose 13 percent from 17,200 to 19,416. In the town it rose 113 percent to 4,416. Eleven "barrios" gained and an equal number lost, but their percentages were far higher. In Barrio Casey Abajo the population dropped 59 percent from 143 to 58 residents. Rfo Arriba went from 140 to 82. Añasco Arriba from 1,126 to 487.

Guayanilla: Industrialization on the south coast helped raise its population by 4.3 percent from 17,396 to 18,144. The town expanded by 69 percent to 5,189. Twelve of the seventeen "barrios" lost population. Barrio Cedro almost ceased to exist falling from 145 to 18 persons. Barrio Barrero was down from 723 to 477. Barrio Pasto in 1960 had 1,000 people but in 1970, only 645.

Lajas: Lajas was up 7.6 percent from 15,375 to 16,543. But the town rose from a scanty 914 to 3,391 residents. Seven of the eleven "barrios" lost population.

Las Marías: Population wise Las Marías lost 15 percent, from 9,237 to 7,841. The town itself lost 7.3 percent to 474 residents, thereby making it the second smallest town in Puerto Rico; that is next to the town of Dewey on the island of Culebra.

Maricao: In 1970, the inhabitants of the district went down to 5,991 from 6,990, or a loss of 14.3 percent. However, the town itself went up from 1,475 in 1960 to 1,492 in 1970. This represents a shift of 1.2 percent.

Mayaguez: Mayaguez gained 2.4 percent from 83,850 to 85,857. The city increased 37 percent to 68,872. Nine "barrios" were

added to the city.

San Germán: This university town gained 1.2 percent from 27,667 to 27,990. Since it is the seat of an institution of higher learning, the increase in San Germán might seem very modest, but the town itself grew by 49 percent, bringing its total population to 11,613. Fourteen "barrios" declined, while seven were incorporated into the town.

Yauco: Yauco experienced an extremely modest increase, from 34,780 to 35,103, or 0.9 percent. The town's gain of 43.6 percent represented a growth rate from 8,996 to 12,922. Seventeen of the twenty rural "barrios" declined by 16 to 57 percent.

The following table, Table III, depicts the distribution of the number of housing units to be found throughout the region by municipalities.

Table III-Number of Housing Units in the Region by Municipalities

<u>Municipalities</u>	<u>Number of Housing Units</u>		<u>Percent of Change</u>
	<u>1960</u>	<u>1970</u>	
Añasco	3,730	5,045	37.3
Cabo Rojo	6,356	8,272	30.2
Guánica	3,454	4,462	29.2
Guayanilla	3,878	4,598	18.6
Hormigueros	1,711	3,105	81.3
Lajas	3,891	5,060	30.1
Las Marías	2,030	2,117	4.4
Maricao	1,596	1,659	3.9
Mayaguez	21,111	23,908	13.2
Sábana Grande	3,715	4,652	25.2
San Germán	6,553	7,946	21.3
Yauco	7,382	8,260	11.9

Source: U.S. Department of Commerce, Bureau of the Census, Part 9, 1960, and PC (1) - A53, P.R., 1970.

From the foregoing table, it should be noted that, even in localities that registered decreases in population such as Las Marias and Maricao, very modest gains in housing availabilities had occurred. For the rest of the region, the range of such increases was 69.4 percent - 81.3 in Hormigueros and 11.9 in Yauco.

In 1960, the population per household in the region under study ranged from 4.23 to 5.31, or a range differential of 1.08 persons. For the same period, the average number of inhabitants per household Island-wide was 4.79 persons.^{4/}

The Economy of Puerto Rico: 1961-1970

Table IV-Gross National Product of Puerto Rico (Million Dollars)

<u>Fiscal Years</u>	<u>Amount</u>	<u>Amount of Change</u>	<u>Percent of Change</u>
1950	755		
1960	1,681	+ 926	12.2
1965	2,748	+ 1,067	6.3
1970	4,607	+ 1,859	6.7

Source: Economic Report to the Governor, Planning Board, Bureau of Economic Planning.

During the decade 1961-1970, the gross national product of Puerto Rico (in current dollars) compared favorably with the rate of growth on the mainland. The growth rate in 1960 was \$926 million dollars or approximately 12.2 percent over the rate recorded for the fiscal year 1950. In 1965 and 1970 the rates of growth were \$1,067 million (6.3%) respectively. For the mainland the rates were 6.3; 8.1 and 7.7 percent respectively.^{5/}

For the corresponding period as indicated in the foregoing paragraph, the net income in Puerto Rico from all sources was as follows:

Table V-Net Income in Puerto from All Sources: 1961-1970 (Million Dollars)

<u>Fiscal Years</u>	<u>Amount</u>	<u>Amount of Change</u>	<u>Percent of Change</u>
1950	614		
1960	1,355	741	12.1
1965	2,314	959	7.1
1970	3,821	1,507	6.5

Source: Economic Report to the Governor, Planning Board, Bureau of Economic Planning.

It should be noted that for the period 1960-1970, the rates of increase in the net income from all sources closely paralleled those of the gross national product.

In terms of per capita, income in Puerto Rico was estimated to have reached levels more favorable than in any other country in Latin America, and surely the highest in 1970. See Table VI.

Table VI-Per Capita Income in Puerto Rico: 1950-1970 (Current Dollars)

<u>Fiscal Year</u>	<u>Amount</u>	<u>Amount of Change</u>	<u>Percent of Change</u>
1950	279		
1956	445	166	9.9*
1960	582	137	7.7*
1964	840	258	11.1*
1965	915	75	8.9
1966	993	78	8.5
1967	1,085	92	9.2
1968	1,195	110	10.1
1969	1,300	105	8.8
1970	1,427	127	9.7

*Estimated annual average

Source: Economic Report to the Governor, Planning Board, Bureau of Economic Planning.

Table VII-Income in the region in 1960 by Municipalities

<u>Municipalities</u>	<u>Median Income Families</u>	<u>Median Income Male, 14 Yrs. & Over</u>	<u>Median Income Female, 14 Yrs. & Over</u>
Añasco	\$ 680	\$ 528	\$ 224
Cabo Rojo	954	783	279
Guánica	1,135	891	316
Guayanilla	770	621	333
Hormigueros	1,213	848	300
Lajas	968	775	286
Las Marías	637	535	208
Maricao	578	488	221
Mayaguez	1,341	1,111	527
Sábana Grande	1,082	847	443
San Germán	948	722	305
Yauco	936	696	300

Source: U.S. Department of Commerce, Bureau of the Census,
Vol. 1, pp. 53-206 ff.

According to the 1970 Statistical Abstract of the Bureau of the Census, U.S. Department of Commerce, the median income of persons 14 years old and over was \$819, whereas it was \$1,268 for families in Puerto Rico. Viewing the discrepancies between these figures and those shown in the above table, one can only surmise that such discrepancies in a large measure contributed to the decision to grant longer periods of tax-free incentives and the formulation of the Development Plan for the Southwest Region of Puerto Rico.

Comparable statistics for 1970 as those given above for 1960 are not available at this writing in order to make possible intelligible comparisons. However, by referring to tables III and VI above, it can be reasonably inferred that the progressive increases in per capita income in the latter part of the 1960's have, in a large measure, contributed to the sharp increases in housing units during that decade.

Despite some slow starts in the earlier part of the decade of the 1960's, Puerto Rico experienced a healthy and consistent growth in employment in the latter part of that decade. (See Table VIII below). In 1960 the number of gainfully employed was reported to be 543,000, or 53,000 less than those similarly employed in 1950. This represented a drop of approximately 8.9 percent. Then in 1965, gainful employment increased by a little more than 25.2 percent, bringing the total to some 680,000. This therefore, represented a net gain in employment of about 16.3 percent; or there were in the neighborhood of 84,000 more job opportunities in Puerto Rico in 1965 than in 1950.

In 1970, the story was the same although the rate of climb in employment was less pronounced than during the previous five-year period. Gainful employment in 1970 reached the level of 738,000 - an increase of a little more than 8.5 percent, or 58,000 more new jobs than in 1965.

Table VIII- Employment Growth in Puerto Rico (Thousands)

<u>Fiscal Year</u>	<u>Employment</u>	<u>Quantity</u>	<u>Change Percent</u>
1950	596		
1960	543	53	8.9
1965	680	137	25.2
1970*	738	58	8.5

Source: Statistical Abstract, U.S. Dept. of Commerce, Bureau of the Census

*Planning Board, Bureau of Economic Planning

With respect to the region in 1960, total civilian labor force employed was as follows:^{6/}

<u>Places</u>	<u>Male-14 yrs. & Over</u>	<u>Female-14 & Over</u>	<u>Total</u>
Añasco	3,096	948	4,044
Cabo Rojo	4,872	1,076	5,946
Guánica	2,308	528	2,836
Guayanilla	2,932	672	3,604
Hormigueros	1,540	448	1,988
Lajas	3,052	664	3,716
Las Marías	1,688	268	1,956
Maricao	1,140	176	1,316
Mayaguez	15,500	5,988	21,488
Moca	3,888	398	4,284
Sábana Grande	2,692	936	3,628
San Germán	5,284	1,640	6,924
Yauco	5,904	1,664	7,568

It should be noted that employment in the region was approximately 9.9 percent of the total for Puerto Rico for the year under consideration.

At this writing, information comparable to the foregoing data is not available. Nevertheless some indication should be given concerning the existing employment level in the region, bearing in mind that the data furnished exclude government employees, self-employed persons, farm workers, and domestic service workers but include situs employees.

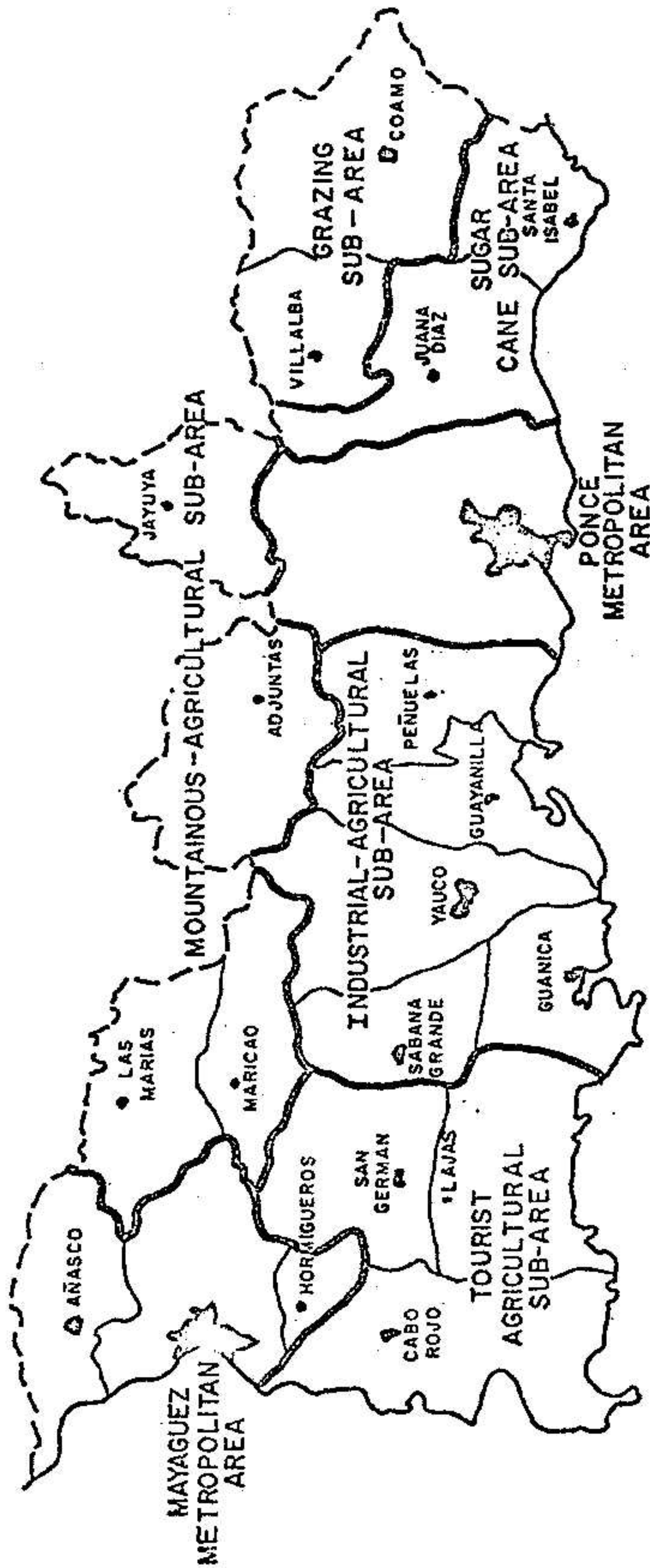
<u>Places</u>	<u>Employment</u>
Añasco	838
Cabo Rojo	1,898
Guánica	1,247
Guayanilla	350
Hormigueros	800
Lajas	852
Las Marías	30
Maricao	245
Mayaguez	16,689
Moca	332
Sábana Grande	701
San Germán	2,601
Yauco	1,956

Source: Country Business Patterns 1970, CPB 70-53, U.S. Dept. of Commerce, Bureau of the Census.

This is quite relevant and important because many more persons living in the municipalities of the region are known to be gainfully employed elsewhere.

Economic Development of the Region:

Referring to Figure I, the region as contemplated in this



METROPOLITAN AND SUB-AREAS OF THE SOUTHWEST REGION

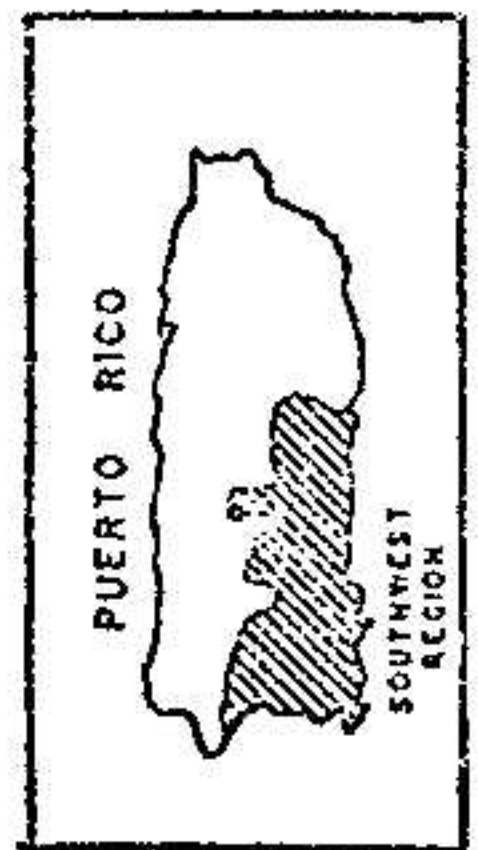
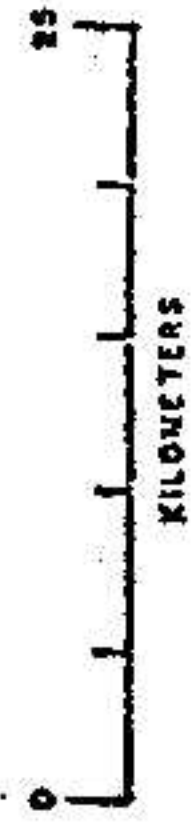


Figure-9

study is considerably more restricted than that envisioned by the Development Plan for the South-West Region of Puerto Rico.^{7/} The Development Plan's eastern boundaries start as far east as Coamo, and progressively extend westward as far as Mona Passage, totally encompassing the region of study. (See Figure 9) A very rough estimate would seem to indicate that the latter is approximately one-half of the latter.

Stated in general philosophic terms, the objectives of the Development Plan are described as follows:^{8/}

1. Raise levels of income and enhance the quality of life of the people in the area;
2. Formulate a pattern of land allocation and a related schedule of investment tending toward the optimization of objectives;
3. Specify direct and indirect sector and industry contributions that would make possible the realization of the broader income and welfare goals.

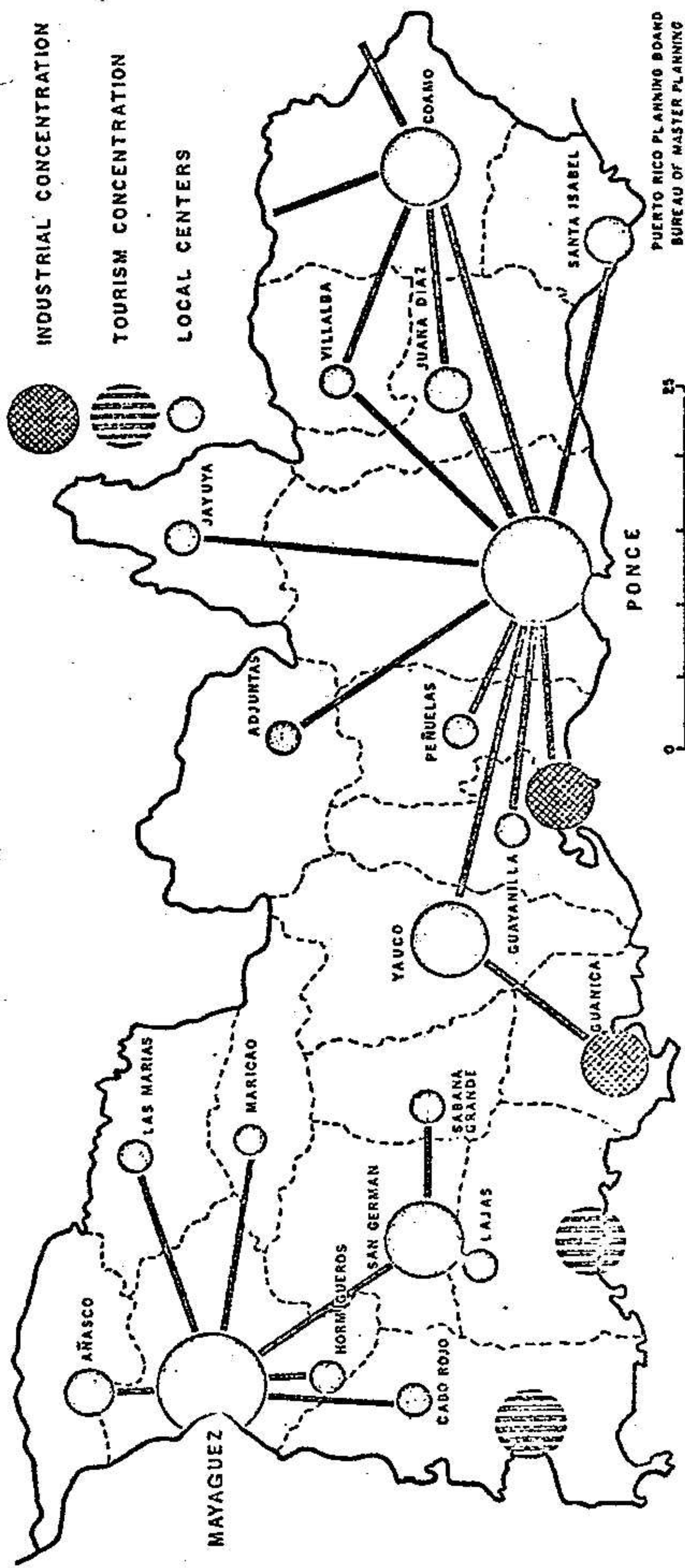
Based on topography, present land use and related economic factors and developmental potential the region constitutes: 1) the Mayaguez Metropolitan Area, 2) a tourist-agricultural sub-area, 3) an industrial-agricultural sub-area, and a mountainous-agricultural sub-area. Añasco and Hormigueros are included in the Mayaguez Metropolitan area; Cabo Rojo, San Germán and Lajas in the Tourist-agricultural sub-area; and Las Marías and Maricao in the Mountainous-Agricultural Sub-Area. Mayaguez is the regional center; whereas San Germán and Yauco are subregional centers.

Mayaguez is bounded in the east by mountains and in the west by the Mona Passage. As it is expected that the city will

LEGEND

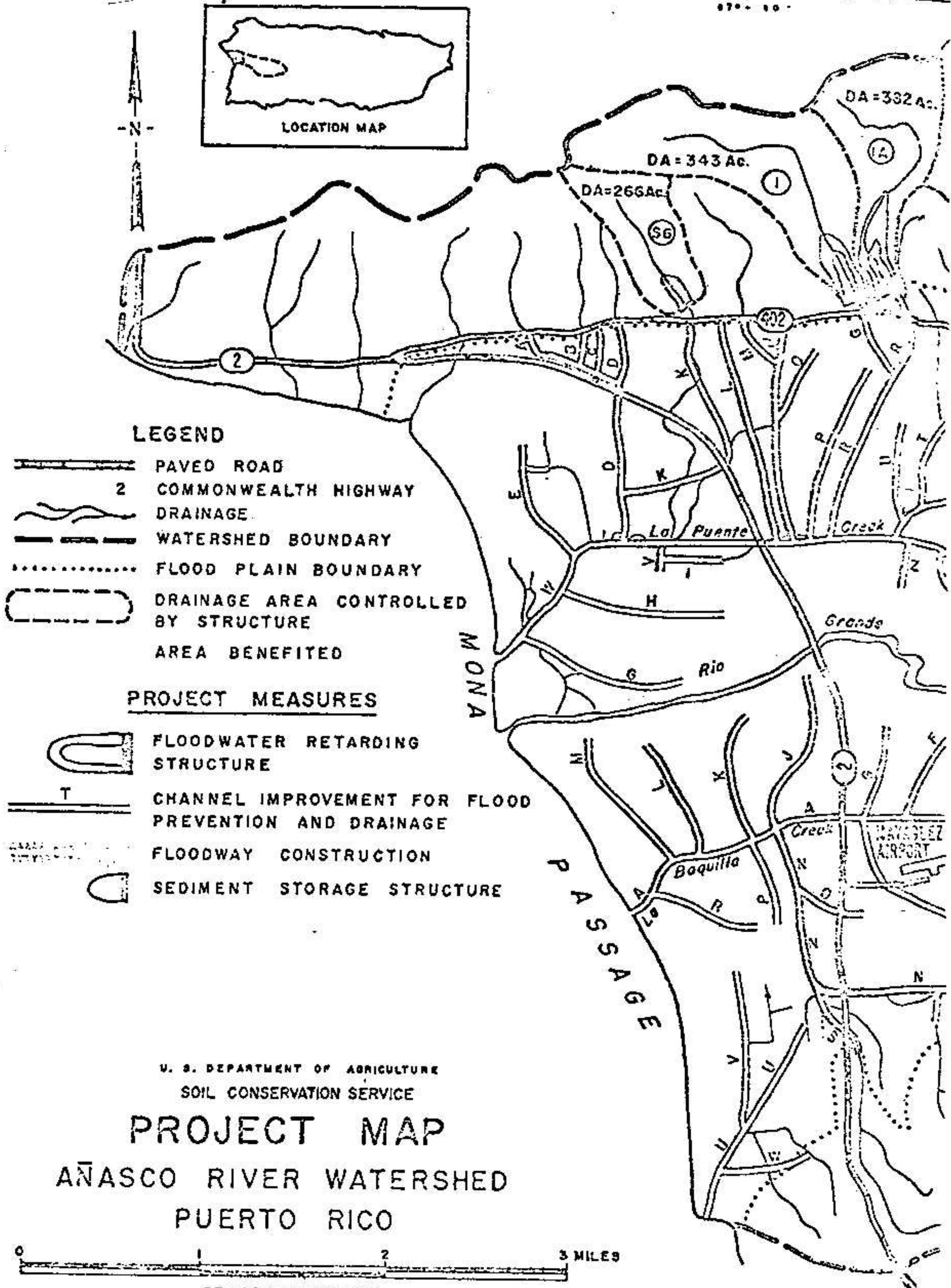
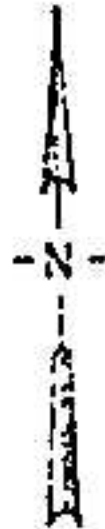
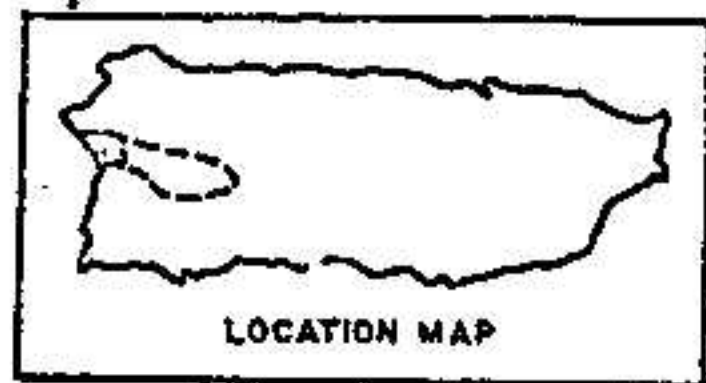
URBAN HIERARCHY
SOUTHWEST REGION

- REGIONAL CENTERS
- SUB-REGIONAL CENTERS
- INDUSTRIAL CONCENTRATION
- TOURISM CONCENTRATION
- LOCAL CENTERS



PUERTO RICO PLANNING BOARD
BUREAU OF MASTER PLANNING
JANUARY 1969

FIGURE -10



LEGEND

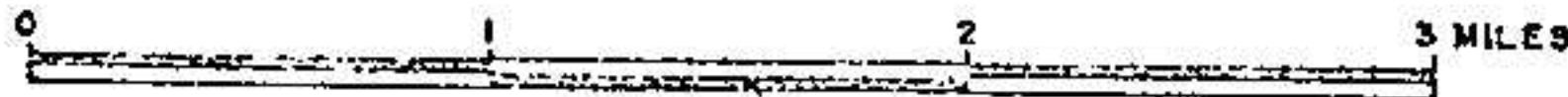
- PAVED ROAD
- COMMONWEALTH HIGHWAY
- DRAINAGE
- WATERSHED BOUNDARY
- FLOOD PLAIN BOUNDARY
- DRAINAGE AREA CONTROLLED BY STRUCTURE
- AREA BENEFITED

PROJECT MEASURES

- FLOODWATER RETARDING STRUCTURE
- CHANNEL IMPROVEMENT FOR FLOOD PREVENTION AND DRAINAGE
- FLOODWAY CONSTRUCTION
- SEDIMENT STORAGE STRUCTURE

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

PROJECT MAP
AÑASCO RIVER WATERSHED
PUERTO RICO



REVISED-AUGUST, 1964
WATERSHED AREA 126,126 ACRES

870-10

870-10

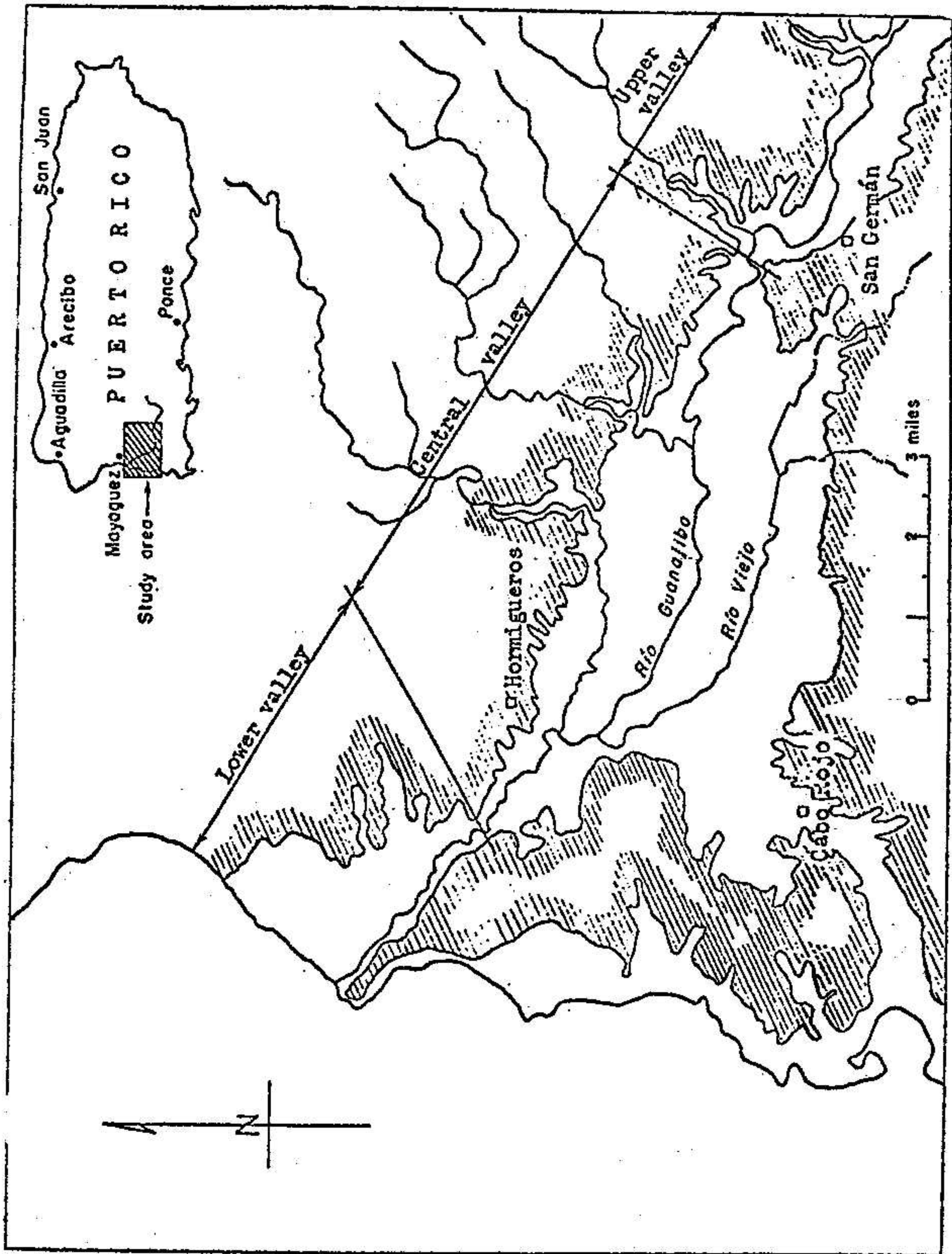


Figure 10b, Location of the Bajura Watershed.

have a population density of some 125,000 by 1985, the possibilities for expansion would seem to be to the north and to the south. An undetermined number of urban inhabitants could be accommodated to the north toward Añasco. Mention has already been made of this trend and the greater possibilities that are in the offing are being converted into realities by the continuing influx of new industries and existing work on the Añasco River watershed.^{9/} To the south an estimated 50,000 suburbanities could likewise be accommodated in suburban areas whose development could be linked to a parallel development of tourist-recreational sites in the Cabo Rojo and Lajas coastal areas, including the world-famous bioluminescent bays at La Parguera Village. (See Figure 10). These are within reasonable driving distances. As in the case of the northern expansion of the Mayaguez regional center, the expansion to the south would open up tremendous possibilities due to the near completion of Highway Number Two and the initiation of work on the Bajura Watershed.^{10/}

Also located nearby are the agriculturally rich Añasco, Lajas, and Bajura valleys that are slated for development.

See Figure 11 for the envisioned economic structure of the region.

The fields of development envisioned under the Developmental Plan can be briefly summarized as follows:^{11/}

1. Adoption of an intensified job training program and generation of some 100,000 additional jobs by 1985;

2. Recognizing that, although heavy industries (the principal focus of the Economic Development Administration's promotional efforts) pay high wages and their employment impact is small in relation to required capital investment, the Commonwealth Government envisages the establishment of "light industries with forward and backward linkages" with heavy industries for the purpose of increasing and diversifying the economic activities within the region;
3. Intensification of tourism in the region through the development of outdoor recreational areas in such abundant natural assets as lakes, forest, upland retreats, white gentle beaches, and phosphorescent bays, and by opening up various fields of investment;
4. In the field of agriculture, the Commonwealth Government aims to boost employment by 20,500 jobs (8 percent of total regional employment) and income from around \$67 million in 1967 to \$100 million in 1975 and \$115 million in 1985 by:
 - a. Rehabilitating and providing good drainage for some 10,000 "cuerdas"* in the Añasco and Guanajibo valleys;
 - b. Restoring some 4,000 "cuerdas" of highly productive land;
 - c. Correcting salinity tendencies of some 2,500 "cuerdas" of farmland in the Lajas Valley;

*"Cuerda"-Acres-(4,840 square yards, 43,560 square feet.)

- d. Increasing the region's capacity to produce foods for which there is ample local demand;
 - e. Diversifying and increasing food production in the form of meat, eggs, poultry, dairy products, vegetables, and fruits;
 - f. Stimulating the processing of agricultural products and by-products, such as the canning and preserving industries, increased use of baggase in paper and construction material manufacturing.
5. Improvement of access roads to, and within, the region. With the exception of the nearly completed Highway Number Two, which serves as the principal arterial highway, the Government recognizes the need for additional metropolitan expressways and construction of improved roads from Yauco to Boquerón and from Hormigueros to Boquerón.
6. Development of port facilities consistent with uplifting programs in agriculture. Because of limitations imposed by topography and poor soil conditions, such sites as Guayanilla, Guánica and Añasco have been favorably considered from the standpoint of physical characteristics to the exclusion of economic variables.

In addition to the specific programs briefly summarized above, the official plan of the Government includes provisions covering improvements in education, health, public welfare services, water supply, waste disposal, electric power, airport development,

and rural settlements within the region.

Summary and Analysis:

Great changes were wrought in the region of study during the decade of the sixties.

1. Growth of population was experienced in the region as in any other sector of Puerto Rico, the difference being in the rate of growth. The population growth rate for all of Puerto Rico was 14.5 percent, whereas it was 11.8 in the region, or a difference of a slight 2.7 percent.
2. Nor was the region an exception in the relentless trend toward urban growth of the number of "barrios" and of "barrio" life. Except for Las Marias and Maricao, which registered decreases of minus 15.1 and minus 14.3% respectively every municipality experienced sizeable increases in their urban population.

In order to prevent the total elimination of rural life, it is evident that the Commonwealth Government has yet to develop and put into effect a program of industrial and economic development designed to reverse the undesirable trend of urban development. Such a program should, in addition to having an economic multiplier effect, not uproot people from their natural and traditional social environment.

3. While comparable statistics on employment and

income for 1970 are not presently available for purposes of comparison with those of 1960, reasonable inferences can be drawn. If in 1960 the employment level for the region was 9.9 percent of the total for Puerto Rico, assuming that proportion to be constant, the level of employment for the region in 1965 and 1970 was 67.32 thousands and 73.06 thousands respectively, or an overall increase of approximately 36 percent.

Income can be viewed in the same fashion. For the twenty-year period 1950-1970, per capita income in Puerto Rico rose from \$279 to \$1,427, or an overall increment of approximately 412 percent. This could mean that the income of every man, woman and child in the region was at least close to that amount. A much more meaningful significance looms when this estimate is "compared" to that of the median income of families in the region in 1960, which was approximately \$980.

4. Quite a notable index in the evident rise in income in the region is in the number of housing units available. Although there were population losses in the Las Marías and Maricao districts, there nevertheless were modest gains in housing. It is probable that, with increased income, large households are breaking up into smaller ones. For the rest of the region the rise in available housing units ranged from 81.3 in Hormigueros

and 11.9 percent in Yauco. Other municipalities likewise registered quite sizeable increases.

5. The Government has undertaken a very broad socio-economic development plan for the region. Even if the scheme was motivated by the desire to counter what the authorities consider as an undesirable trend in the metropolitan northeastern part of the Island, it cannot but result in the enhancement of the level of life for every man, woman and child in southwest Puerto Rico.

FOOTNOTES

Part IV-

1. Current Population Reports, Series P-25, No. 436, U.S. Dept. of Commerce, Bureau of the Census.
2. Idem., Series PC. (PI) - 53.
3. Population of Cities, Towns and Villages, U.S. Dept. of Com. Bureau of the Census PC (1) - A53.
4. Census of Population, 1960, Vol. 1, Part 53, U.S. Dept. of Com. Bur. of the Census; also see Stat, Abs. 1970.
5. Statistical Abstract, U.S. Dept. of Com, Bur. of the Census.
6. Idem, fnte 4.
7. Development Plan for the Southwest Region of Puerto Rico, Puerto Rico Planning Board, Bur. of Master Planning.
8. Ibid, pp. 16-17.
9. Watershed Work Plan: Añasco River Watershed, U.S. Dept. of Agriculture, Soil Conservation Service.
10. Watershed Work Plan: Bajura Watershed, U.S. Dept. of Agr. Soil Conservation Serv.
11. Puerto Rico Planning Board, op. cit., pp. 18-38.

V-WATER PRODUCTION IN THE REGION

Referring to the quotation at the very beginning of this paper from James A. Michener's best-selling novel of a few years ago entitled The Source, water is shown as having always played a vital role in man's life from the dawn of civilization. Whether it is in the most intimate aspect of his being; whether it is in quest of wealth and his destiny; whether it is in man's insatiable desire for knowledge of the origin and maintenance of life in the depth of oceans and beyond the blue where only the angels dare to tread; whether it is in the form and beauty of his surroundings; whether it is in the prospects of physical renewal, solace and comfort; or whether it is in his continuous struggle for understanding of the Spirit, man has sought to achieve these not independently of, but in association with water. Water is man's life support unit.

Whether the motivations which have underlain water production in Puerto Rico resemble, parallel, or negate what have been expressed or implied in the foregoing paragraph are outside the scope of this paper, its focus has been the effort of detailing the impact of industrial and economic development upon water availabilities in the region.

Water production in Puerto Rico during the decade of the sixties can be characterized by its steady increases. In fiscal year 1961-1962, total water production for the Island was approximately 40.67 billion gallons and, in 1970-71 it was close to 77.67 billion gallons, or an increase of some 91 percent. (See Figure 12)

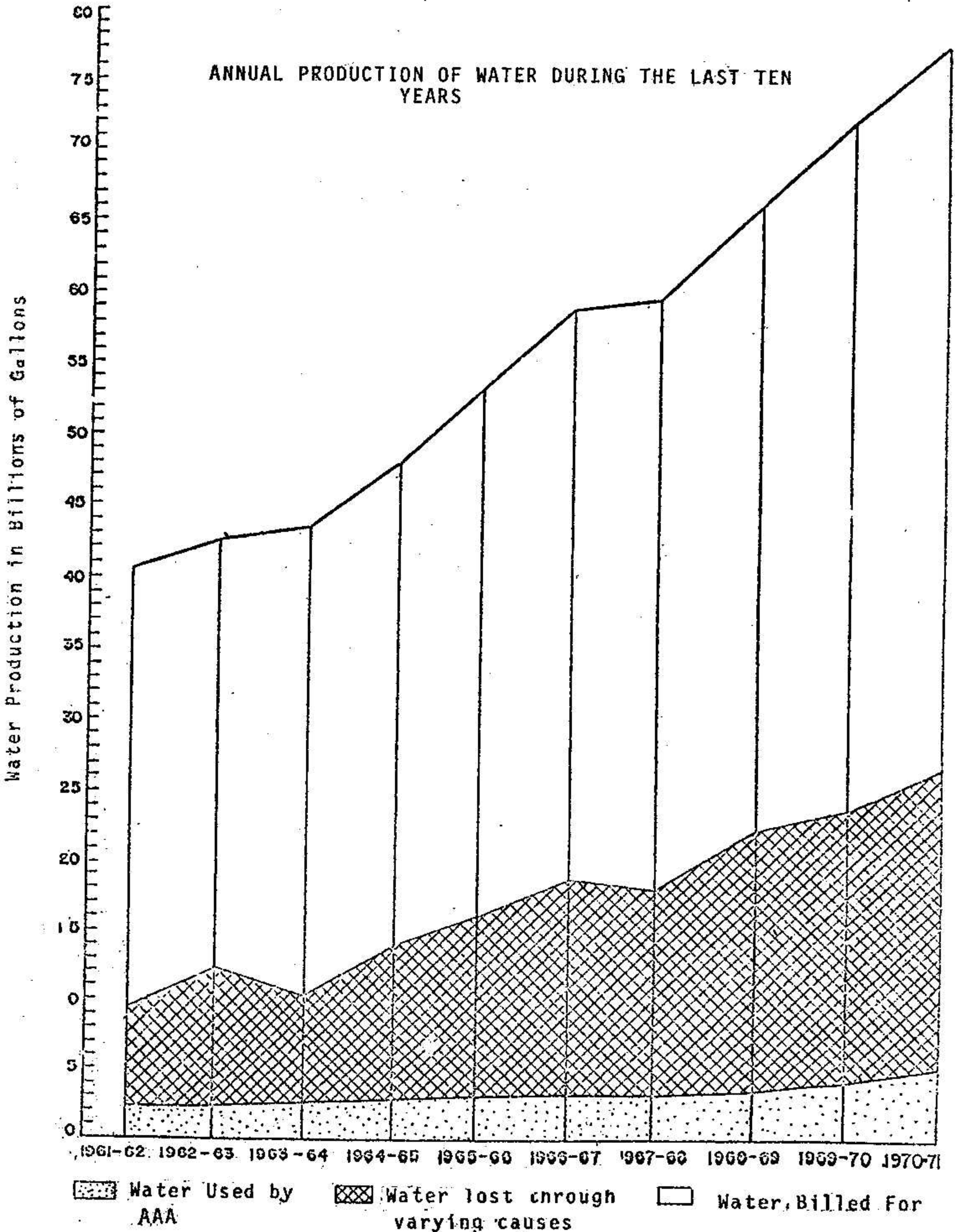


Figure-12

Losses for the same period ranged from 7.50 billion gallons to about 21.67 billion gallons, or an average of 13.75 billion gallons annually. Expressed in percent, losses during the fiscal year 1961-1962 were 18.4; whereas in 1970-1971 they were 27.9, or an average of some 23.78. See Table IX.

Table IX-Water Production and Losses in P.R.: 1961-62 to 1970-71

<u>Fiscal Year</u>	<u>Total Prod. Bil. Gal.</u>	<u>Losses Bil. Gal.</u>	<u>Losses in % Production</u>
61-62	40.67	7.50	18.4
62-63	42.67	9.50	22.2
63-64	43.33	8.33	19.2
64-65	47.50	10.50	22.1
65-66	53.00	12.00	22.6
66-67	59.00	14.67	25.0
67-68	88.82	14.33	24.0
69-70	66.33	19.00	28.7
70-71	77.67	21.67	27.9

Courtesy: Aqueducts and Sewer Authority.

Table X . Water Production in the Region.- MGD

Centers	FISCAL YEAR											Per- Cent Incr.	Annual Average
	61-62	62-63	63-64	64-65	65-66	66-67	67-68	68-69	69-70	70-71			
Añasco	PF	0.31	0.24	0.24	0.25	0.34	0.40	0.44	0.51	0.54	0.61	96.5	0.39
Cabo Rojo	PP	-	-	-	-	-	-	1.05	1.41	1.42	1.36	29.6	1.31
Guánica	PP	-	-	-	-	-	-	0.40	0.58	0.65	0.67	68.0	0.57
Guayanilla	PP	-	-	-	-	-	-	0.47	0.48	0.66	0.78	66.0	0.60
Hormigueros	PP	-	-	-	-	-	-	0.28	0.34	0.45	0.50	78.5	0.39
Lajas	PF	-	-	-	-	-	-	-	0.37	0.76	0.75	102.5	0.62
Las Marías	PF	0.05	0.06	0.06	0.08	0.10	0.10	0.12	0.15	0.17	0.17	240.0	0.10
Maricao	PF	0.08	0.08	0.10	0.10	0.12	0.16	0.18	0.17	0.17	0.17	112.0	0.13
Mayaguez (Viejo)	PF	0.72	0.89	1.11	0.68	1.67	2.70	3.26	2.75	1.87	1.13	57.0	1.68
Mayaguez (Miradero)	PF	4.39	4.04	4.77	5.44	6.01	5.98	6.49	7.91	9.49	10.48	139.0	6.50
Sábana Grande	PF	0.42	0.45	0.49	0.55	0.55	0.63	0.61	0.75	0.84	0.87	107.0	0.61
San Germán	PF	-	-	-	-	-	1.49	1.52	1.39	1.40	1.53	2.68	1.46
San Germán	PP	-	-	-	-	-	-	0.15	0.06	0.01	0.04	(0.73)	0.06
Lajas		1.14	1.18	1.19	1.15	1.30	-	-	-	-	-	14.0	1.19
Yauco	PF	0.99	1.00	0.99	1.03	0.99	1.17	1.23	1.27	1.44	1.33	34.4	1.14
Total		8.10	7.94	8.95	9.28	11.08	12.63	16.20	18.14	19.87	20.39	-	-
Percent Increase		-	(1.97)	12.30	3.70	19.39	14.00	28.30	11.97	9.55	2.62	151.6	14.96
Annual Average		1.01	0.99	1.12	1.16	1.38	1.58	1.25	1.29	1.42	1.45	-	-

Courtesy: Aqueduct and Sewer Authority with the exception of the computations.

To some extent water production in Puerto Rico has been supplemented by independent rural aqueducts. In fiscal 66-67, it was reported that there were 141 such independent producers, an amount which included an increase of 13 over the previous fiscal year.^{1/} In fiscal year 1970-71, the number of rural independent producers had further increased by 25.5 percent, or 36 more over the total in the 1966-67 fiscal year.^{2/}

In fiscal 1970-71, water production by the rural independents amounted to 2,726mg, or 28 percent over the preceding year. Of this total, 928,375 mg came from superficial sources (34%); whereas 1,798.381 mg (64%) came from deep wells.

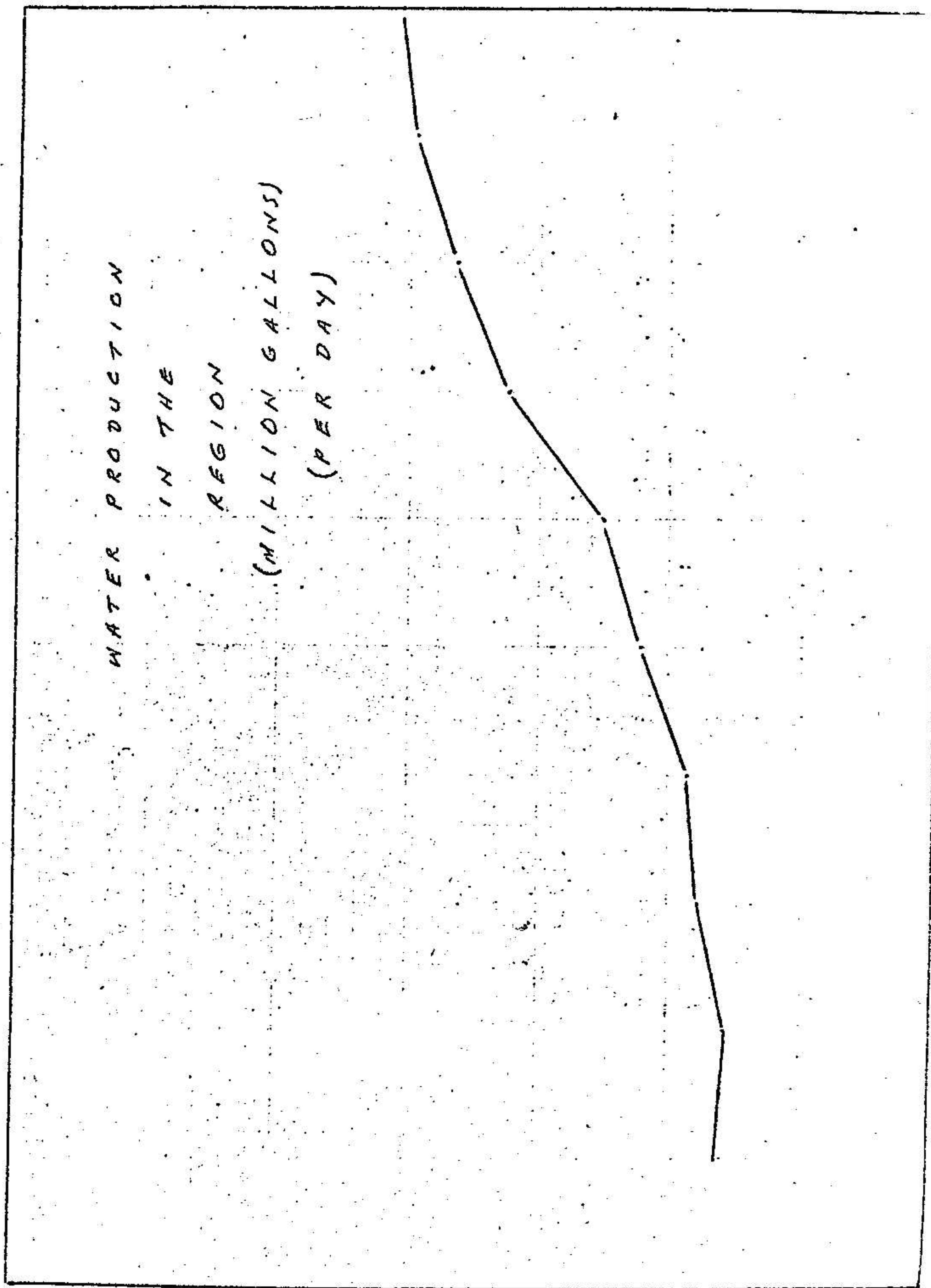
Compared to the total production by the Aqueducts and Sewer Authority, the amount contributed by the rural independent producers constituted but 4.4 percent.

Table X indicates the status of the production of water in the region during the decade of the sixties. In fiscal year 1961-62, total water production was 8.10 mgd; by 1970-71 it was 20.39 mgd; or an over-all total increase for the period was 14.96 percent.

When water production for Puerto Rico and that of the region are graphically compared, both profiles show constant, progressive increases except that, for Puerto Rico, the rate of increase is steeper than that for the region. See Figure 13. Such a difference could mean a faster socio-economic development elsewhere in the Island, or that increases for the region are much more deliberate.

Of the 20.39 mgd produced in the region in fiscal 1970-71,

WATER PRODUCTION
IN THE
REGION
(MILLION GALLONS)
(PER DAY)



61-62 63-64 64-65 65-66 65-67 67-68 68-69 69-70 70
Y E A R S

25
20
15
10
5
N O I T C U D O R P

Figure-13

16.45 percent or 3.35 mgd, came from deep wells and the balance from filtration plants. Judging from the progressively decreasing output from deep wells in the San Germán area, it would seem that production from such a source is being phased out.

Every municipality in the region, during the period, registered water production increases, from a modest 16.68 percent for San Germán to 240 percent for Las Marías. A 112 percent increase was also registered in Maricao. The phenomena in both instances are somewhat difficult to understand in as much as population, the number of households, and the population per household have been shown to be diminishing.

Analysis of Water Production:

In the official program of the Government for the industrial and economic development of the region, water was regarded to be in short supply: "The Southwest Region has a very serious water shortage. Several parts of the Mayaguez Subregion are inadequately served"...^{3/} A much more interesting question would be whether or not water availabilities match certain aspects of growth in the region as defined at the outset of this paper. Based on previous analyses, a comparison of the rate of increases in households and housing units with those of water availabilities might produce some illuminating information. The following table, Table XI, gives such a comparison.

Table XI-Comparison of Rates of Increases in Household and Housing Units with Water Rates: Percent

<u>Municipalities</u>	<u>Households</u>	<u>Housing Units</u>	<u>Water Production</u>
Añasco	26.6	35.3	96.5
Cabo Rojo	22.8	30.0	29.6
Guánica	24.7	19.2	68.0
Guayanilla	12.8	18.6	66.0
Hormigueros	75.8	81.5	78.5
Lajas	22.8	30.1	102.5
Las Marías	-0.6	4.3	240.0
Maricao	-5.3	3.9	112.0
Mayaguez	11.6	13.3	196.0
Sábana Grande	19.7	25.2	107.0
San Germán	16.9	21.2	16.7
Yauco	11.5	11.9	34.4

From the foregoing table, it would seem that the growth rate in housing units in Cabo Rojo, Hormigueros and San Germán has outstripped water production. Water availabilities for the rest of the region seem to be ample, although, as it has already been indicated, it is quite difficult to comprehend the quite liberal increases in water supply for Las Marías and Maricao although the number of households in both municipalities has decreased, the number of housing has increased. It is possible that, with increased income, some large households have broken into smaller ones to establish their own homes.

An interesting side information emanating from this comparison is the trend in the population per household. In every municipality of the region, decreases in the number of inhabitants per household were registered between 1960 and 1970. Such decreases ranged from 0.41 to 0.79, or an average of 0.58. It should be noted that the more highly urbanized areas have less inhabitants per household. This could be significant especially where the method of determining water requirements is based on the number of households.

Because the number of households does not recognize certain important socio-economic factors, perhaps a more workable basis for anticipating water requirements is the use of housing unit availabilities. This is more closely related to the level of income, amount of educational preparation, and type of value systems that have quite an impact on the patterns of water usage.

Perhaps the use of housing units as a predictor can be further refined in order to enhance its usefulness. A separate study,^{4/} sponsored by the Water Resources Research Institute, advocates the use of the number of rooms in determining water requirements in urbanization-type dwellings and the number of bedrooms in public-type dwellings.

Water resource development decisions in Puerto Rico are based on the results of a benefit-cost analysis.^{5/} However, it should be pointed out that there is considerable contention concerning the use of this method in evaluating public resource development projects, particularly in the field of water resource development. The main criticisms against benefit-cost analysis

may be summarized as follows:^{6/}

that it is merely a waste,

that it understates induced benefits,

that decisions by the Government are essentially political and not economic and, therefore, reliance should be on the political process,

that inflated benefit-cost ratios may be used by the Government to propose projects that are economically unsound for purposes of empire building of a particular agency or to satisfy a certain pressure group,

that because of the foregoing, willingness to pay should be the criterion, rather than benefit-cost.

Because of the enumerated objections it would seem that benefit-cost as a form of analysis appears to be doomed. However, one proponent of the system contends that benefit-cost analysis by the Government is nevertheless worthwhile in spite of its weaknesses because "its risks and its relatively small, direct influence upon the actual course of events". This proponent goes on to state that there is no substitute for benefit-cost analysis in public resource development, for "there are potentialities for improvement that may render the practical influence of benefit-cost analysis considerably more potent". The potentialities for improvement may be attained by:^{7/}

1. Dropping consideration of all classes of secondary benefits if the problem area is project selection. There should be a more careful evaluation of primary benefits and costs, since secondary benefits and costs have long been suspected as facilitating double counting and other forms of padding benefits.
2. Clearly differentiating the purposes of benefit-cost

analysis. Some items considered for project selection should not at all be considered for repayment, or the reverse. This is to say that recreational benefits should be considered for project selection but excluded for repayment as a matter of policy or practical expediency.

The improved benefit-cost system of analysis would have the following advantages:^{8/}

1. Restrains the abuse of economic arguments in the political process, by providing a calculation in which the general public would and could have confidence,
2. Stimulates scientific understanding as it forces the user to take account of his preferences, or "to scrutinize whether or not he has considered all relevant variables and to get some idea of the relations among the variables and the institutional restrictions in economic measurement".
3. Provides a calculation that is accessible to the general public to be scrutinized in every detail.

In the matter of choosing alternate projects for development, the benefit-cost method may be further improved by coupling the estimates with the simplex method in linear programming. It is "an algebraic iterative procedure which will solve exactly...any linear programming problem in a finite number of steps, or give an indication that there is an unbounded solution...The simplex method is a procedure for moving step by step from a given extreme point to an optimal extreme point...moves along an 'edge' of the region

of feasible solutions from one extreme point to an adjacent one. Of all the adjacent extreme points, the one chosen is that which gives the greatest increase (or decrease) in the objective function...At each extreme point, the simplex method tells us whether that extreme point is optimal, and if not, what the next extreme point will be..."^{9/}

An alternate method of evaluating projects in water resource development could be an adaptation of Leontief's system of input-output analysis. Such an adaptation has been made by a research team at Texas A&M University.^{10/} It is stated that when "Once the in-put-output model has been constructed for the watershed area for a base period and the functional relationship between water as a resource requirement and total output is determined, this model can be used to forecast the impact on the watershed economy of increases in the supply of water available to industries...in-output or interindustry models are capable of specifying quite detailed economic relationships in the geographical area under study".^{11/}

Regardless of the method used for estimating the worth of a water resource project, it has been established time and again to be good practice to employ a companion system, particularly if the design of such a system enables the costs to be held down, or close, to the original estimates. The critical Path Method (CPM)^{12/} is of such a design and its acceptance has been unquestioned in a great variety of significant enterprises. This system provides a rational basis for planning and scheduling the component activities of a project, for monitoring progress, and for focusing attention on areas where improved performance is needed to meet project deadlines.

The Critical Path Method is based on the premise that if all activities that must be accomplished to complete a project are known and if the time to accomplish each of them can be estimated, then these activities can be depicted in a logical relationship by means of a diagram or net-work from which the duration of a project and the specific activities controlling its completion within a specified time period can be determined. In addition, the effect of a delay on the completion of a project or in the accomplishment of any of its component activities, can be evaluated.

The advantages of CPM has been described as follows:

1. It gives a contractor control over the job - money, time and labor,
2. Saves a contractor and client money,
3. Analyzes and shows trouble spots immediately,
4. Eliminates a majority of lost motion,
5. Reduces unavoidable job delay costs by showing the most economical route to return to the original schedule,
6. Offers the most reliable basis for time extension negotiations,
7. Serves as cost and manpower control system,
8. Provides interdepartmental control and communication systems.

The Critical Path Method has rapidly gained acceptance in the construction industry - missile bases, dams foundations, industrial plants, high rise buildings, and highways to name but a few. Per-

haps it can also be used to great advantage in water resources development in Puerto Rico.

During the study, it became apparent that the planning and expansion of water facilities in Puerto Rico devolves upon the Planning Area, one of the principal subdivisions of the Aqueduct and Sewer Authority. The record of achievement is unquestionable, particularly, as that record indicates that water availabilities in Puerto Rico have been increased 650 percent since fiscal year 1961-1962. Nevertheless, the question as to the adequacy of the existing set up is raised. Increasing water availabilities is much more ramified than had been realized and its impact is likely to be felt in every aspect of man's life.

It is therefore proposed that a change of approach be considered: from one that is unilateral to one that is multidimensional or interdisciplinary. No major disruptive organizational change is involved, for after a project coordinator is appointed, he in turn can select his staff assistants from other divisions of the same organization or from different departments or agencies of the government. Through this approach genuine expertise can be brought to bear on the various aspects of water resource development.

The group should be constituted on an ad hoc basis. The members of the group, including the project coordinator, could be appointed only for the duration - from the planning and installation - of a single project and after which each could return to his home organization. While each member of the group would remain responsible to his own superior in his home organization, overall responsibil-

ity for a particular project would rest upon the project coordinator.

This approach has several distinct advantages, among them:

1. Brings together experts who have real, intimate knowledge of a problem,
2. Prevents overlapping functions and eliminates inter-necine "warfare" over jurisdictional aspects of a situation,
3. Makes greater and more economic use of available talent,
4. Provides greater latitude in the exercise of judgment, and hence the desire on the part of group members to excel because of the opportunities for self-realization,
5. Covers all aspects of a problem,
6. Achieves overall economy of operations.

Summary and Analysis:

From what appears on the record, water production seems to have been able to keep up with expanded needs - needs that are directly traceable to the overall improvement of the socio-economic well-being of the people in the region. The few spots which might engender a few questions to be asked do not seem to have overt water shortage. One can only surmise that water requirements unfilled by the Government system are being met by privately-owned, independent water aqueducts. And where there appears to be excesses of supply, one can only speculate on the explanation(s), if any, for the inadvertence. Planning for increased water avail-

abilities and executing those plans may be facilitated by the adoption of certain techniques proven to be effective in other endeavors.

FOOTNOTES

Part V-

1. Annual Statistical Report to the Executive Director, Fiscal Year 1966-1967, Puerto Rico Aqueduct and Sewer Authority, p. 11.
2. Op. cit., 1970-71, p. 12.
3. Planning Board, op. cit., 32.
4. Ausberto Guilbe - Quantitative Analysis of Residential Water-Use Patterns in Mayaguez, Puerto Rico, Water Resources Research Institute, June, 1969.
5. Information secured from an interview with an official in the Planning Area, Aqueducts and Sewer Authority.
6. S.V. Ciriacy-Wantrup - "Benefit Cost Analysis and Public Resource Development", Economics and Public Policy in Water Resource Development, Stephen C. Smith and Emery N. Castle, eds., Iowa State University Press, Ames, Iowa, p. 10.
7. Ibid., p. 14 ff.
8. Ibid, pp. 10-11.
9. G. Hadley - Linear Programming, Addison-Wesley Publishing Co. Inc. Reading, Mass. Also see Edward H. Bowman and Robert B. Fetter - Analysis for Production and Operations Management, (3rd. ed), Richard D. Irwin, Inc., Homewood, Illinois, pp. 83-94.
10. Robert J. Canon and Warren L. Trock - Input-Output as a Method of Evaluation of the Economic Impact of Water Resources Development, Water Resources Institute, Texas A&M University, May 1968; also see G. Hadley, op. cit., pp. 487-490.
11. Ibid., pp. 62-66.
12. L. R. Shaffer, J.B. Ritter & W.L. Meyer - The Critical Path Method, McGraw-Hill, New York; also see R.I. Levin & C.A. Kirkpatrick, Planning and Control with PERT/CPM, McGraw-Hill, New York.

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