Coastal Modification and Land Transformation in the San Juan Bay Area: Puerto Rico.

Jose Seguinot-barbosa
Louisiana State University and Agricultural & Mechanical College

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COASTAL MODIFICATION AND LAND TRANSFORMATION IN THE SAN JUAN BAY AREA:
PUERTO RICO

A Dissertation
Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy
in
The Department of Geography and Anthropology

by
José Seguinot-Barbosa
B.A., University of Puerto Rico, 1975
M.A., Universidad Nacional Autónoma de México, 1978
December, 1983
DEDICATION

To my lifelong friends; to you I owe a great deal of what I am.
To all people who seek social justice and peace among men.
ACKNOWLEDGEMENTS

A large number of people have been involved in the completion of this dissertation. On first instance, I will thank the following institutions at San Juan, Puerto Rico for the information and facilities they provided me: Marine Geology Division of United States Geological Survey, Inventory of Natural Resources Section of the Department of Natural Resources, Historical Archives of Puerto Rico, Puerto Rican Collection at the University of Puerto Rico Library, San Juan Land Use Division of the Puerto Rican Planning Board, Division of Photogrammetry Department of Public Works, Corps of Engineers, and the Planning Division of the Municipality of San Juan. I want to thank the University of Puerto Rico's geography students (August to December 1982) for their help in gathering this information.

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ABSTRACT

This dissertation presents the geographical transformation registered in the San Juan Bay, Puerto Rico, and its surroundings. Emphasis has been given to the human impact, originated by various cultural groups, on the landscape.

Stratigraphical and sedimentological analysis, as well as geological documentation have been used to reconstruct the geological history of the Bay, which is characterized by a series of volcanic rock formations followed by another series of sedimentary depositions. Subsequently, sea level changes and tectonic movements have altered these depositions, giving rise to an estuarine system.

The geographical history of each cultural period has been reported with the help of historical documents and maps, as well as with data compiled in the field. These three periods are: the Indian Period, characterized by the successive presence of the Igneri, Arawak, and Taíno Indians between 300-1530 AD; the Colonial Period, dominated by the Spaniards from 1508 to 1898, and including the arrival of the Negroes after 1530; and the premodern-modern period, marked by the strong influence of the North Americans. The last forty years' landscape changes have been reproduced via remote sensing techniques, field verification and personal interviews.

Human activities have directly affected those aspects associated with the geomorphology, oceanography, biogeography and climatology of the area. These changes came as a result of landfills, dredges and
vegetational cutoff, among others. All this human activity has modified the bay's natural processes, such as erosion, deposition, and water circulation. Cartographic, remote sensing, statistical interpretation and historical analysis have been the principal methods used to determine the impact of human occupancy.

As a result of these human activities, the coastal morphology and the bathymetry of the bay have been altered, destroying old coastal features in some parts and creating new ones in others. Climate has probably been modified through the increase of annual temperature and variation in the precipitation patterns.

Based on the investigation it can be inferred that the human influence on the geographical evolution of the zone has been much more significant than that of any natural element. Approximately 85% of the original landscape has been transformed into a human scenery.
Coastal geography is a subject that has been studied worldwide, especially during recent years. As a result, many researchers including anthropologists, geographers, geologists, historians and other scientists have been involved in the process of producing important information related to this subject. Continuing with this trend this dissertation intends to analyze the factors and agents responsible for the land transformation process that has taken place in the San Juan Bay area since its origin to the present, the processes involved, and the resulting emergence and submergence of cultural and physical geographic forms.

The first objective of this work is to present the geographical evolution of the area under study, reconstructing those past landscapes according to the documentary and field data collected. Other objectives include the determination of the human impact in the area and the qualification of the most important ecological changes.

San Juan, the capital city, is the most important area of Puerto Rico. Its great importance is felt in the historical, cultural, and economic development of the island. The modern city is located 18°N and 66°W. This metropolitan area extends toward the east to the municipal boundary of Carolina, (Fig. 1-1) toward the west coast as far as the municipal boundaries of Bayamón, Cataño and Toa Baja. In the south, the city is limited by the municipal boundary of Guaynabo and Trujillo Alto. The old city is located on an islet surrounded by
the Atlantic ocean to the north, the main island to the south and east, and a bay to the west.

This bay, known as the San Juan Bay, has played a key role in the development and significance of the region. However, very little geographical research has been done on this region despite its well known importance. Located here is the most significant port of Puerto Rico and the eighth most important in the world in terms of tonnage.\(^2\)

The San Juan Bay area is the most important historical and economic region of Puerto Rico and also represents the most diversified land use sector in the San Juan metropolitan area. Parks, residential areas, heavy industries, port facilities, recreational areas, and public services can be found together forming an urban belt surrounding the bay. The outcome of all this human activity in the San Juan Bay area represents one of the most altered ecological systems of Puerto Rico. Some of the environmental changes that occurred in the past and are still taking place in the region are dredging, landfilling, river diversion, and land clearing.

Evidently this area has experienced very significant land transformation due to rapid and extensive urban development and little has been written about these changes. Therefore, this dissertation is a good starting point to analyze the natural and cultural factors involved in the rapid littoral and maritime changes of San Juan Bay and its vicinity.

Land transformation is a term associated with land conversion, consequently it is used as synonymous.\(^3\) Since 1944, "land conversion" has been defined as the changing in land use from one economic activity to another.\(^4\) This definition has been used through the
While "land conversion" refers only to land-use changes, "land transformation" implies all kinds of changes that occur in the landscape, cultural and physical, caused by man or by nature.

Land transformation includes land use and land cover changes, as well as its classification categories, the land use level (intensive-extensive), the construction, destruction, abandonment or change of use of different structures, the human impact in a certain area at a specific period of time, the changes through time of the natural and cultural condition of a particular area, the political facts and decisions that produce those changes, and also, the natural causes. Land transformation includes also the feedback relations among the different variables and processes involved in the landscape changes and the resulting geographic forms. Furthermore land transformation not only covers surface changes, but also includes changes in the submerged conditions of one region.

For the purpose of this study the San Juan Bay area has been geographically defined according to ecological, historical and economic criteria. This area will cover more or less the extension presented in Fig. 1-2. This section includes basically the following metropolitan sectors, San Juan Bay Islet, Miramar, Condado, Santurce, Isla Grande, Martín Peña, Hato Rey, Puerto Nuevo, Caparra, Buchanan, Sabana y Amelia, Cataño, Bay View, Palo Seco, Isla de Cabras, Palmas, and Levittown.

A clearer understanding of the San Juan Bay area is expected once this work is completed. Some of the important points that will be emphasized are: the geological formation of the area studied, the
characteristics of the first coastal features such as dunes, swamps, mangrove, beaches and sand banks, the presence of the first Indian elements and their influence in the area, the first Spanish settlement and first significant coastal landscape changes, the introduction of new flora and fauna and their effect on the natural landscape of the region, human modification of the seashore and its submerged environment as a result of military, commercial, agricultural and industrial activities, and finally, the transformation from a rural to an urban landscape.

Some closely related geographical research methods are used to achieve the objectives of this work. The reference framework for these techniques is obtained from important research articles. One of the most valuable sources is Research Techniques in Coastal Environments, published by the School of Geoscience at the Louisiana State University. In reference to the cartographic techniques, applied to the historical interpretation of landscape, the following publications are used; Carr, Chardon, Boer and Carr, and Verger. Hewlett's article is used as a reference for the field work and interpretation of documents, but the most useful source for document analysis is Doe. In relation to the archeological data, the most valuable articles are the ones published by Flenley and Oldfield. There are hundreds of studies dealing with remote sensing techniques in coastal areas. Those used here are Wray, Welsted, Nichols and Trumbull.

This project's fieldwork included the gathering of geological data from the ground and the verification of past geological information. Some stratigraphic analysis was done in areas such as

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the western bank of Bayamón river and in front of the "Capitolio". Samples from the bay bottom were analyzed in the laboratory of the Department of Natural Resources at San Juan and interpreted by this dissertation's author. Bathymetric data were also taken in conjunction with the marine geology section of the United States Geological Survey.

We reviewed the San Juan Bay area by boat, land and air, and took more than 200 slides, all of which have been individually studied. Close contact was established with the archaeologists working at San Juan Bay area sites. The results of their studies were analyzed in terms of this dissertation's goals. The field work also includes the survey of 22 sites in the area surrounding the bay (Fig. 7-15). This survey included the collection of geological, vegetational, archaeological, historical, and land use data.

Extensive amounts of historical information were processed from the Historical Archives of Puerto Rico and the Puerto Rican Room at the University of Puerto Rico. Early descriptions, maps, drawings and photos have been used for the reconstruction of previous landscapes of the San Juan Bay area.

The resolution of some of the maps used in this dissertation is low. For example, figures 4-22 and 5-9 appear to be illegible, but they have been included in the work, along with some others, because they indicate the type of map which the authors were able to analyze, they show general features of the area under study and, of greater importance, because this is the first time that they have been quoted in the literature. However, they have been used as a basis for other maps constructed by the author (For example, figure 5-10 is based upon
figure 5-9). Unfortunately, these original maps have been greatly reduced, losing a great deal of detail in the process.

The last forty years (1940-1980) of landscape have been reconstructed through the use of remote sensing, field verifications and personal interviews. The documented data for this period have been obtained from the Historical Archive of Puerto Rico, other literature sources and a review of the newspapers of the last fifty years, particularly "El Mundo".

A considerable amount of reference sources has been consulted for the realization of this work. Dissertations similar to the one presented here have been done at Louisiana State University by Gary Dunbar,20 Roger Trindell21 and Frank Gable.22

In his work Dunbar presents the geographic evolution of the North Carolina Outer Banks based on historical documentation such as early descriptions and maps. His research covered the colonial to the modern period. Trindell uses a similar approach to describe the land transformation process of the southern New Jersey port. He particularly emphasizes the development of commercial and port activities in this area. A slightly different geographical perspective is used by Gable in his study of the south Boston flats, between 1863-1920. His main objective was to describe the development of land reclamation process during that time.

Another useful source was Geoscience and Man, journal of the School of Geoscience at Louisiana State University.23 Dr. Roland Chardon, advisor to the author of this dissertation, has done work of this nature on Biscayne Bay, Florida.24
The philosophical framework for this work was obtained from Sauer's papers, *The Morphology of Landscape*[^25] and *Foreword to Historical Geography*[^26]. In the last fifteen years other papers have expanded this subject, for example, David Hill's paper in 1970[^27] and Gumiler's paper in 1966.[^28] Moore and Chater[^29], Rollinson[^30], Johnson[^31], Steven[^32], Zunica[^33], Thorpe[^34], McGaltan[^35], and Stanfield[^36] have done research in the land transformation process in different countries. One significant publication used in this research was the Western Port Bay Environmental Studies written by Butcher.[^37]

This project includes a review of the last fifteen years (1965-1980) of international literature in coastal historical geography. During these years, several important publications appeared in coastal geography. For example, Temple[^38] studies the land use patterns in coastal Sumakaland, Tanzania, where the variation of land use and settlement pattern closely reflect the character of the physical environment. Cameron[^39] uses aerial photographs obtained at intervals ranging from 2 to 20 years to detect long term coastal changes in the Bay of Fundy resulting from wave and current action.

Using a geomorphological approach, Milliman[^40] in 1967 published a paper that emphasizes the geomorphological formation and evolution throughout the Quaternary of Hogsty Reef in the Bahamas. About the same time, Emery[^41] publishes one of the most significant books related to the historical geography of the Atlantic coast. He studies the evolution of this coastal fringe area during the last 11,000 years. According to his information, during the period that man has inhabited this zone, the shoreline has moved more or less progressively inland in response to a general rise of sea level.

[^25]: Sauer's paper, *The Morphology of Landscape*
[^26]: Sauer's *Foreword to Historical Geography*
[^27]: David Hill's paper in 1970
[^28]: Gumiler's paper in 1966
[^29]: Moore and Chater's paper
[^30]: Rollinson's paper
[^31]: Johnson's paper
[^32]: Steven's paper
[^33]: Zunica's paper
[^34]: Thorpe's paper
[^35]: McGaltan's paper
[^36]: Stanfield's paper
[^37]: Butcher's *Western Port Bay Environmental Studies*
[^38]: Temple's study
[^39]: Cameron's study
[^40]: Milliman's paper
[^41]: Emery's book
Early Maps as Historical Evidence for Coastal Change, an article written by Boer and Carr in 1969, investigates the formation of past coastal features using the analysis of old maps. A similar type of approach is used by Rollinson, as he studies the coastal changes on Walney Island from the middle ages up to the present, and by Verger, when he established what he called "dynamic cartography".

Throughout the seventies, several papers using the historical-coastal approach appeared. In 1973, Terich and Komar wrote a book dealing with the development and erosion history of the Bayocean Spit in Tillamook, Oregon. The purposes of this study were to recount the growth and decline of Bayocean Park and to investigate the erosional and depositional pattern of Bayocean Spit. The same type of paper was done by Tanner on the Florida Big Bend Coast. His paper deals with the wave energy balance and the history of accretion and erosion in this coastal section of Florida.

The human influence in coastal areas is a research area that has been strongly emphasized after 1975. One of the best examples of this approach is a study of the Mobile Bay area done by Sapp, Emplaincourt and Hardin. This study uses aerial photographs in order to determine shoreline changes caused by man or nature in this area. A second example is the study presented by Zunica, in which he describes the effect of human activities on the Italian coast throughout history.

Two studies that emphasizing the economic or cultural aspect more than the physical one are the papers written by Hilling, and Stanfield and Richardson. The first analyzes the port activities...
in Ghana and the second the geographical evolution of Atlantic City
and Cape May since 1870.

It seems that the most common type of coastal historical papers
are those referring to physical coastal changes. In 1977 Norton published an article about the shoreline in the Gulf of Mexico. He concludes that the regional distribution of shoreline erosion and accretion largely reflects changes in littoral drift cells, decrease in sediment supply, and a continuing rise in relative sea level, including compactional subsidence. Another study, similar in scope, is the paper published by Bird. The first gives information about the geologic setting, climate, storm history, and morphological changes of Ponce de Leon Inlet in Florida. The second studies the shoreline changes in Victoria, Australia based on a comparison of 19th century maps with 1934-45 aerial photographs.

Extensive historical and modern literature exists about the San Juan Bay area. The list of references at the end of each chapter includes a selection of these works. The most useful sources about the land transformation process in San Juan Bay are Hostos, Castro, Coll y Toste, Actas del Cabildo de San Juan, the Historical Archive of Puerto Rico, and the newspaper "El Mundo".

Hostos' book is an excellent work covering the historical evolution of San Juan city up to 1898, with emphasis on the economic, military, and geographical aspects. Castro's reference is a comprehensive book which not only describes the architectural pattern of San Juan throughout space and time, but also presents the general historical development of the city up to the 19th century. Coll y Toste is perhaps the best primary source dealing with Puerto Rican

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history. His work includes 13 volumes of natural, economic, and political history of Puerto Rico for the period from the 16th to the 19th century. Actas del Cabildo de San Juan contains an extensive collection of City Hall documents detailing the administrative aspects of the city of San Juan. The Historical Archive of Puerto Rico contains a large collection of maps, figures, tables, and documents never published before. The newspaper "El Mundo" reported on valuable information about the environmental and economic aspects of the San Juan Bay, especially during the last forty years.

The literature relating to coastal geography in Puerto Rico is not as extensive as that of historical geography. The most valuable sources to this work are references by Kaye and Williams, two publications by the Department of the Army, and a publication by the Department of Natural Resource, entitled Shoreline of Puerto Rico.

Kaye's study analyzes the evolution of the coastal forms and processes in Puerto Rico, especially during the Quaternary period. His study emphasizes the agents that produce coastal changes, such as sea level changes, waves, tides, currents, and human activities. Williams presents specific research dealing with the formation of the Bayamón and Rio de La Plata coastal plains. He describes the geologic nature of this area and its geomorphic evolution. The San Juan Harbor is a general communication that includes valuable information about current tides, waves and winds of the study area. General Design Memorandum on San Juan Harbor presents a unique research project containing data associated with the environmental aspects of dredging in San Juan Bay and the economic impact of the proposed dredging project. Shoreline of Puerto Rico is a report focusing on different
aspects of the beaches of Puerto Rico. This study is primarily concerned with beach development, the processes of sand movement, and the human impact on the beach system.

Within the literature existing on Puerto Rico, this dissertation represents a new approach to coastal research in terms of methods, techniques and scope. The approach of combining traditional methods (such as the comparison of maps) with more modern techniques, (as the combination of early descriptions with remote sensing and statistical interpretation) or the combined analysis of natural and cultural history, are not commonly found in the present literature.

This study thus represents a significant contribution to the field of coastal geography in Puerto Rico, because it is the first work using the geographical approach in a place totally surrounded by coastal features.

This study is also probably the only one dealing with local land transformation in a specific region; internationally it is one of the few works of this magnitude concerned with the complex world of man-land relationships in a coastal environment.
CHAPTER I

FOOTNOTES

1 The island of Puerto Rico has been politically divided into 76 "municipios" which represent the smallest administrative units of the country, shown in Fig. 1-1.

2 "San Juan Ente los Primeros 10 Puertos del Mundo", El Nuevo Día, (San Juan, June 28, 1982) 51.

3 Best, Robin H., Land Use and Living Space (New York, Methuen, 1980), 90.

4 Granham, Edward H., Natural Principles of Land Use (New York, Oxford University Press, 1944) 104. Granham was one of the first persons who defined the concept land conversion.

5 After 1944 the land conversion concept was widely used again. In 1969 J. R. Drewett designed a theoretical model for rural-urban land conversion, and L. S. Bourne designed a model using linear regression to understand the land use changes in Toronto. Three years later, Marion Clawson defined the concept in the United States; and in 1981 Robin H. Best reused the idea, in its traditional manner, to explain the land conversion process in England.

6 Based on the criteria expressed by the Coastal Zone Program of Puerto Rico, the Planning Board of Puerto Rico, the Corp of Engineering and the author of this dissertation, the San Juan Bay area should cover approximately the area described in Fig. 1-2. However, the information available concerning this area will vary depending on the specific period being studied and the amount of data available.
15


17. Welsted, John, "Air Photo Interpretation in Coastal Studies: Example from the Bay of Fundy, Canada* Photogrametria*, (Vol. 35, no. 1, 1979), 1-29.


Trindell, Roger T., *Historical Geography of Southern New Jersey as Related to its Colonial Port*, (Dissertation, Louisiana State University, Baton Rouge, 1966).


Chardon, Roland E., publications include:
a. "A Geographical History of the Biscayne Bay Area", Presented at Biscayne Bay Symposium I, Published as part of the University of Miami Sea Grant Special Report No. 5 (Coral Gable, 1976).
b. "Effect of Man on the Shore Vegetation of Biscayne Bay",
Presented at Biscayne Symposium I, Published as part of the University
of Miami Sea Grant Special Report No. 5 (Coral Gable, 1976).
c. "Coastal Barrier Changes, 1770-1867, Biscayne Bay Area, Florida",
d. "Cartographic Analysis of Coastal Change: Natural and Urban",

25 Sauer, C. O., Land and Life, (Los Angeles, University of
California Press, 1963), 315-351.
26 Ibid., 351-380.
27 Hill, David A., "The Transformation of Traditional Landscapes",
28 Gumiler, L. N., "On the Subject of Historical Geography,
29 Moore, P. D. and E. H. Chater, "The Changing Vegetation of West
Central Wales in the Light of Human History", Journal of Ecology,
30 Rollinson, W., Coastal Changes on Walney Island: a Historical
Appraisal, (Department of Geography, University of Liverpool Research
paper 8, 1971), 1-12.
31 Johnson, Douglas L., Jabal al-Akhdar, Cyrenaica: a Historical
Geography of Settlement and Livehood, (Department of Geography,
32 Stevens, Stanley D., "Lighthouse Point, Santa Cruz, Discovery
of Historical Land Use Through Maps, Photos and Text", (Special
Libraries Association Geography and Map Division Bulletin 92, 1973),
2-11.


43 Rollinson, W., "Coastal Changes on Walney Island, A Historical Appraisal, Department of Geography, University of Liverpool Research paper 8, (1971), 1-12.


53 de Hostos, Adolfo, *San Juan Ciudad Murada*, (San Juan, Instituto de Cultura Puertorriqueña, 1966).


57 *Historical Archive of Puerto Rico*, Fund of Public Work and Fund of Ports and Piers, Book of Resolutions and Ordinances.


Department of Natural Resources, *Shoreline of Puerto Rico*,
(Coastal Zone Management Program, 1978).

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CHAPTER II
ORIGIN AND FORMATION OF THE SAN JUAN BAY AREA

Introduction

The San Juan Bay area is the result of a complex geologic history, during which alternating eustatic sea level changes and significant local tectonic movements have determined its geologic character.

The basic outline of the San Juan Bay area was determined during the Quaternary period. While some of the bay's features were formed during the Tertiary, the most important factors determining the present configuration of the bay occurred more recently.

The bay was originally formed by the successive deposition of volcanic and sedimentary rocks. The stratigraphic pattern of these depositions and geologic formation are described in Table 2-1. The lowest stratigraphic layers consist of Late Cretaceous and Lower Tertiary clastic and volcanoclastic rocks and thin lava, overlapped by a Middle Tertiary sequence of consolidated sand, silt, gravel and sporadic deposits of limestone. Superimposed on the Middle Tertiary deposits are Upper Tertiary and Quaternary sequences.

The Tertiary Period

The island of Puerto Rico began to form during the Upper Jurassic to the Lower Cretaceous period, approximately 130 to 150 million years ago. The collision of the present Caribbean plate with the North American plate initiated submarine volcanic activity. The first volcanic island (Fig. 2-1) emerged from the sea by the end of the
<table>
<thead>
<tr>
<th>Stratigraphic Unit and Map Symbol</th>
<th>Brief Description</th>
<th>Approx. Feet</th>
<th>Thickness (meters)</th>
<th>Geological Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Artificial Fill (Af)</td>
<td>Sand, limestones and volcanic rock</td>
<td>16'</td>
<td>5m</td>
<td>Holocene</td>
</tr>
<tr>
<td>2. Beach Deposits (Qb)</td>
<td>Sand composed of grain of quartz volcanic rock and shell</td>
<td>3-16'</td>
<td>1-5m</td>
<td>Holocene</td>
</tr>
<tr>
<td>3. Swamp Deposits (Qs)</td>
<td>Sandy muck, clayey sand underlain by peat in mangrove areas</td>
<td>33'</td>
<td>10m</td>
<td>Holocene</td>
</tr>
<tr>
<td>(Bay Mud)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Alluvium Deposits (Qa)</td>
<td>Sand, clay and sandy clay</td>
<td>49'</td>
<td>15m</td>
<td>Holocene</td>
</tr>
<tr>
<td>5. Silica Sand (Santurce Formation) (Qss)</td>
<td>Quartz sand, very pure derived from ferruginous sand by leaching</td>
<td>3-13’</td>
<td>1-4m</td>
<td>Holocene</td>
</tr>
<tr>
<td>6. Eolianite (Qe)</td>
<td>Calcareous sandstone, well cemented, crossbedded</td>
<td>98’</td>
<td>30m</td>
<td>Holocene</td>
</tr>
<tr>
<td>7. Alluvial Fan Deposits (Qf)</td>
<td>Clay, sand and silt</td>
<td>328’</td>
<td>100m</td>
<td>Pleistocene-Pliocene</td>
</tr>
<tr>
<td>8. Older Alluvial Fan Deposits (QTt)</td>
<td>Clay, silt and sand</td>
<td>328’</td>
<td>100m</td>
<td>Pleistocene-Pliocene</td>
</tr>
<tr>
<td>9. Blanket deposits (Tm)</td>
<td>crossbedded quartz sandstone</td>
<td>167’</td>
<td>15m</td>
<td>Miocene</td>
</tr>
<tr>
<td>10. Aymamon Limestone (Tay)</td>
<td>Thick bedded, dense limestone</td>
<td>33’</td>
<td>10m</td>
<td>Miocene</td>
</tr>
<tr>
<td>11. Aguada Limestone (Ta)</td>
<td>Calcarenite, clayey and limestone</td>
<td>262’</td>
<td>80m</td>
<td>Miocene</td>
</tr>
<tr>
<td>Stratigraphic Unit and Map Symbol</td>
<td>Brief Description</td>
<td>Approx. Feet</td>
<td>Thickness (meters)</td>
<td>Geological Period</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>------------------</td>
<td>-------------</td>
<td>--------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>12. Cibao Formation (Tc)</td>
<td>Chalk, soft limestone, sandy clay</td>
<td>66'</td>
<td>20m</td>
<td>Miocene-Oligocene</td>
</tr>
<tr>
<td>13. Mucabarones Sand (Tm)</td>
<td>Quartz rich sand and some gravel</td>
<td>295'</td>
<td>90m</td>
<td>Middle-Oligocene</td>
</tr>
<tr>
<td>14. San Sebastian Formation (Ts)</td>
<td>Sandy clay containing pebbles of silicified volcanic rock</td>
<td>131'</td>
<td>40m</td>
<td>Middle-Oligocene</td>
</tr>
<tr>
<td>15. Diabase (Intrusive Rock) (Td)</td>
<td>Dark-gray course to fine diabase</td>
<td></td>
<td></td>
<td>Eocene-Paleocene</td>
</tr>
<tr>
<td>16. Rio Piedras Siltstone (Tr)</td>
<td>Thin bedded and laminated siltstone</td>
<td>2624'</td>
<td>800m</td>
<td>Eocene-Paleocene</td>
</tr>
<tr>
<td>17. Guaracanal Andesite (Tg)</td>
<td>Poorly stratified tuffaceous wacke and pebble to cobble conglomerate</td>
<td>558'</td>
<td>170m</td>
<td>Paleocene</td>
</tr>
<tr>
<td>18. Monacillo Formation (Km)</td>
<td>Mudstone, conglomerate and tuffaceous siltstone</td>
<td>1312'</td>
<td>400m</td>
<td>Upper Cretaceous</td>
</tr>
<tr>
<td>a. Trujillo Alto Limestone Member (Kmt)</td>
<td>Fossiliferous dark gray calcarenite</td>
<td>328'</td>
<td>100m</td>
<td>Upper Cretaceous</td>
</tr>
<tr>
<td>19. Guaynabo Formation (Kg)</td>
<td>Gray wacke, conglomerate and shale</td>
<td>3608'</td>
<td>1,100m</td>
<td>Upper Cretaceous</td>
</tr>
<tr>
<td>a. Leprocomio Siltstone Member (Kgl)</td>
<td>Thin bedded and laminated tuffaceous calcareous siltstone</td>
<td>328'</td>
<td>100m</td>
<td>Upper Cretaceous</td>
</tr>
</tbody>
</table>
TABLE 2-1. continued.

<table>
<thead>
<tr>
<th>Stratigraphic Unit and Map Symbol</th>
<th>Brief Description</th>
<th>Approx. Thickness</th>
<th>Geological Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>b. Martin Gonzalez Lava</td>
<td>Porphyritic basalt</td>
<td>377' 115m</td>
<td>Upper Cretaceous</td>
</tr>
<tr>
<td>Member (Kgm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20. Hato Puerco Tuff</td>
<td>Massive volcanic and metavolcanic and some stratified ash</td>
<td></td>
<td>Upper Cretaceous</td>
</tr>
</tbody>
</table>

Upper Cretaceous. Limestone was deposited around the volcanic islands; where warm, clean, and shallow waters dominated.¹

In the area of San Juan, the center of volcanic action was located to the southeast of the present city, in the direction that today constitutes the western piedmont of the Luquillo mountain range² (Fig. 2-1). The eruptions of these volcanoes produced the Hato Puerco formation and the entanglement of islands known as the Guaynabo formation (Fig. 2-2).³ Marine fossils collecting around the later formation, created the Trujillo Alto limestone.

Towards the end of the Upper Cretaceous period the island of Puerto Rico was subjected to geologic compression. These great movements, oriented from the north and northeast, folded and faulted the volcanic and sedimentary rocks of the earlier Cretaceous.⁴ It was during the Upper Cretaceous period that the grand fault system located in the area comprising Guaynabo, Monacillo and Cupey was formed.⁵ At the same time, a hill system, originated south of the bay, and was immediately denudated, thereby depositing eroded materials in the old shoreline, and constituting then, the Monacillo formation.

During the Paleocene period, and as a consequence of a long interval of erosion, the Guaracanal formation was exposed to the surface. Most of the sediments that later constituted the Rio Piedras formation originated from this formation.

At the beginning of the Eocene, a second extensive period of folding and faulting occurred in the Greater Antilles due to the subduction of the North American plate under the Caribbean plate.⁶ The major impact of this phenomenon on the San Juan Bay area was the
Figure 2-1

Puerto Rico at the Upper Cretaceous

Source: Rafael Pico, Nueva Geografía de Puerto Rico, 1975
formation of new fault lines, and the extension of the ones that already existed.

In the Eocene-Oligocene interval of erosion, the corresponding rivers of the area of San Juan adjusted their flow pattern toward the north. As a result of vertical and horizontal movements of the massive rocks, east-west fault lines were created. In the San Juan Bay area, the Puerto Nuevo and the Quebrada Margarita rivers continued their work of eroding, transporting and depositing debris currently found in the San Sebastián and Mucarabones formations. It is during this period that the Bayamón river began to expand laterally, and to form what Monroe identified as the old delta of the Bayamon river.

The Aguada formation represented by Monte Canejas, located north of Fort Buchanan and south of Puerto Nuevo Bay, was formed by sediments deposited under flooding conditions of the rivers and adjacent creeks. By the middle Miocene the coastline became a line of haystack hills, or "mogotes", oriented east-west and parallel to the coast.

On the other hand, the Aymamon limestones were deposited before the island rose by the end of the Miocene. These limestones were formed in a warm and shallow depositional environment due to the low erosive capacity of the adjacent rivers. Aymamón outcrops are found at the outlet of Caño Martín Peña in Laguna San José (Fig. 2-2).

Due to uplifts at the end of Miocene, the rivers were rejuvenated increasing their sediment transport capacities. Simultaneously, the valley corresponding to the San Juan Bay area rose. Under these circumstances, the meanders of the Bayamón river remained entrenched, starting a new stage of lateral expansion.
With the coming of the Pliocene, the fluvial erosion and deposition increased due to new uplifts in the Cordillera Central. The evidence for these uplifting movements exists in the old alluvial deposits, in the form of terraces and alluvial fans, along the edges of the Bayamón and Río Piedras rivers, and in other systems of smaller creeks which created the extensive formation of old alluvial deposits south of Laguna San José. These sediments are the result of a process of natural filling at the end of the Tertiary period.\(^\text{12}\)

**The Quaternary Period**

Within the geological history of Puerto Rico, the formation of the San Juan Bay environs corresponds to the most recent geological period. The bay area was formed during the last million years as a result of eustatic sea level and tectonic changes.

Before the Pleistocene, eustatic sea level fluctuations caused a lowering of the sea level down to 35 meters (132 feet) below, and a rising of up to 38 meters (125 feet) of height above present mean sea level (MSL).

Kaye\(^\text{13}\) and William\(^\text{14}\) have identified four periods of rising sea level in Puerto Rico during the Quaternary Period. These periods include a first rising of 2 meters (6.5 feet), a second one of 8 meters (26 feet), a third of 20 meters, (66 feet) and a last of 38 meters (125 feet).

The existence of certain sites prove the variety of eustatic sea risings in the San Juan Bay area. Beneath the east walls of Fuerte de San Cristobal, (Fig. 2-2), next to the main entrance of the Capitol evidence exists, according to Kaye, of a rise of sea level to 2 meters (6.5 feet) above MSL.\(^\text{15}\) The fact that on deposits of eolianite
(cemented dunes) the east and west sides of Isla de Cabras, as well as the southern side of Punta Salinas, reach a height of 8 meters (26 feet) above MSL suggests that sea level once reached this height.\textsuperscript{16}

According to Williams,\textsuperscript{17} the alluvial terraces along the Bayamón and La Plata rivers reach an elevation of 120-125 meters (394-410 feet), giving evidence of a maximum rise of the sea level of that magnitude. The alluvial deposit in the high parts of Rio Bayamón, Rio Piedras and Quebrada Margarita show that once the sea reached a height of 38 meters (125 feet).\textsuperscript{18}

As a result of these eustatic sea level changes, eolianites were formed. Appearing today like a line of sand reef parallel to the northern coastline extending westward from San Juan to Arecibo, this deposit is geologically known as the San Juan formation (Fig. 2-3). According to Kaye,\textsuperscript{19} four layers of dunes beneath the Fuerte de San Cristóbal, corresponding to four eustatic sea level changes, were deposited by large quantities of sand transported by winds. These dune lines mark the old coastlines, which are presently submerged (Fig. 2-4).

Some lagoons began to develop behind the sand dunes of the San Juan formation both as a consequence of the partial interruption by the dunes of the river flow, and of sea flooding during the periods of sea level risings. This allowed the development of several estuarine systems, such as the lagoons of Torrecillas, Laguna San José and Bahía de San Juan. Many of these estuaries began to be filled by the washout flows of the rivers, forming swampy areas such as Ciénaga Las Cucharillas and the Sabana Seca Swamp (Fig. 2-2).
Fig. 2-4. Cemented sand (E.-E.) formation under San Cristóbal Castle. Source: Clifford A. Kaye, Shoreline Features and Quaternary Shoreline Changes, Puerto Rico.
One of the sand deposits, formed at the time when the sea level was higher than today, is represented by the Santurce formation (Qss) (Fig. 2-2). Located in the area bearing its name, this formation includes a variety of quartz ferruginous sand, deposited by the wind or redeposited by the water after being leached. On the other hand, the alluvial sediments of the Holocene (Qa) were formed under extreme conditions of sea level rising and lowering. For instance when the level rose during the last interglacial period, the rivers drowned their valleys. On the other hand, when the sea level was low, (during the Wisconsin glaciation), the rivers prograded their outlets, forming valleys and canyons.

Recent studies done by the Division of Marine Geology of the U.S. Geological Survey in San Juan have proven the existence of two underwater canyons in the area near San Juan Bay. One of them is located exactly opposite the outlet of Bayamon river, and the other is located in front of the actual outlet of Cocal river.

Significant sediments from this glacial period are the deltaic sediments deposited by the Bayamón river and its abandoned tributary, the Caño de Aguas Frías. The sediments extended from Cataño westward up to Sabana Seca Swamp (Fig. 2-2).

Swampy areas developed over the alluvial deposits of the Holocene (Qs) due to the periodic floods of these zones by the rivers. It was in this manner that the swampy area of Sabana Seca and Ciénaga Las Cucharillas was formed. The first was developed by the effect of Bayamón and La Plata rivers, and the second was due to the effect of Caño de Aguas Frías. Most of the sediments identified today as
man-made landfill deposits (Af) were previously swampy regions (Fig.
2-2).

Recent studies on sea level changes indicate that the area of the
San Juan Bay displayed a tendency to rise slowly with respect to the
sea level. According to Williams,24 recent changes can be proven by
the existence of eolianite banks that are eroded between one and two
meters in the northern part of Isla de Cabras. Behind this bank
exists a small cliff of 2 or 3 meters (7-10 feet) of height that
proves the slow terrestrial rise that this region displays.

In summary, the Pleistocene features of San Juan Bay area were
formed under the combined influences of eustatic sea level and
tectonic changes. Based on the literature, there is a consensus that
the area of San Juan Bay has registered at least four changes in its
sea level in the Pleistocene three rising periods and a falling one.
These fluctuations have not been dated precisely, so it is almost
impossible to reconstruct the geographical conditions of any given
time during that period.

We can, however, make educated guesses, and suggest that San Juan
Bay area probably registered sea level rises of 15-20 meters (49-66
feet) about 120,000, 105,000 and 85,000 years ago,25 and a lowering of
15 meters (49 feet) 95,000 years ago.26

The last 20,000 years of sea level changes include a lowering of
approximately 123 meters below present levels, reached approximately
19,000 years before present. This lowering extended to about 130
meters (426 feet) below present levels approximately 16,000 years B.P.
The rate of sea level rise was rapid, but around 7000 B.P. it began to
slow down, reaching its present level approximately 4000 years B.P.27

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After reaching this level, the general tendency of sea level change in the Atlantic Ocean has been to rise at a rate not greater than .011 ft. per year (3.35 mm). However, the San Juan Bay area is also uplifting tectonically, making an accurate estimation of local sea level rise hard to determine. It seems that this region is being uplifted, less than 5 mm per year, compensating somewhat for the possible sea level rise of 3.35 mm. Based on the foregoing, we can establish a possible local net sea level rise of no more than 1 mm per year for this area since 4000 B.P. (ca. 2000 B.C.). For the historical period (i.e. since about 1500 A.D.), we may postulate a possible sea level rise of about 50 cm, though this rise is by no means possible.

Once the sea reached its present level, the sediment supplied by the rivers was redistributed along the coast by waves, tides and currents, giving origin to the beach sediments (Qb) located in the area of Condado, Cataño and Levittown (Fig. 2-2).

During the last 4,000 years a refilling process took place, reducing the size of the bay and permitting the formation of sand banks. The underwater topography of the bay was probably characterized by a system of shoals and marshes exposed to the surface during low tide conditions and submerged during high tides. The depth of the bay probably did not exceed 5.2 meters (20 feet) in its deepest parts, which was its central section.

The general landscape in the proximity of the bay of San Juan was complemented during the Holocene period with the formation of Punta Palo Seco and Punta Cataño, as well as Punta Salinas tombolo (Fig. 2-2). These three are physiographic traits resulting from the
deposition of sand by river and coastal currents. While a small line of sand dunes persisted at the southeast border of Bahía de Pueblo Viejo, the beach formations continued to expand in Condado lagoon and in the north coast of the San Juan Islet.

Since the general conditions of the area around San Juan Bay were still in the process of formation, they were modified several times by storms. When man appeared in this region, the bay area had not yet acquired a definite physiographic outline.

**Original Vegetation**

Since the Tertiary Period, various plant successions have characterized the San Juan Bay area. Hollick, in his study of the paleobotany of Puerto Rico, identified some of these successions, particularly those which refer to the lagoons and estuarines environment.

The predominant plants in the San Juan Bay area have been associated with different geological environments: hydrophytic plants are located at the edge of the lagoon and river banks, halophytic plants grow in swampy and mangrove areas, and xerophytic plants appear in beach and sand dune areas.

The Mesophytic Forest, which originally covered the limestone hills and the San Juan consolidated dunes, included such species as, *Bonsena simaruba*, *Clusia rosea* (pitch apple), *Ficus laevigata* (fiddle-leaf fig), *Ficus stahlii* (Jaguey), *Gaussia attenuata*, *Coccolobis grandifolia* (mountain grapes), *Simaruba tulae*, *Petitia domingensis* (bastard stopper), *Pimenta racemosa* (Clinamon busher, bayrum tree), *Buchenavia capitata* (yellow sander) and other species of large trees.
The beach vegetation was basically destroyed by the action of high waves and storms. The original vegetation of this region must have been composed of *Ipomoea pes-caprae* (bay hops), *Canavalia maritima* (bay bean), *Sporobulus virginicus* (sea shore rush grass), *Fimbristylis dichotoma* (junquito), *Kyllinga peruiana*, *Remirea maritima*, *Cakile lanceolata* (sea rocket), *Chamaesyce buxifolia* (lechecillo), and *Borreria verticillata* (botón blanco). Species associated with beach successional vegetation after storm wave activity included *Coccolobis uvifera* (sea grapes), *Chysobalanus icaco* (coco plum), *Scaevola plumierii* (coralillo), *Lantana involucrata* (wild sage), and *Randia mitis* (ink berry).

Most the herbaceous species were represented in the original vegetation, but the predominant herbs were *Crotalaria retusa* (rattleweed), *Indigofera suffructicosa* (anil), *Stylosanthes hamata* (pencil flower) and *Biden pilosa* (shepherd's needle).35

The sand dune vegetation was originally formed by several species such as *Chamaesyle buxifolia*, *Diodia maritima* and *Remirea maritima*. The formation of small dunes attracted new species like *Coccolobis uvifera*, *Scaevola plumierii* and *Chrysobalanus icaco*. After the dunes were established, new species of thicket came to live in the area. This group included *Ipomoea macrantha* (coast moon vine), *Mikania congesta* (guaco), *Smilax coriacea* (greembrier) and *Serjania polyphylla* (basket wood).

The original vegetation of the San Juan consolidated dunes was the same mesophytic forest of the limestone hills. In areas where the dunes were desintegrated by wave action or partial submersion the vegetation consisted of dense mats of *Opuntia dillenii* (prickly pear),
crowded bushed of *Lantana involucrata* (wild sage), and thickets of *Coccolobis uvifera*.

The original fresh water and lagoons vegetation that existed along the shore of such areas as Ciénaga Las Cucharillas and Sabana Seca swamp consisted of *Typha angustifolia* (cat tail) and *Marisaes jamaicensis*. Both species were supposed to have formed the original vegetation at the end of the mud bank areas. In areas where the swamp enters in contact with the beach, as is the case in Bay View and Levittown, a sand bank vegetation grew consisting of clumps of *Scleria hirtella* (cortadora), *Fimbristylis diphylla* (junquillo) and *Aeschynomenna sensitiva* (morivivi).\(^{36}\)

According to a study done recently by the Coastal Zone Program of the Puerto Rican Department of Natural Resources\(^ {37}\) the three types of mangrove [red (*Rhizophora mangle*), black (*Avicennia nitida*), and white (*Laguncularia mangle*)], were represented in the San Juan Bay area's earlier vegetation. The original mangrove areas covered the northeastern part of the Condado lagoon, half of the southern part of the San Juan Islet, and the southern and eastern coast of the San Juan Bay. The growth of mangroves permitted the formation of a system of tidal channels which included Caño Martín Peña, Caño San Antonio, Caño San Fernando and other small streams (Fig. 2-2).
Chapter II

NOTES


3 For details of the nature on each one geological formation please see Table 1-1. The geographic distribution of the geological formation exposed to the surface can be, in the same manner, visualized in Figure 1-2.


6 Malfait, op. cit., 263.


16 Ibid., 131.

17 Williams, op. cit., 166.

18 Monroe 1973., op. cit. map.

19 Kaye, 1959b, op. cit., 141


21 Rodríguez, Rafael, Personal Communication, Marine Geology Project Director, (San Juan, U.S. Geological Survey, Scientific Research Area, Department of Natural Resources, 1982).
According to Williams, op. cit., 178, the Bayamón river was the cause of the existent canyon in the present outlet of La Plata river. However the existence of underwater canyons discovered in 1982, located near areas of the present outlet of Bayamon river, refute this idea, by which we conclude that the underwater canyon located in front of the outlet of La Plata river was formed by this same river and not by the Bayamón river, as William postulates.


Williams, op. cit, 173.


33 The original plant species are presented here by their scientific name, with the English name in parenthesis. Where ever an English name was not available the native name has been used.


36 Ibid., 78

37 Coastal Zone Program, Los Sistemas de Mangles de Puerto Rico, (San Juan, Department of Natural Resources, 1978), 73, 101.
CHAPTER III
THE SAN JUAN BAY THROUGHOUT THE INDIAN PERIOD

Introduction

The first inhabitants of the island on Puerto Rico appeared during the first millennium after Christ.\textsuperscript{1} This group has been named Archaic by Alegría. He has found arqueological data for this Indian group in a cave known as "Cueva María de la Cruz" in Loíza.\textsuperscript{2}

The first inhabitants were followed by successive migrational waves of Indian cultural groups similar to those found in South America. After the Archaics, came the Igneris in 370 A.D., the Arawaks in 750-1050 A.D., the Taínos between 1210-1400 A.D. and the Caribs in 1400 A.D.\textsuperscript{3}

When the Spaniards arrived in Puerto Rico, the Tainian formed the predominant Indian group. They were dispersed and adapted in two different geographical environments: the mountains and the coasts. The Indians who lived near San Juan Bay at this time came from South America, moving across the Lesser Antilles and the eastern coast of Puerto Rico. Even though the predominant group was the Tainians, each one of the earlier cultural groups had left its markings.

Indian Population and Economic Activities

The Indian population in Puerto Rico at the time when the Spaniards arrived has been estimated by Vázquez Calzada to have been about 100,000 people.\textsuperscript{4} Other authors presented in table 3-1, have made larger and smaller estimates. The absence of any information prior to 1492, the limited information provided by the first
TABLE 3-1

Aboriginal Population of Puerto Rico at the Time of the Discovery

<table>
<thead>
<tr>
<th>Author</th>
<th>Estimate</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Vázquez</td>
<td>1 m</td>
<td>Rosenblat (1954, 301)</td>
</tr>
<tr>
<td>Las Casas</td>
<td>600,000</td>
<td>&quot;</td>
</tr>
<tr>
<td>Pedro Mexias de Ovando</td>
<td>500,000-1m</td>
<td>&quot;</td>
</tr>
<tr>
<td>Eliseo Reclus</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>Julian de Acosta</td>
<td>200,000</td>
<td>&quot;</td>
</tr>
<tr>
<td>Vasquez Calzada</td>
<td>100,000</td>
<td>Galiñanez (1977, 161)</td>
</tr>
<tr>
<td>Spinden</td>
<td>100,000</td>
<td>Spinden (1928, 643)</td>
</tr>
<tr>
<td>Rosenblat</td>
<td>50,000</td>
<td>Rosenblat (1954, 102)</td>
</tr>
<tr>
<td>Steward</td>
<td>&quot;</td>
<td>Steward (1949, 664)</td>
</tr>
<tr>
<td>Jess Walter Fewkes</td>
<td>30,000</td>
<td>Rosenblat (1954, 301)</td>
</tr>
<tr>
<td>Tomás Blanco</td>
<td>29,000</td>
<td>&quot; ( &quot; 302)</td>
</tr>
<tr>
<td>Salvador Brau</td>
<td>16,000</td>
<td>&quot; ( &quot; 301)</td>
</tr>
</tbody>
</table>

Sources: Angel Rosenblat, *La Población Indígena y el Mestizaje en América*, 1954


TABLE 3-2

Indian Depopulation Pattern of Puerto Rico

<table>
<thead>
<tr>
<th>Year</th>
<th>Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1500</td>
<td>200,000</td>
</tr>
<tr>
<td>1511</td>
<td>15,000</td>
</tr>
<tr>
<td>1515</td>
<td>4,000</td>
</tr>
<tr>
<td>1531</td>
<td>1,148</td>
</tr>
<tr>
<td>1544</td>
<td>40-100</td>
</tr>
<tr>
<td>1581</td>
<td>12-15</td>
</tr>
</tbody>
</table>

Source: Angel Rosenblat, *La Población Indígena y el Mestizaje en América*, 1954

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historians, priests and government officials, the lack of a rigorous census and the rapid extermination of the natives are some of the causes for the uncertainty of estimates given.

In no other place in the world did an aboriginal population decline as fast as in the West Indies. Puerto Rico was not the exception; although the size of its native population is a matter of speculation, their extinction is obvious. Table 3-2 presents the estimate of the native population and the depopulation pattern for Puerto Rico during 16th century according to Rosenblat.\(^5\)

The principal economic activities of the Taíno Indians included hunting, gathering, fishing, agriculture and pottery. Gathering activities included the collection of wild roots, berries, herbs and fruits from trees. Some of those fruits were the mammel apple, soursop, and guava. Fishing was an important activity and was practiced using different techniques that employed diverse types of nets and cages.

Hunting different kinds of birds and small animals was also an important activity according to Oviedo. Because no large mammals existed, several native species of large rodents, iguanas, and small mammals were hunted.\(^6\)

Although agriculture existed at a simple level, it was the most important economic activity of the natives of Puerto Rico. The basic supply of food came from cropping. However, the existence of the agricultural activity was not based on the intensity of the practice, but on the good "conuco", or slash and burn cultivation, system which provided a relatively high yield crop with little care.\(^7\) The major crops harvested in these mounds were manioc (\textit{Manihot esculenta}), sweet
potatoes (*Ipomea batatas*), red pepper (*Capsicum annuum*), "yautía" (*Xanthosoma sagittifolium*), peanut (*Arachis hypogea*), "lerenes" (*Calathea allouia*), arrowroot (*Maranta arundinacea*), and taro (*Colocasia esculenta*).  

The Indian diet combined crops resulting from their different economic activities. According to Sauer, while manioc and other roots or tuber provided starches and sugars, fishing and gathering of sea turtle eggs, oysters, conches, manatee and fish provided them with the necessary proteins.  

The Indians of Puerto Rico used the available ecological resources according to their capacities. By necessity, plants and animals were adapted and domesticated. Priorities were established for the use of coastal resources, which were expanded and preserved according to societal importance.  

Appendix I presents a list of the most important plants and animals known by the Indians. Obviously the diversity of these species corresponds with the variation of local environmental conditions. The table was constructed using the data obtained from historical, archeological and scientific sources.

**Ecological Impact of the Indian Society in the San Juan Bay Area**

The areas intensely used by the Indians surrounding the San Juan Bay are represented by the Bayamón, Caparra and San Juan Islet Indian Campsites (Fig. 3-1). From these settlements the Indians probably expanded and moved daily across the shore and water of the San Juan Bay gathering, fishing, and hunting in this biologically rich estuarine environment.
Fig. 3-1. Localization of aboriginal activity in San Juan Bay.
At this time, the Bay was probably characterized by a shallow water environment formed by extensive sand bank, located in the shore areas. Behind this section a large mangrove sector was already developed. Between these two areas, sand and sand dunes beaches were formed by the sediment deposited by rivers and shore currents. Various lagoons and swamps were formed by the occasional floods of the Bayamón, Puerto Nuevo and Quebrada Margarita streams; meanwhile, a limestone belt remained behind the mangrove region at the southern section of the bay.

Significant human impacts were those referring to vegetational changes such as the land clearing, the cutting of trees, and the introduction, hybridization and extinction of some plant species. The Indians used different kinds of lithic tools, such as cobbles, scrapers, gravers and hand axes, to cut the vegetation. Large plots of vegetation were used as fuel supplies or as an aid in hunting and fishing activities. Even for agricultural purposes, the Indians eliminated the original vegetation with the idea of growing crop plants which required large amounts of solar energy. Among these plants, are manioc, yam and maize.

As Wadworth indicated, the precolombian forests were necessary for Indian existence. They provided shelter, food, weapons, and implementation of transportation, medicine, dyes, fibers, ropes and fuel.

Perhaps the Indians deforested some particular regions, such as the mouth of Río Bayamón, the areas surrounding Caparra and the San Juan Islet. By fire supression they eliminated the original vegetation, thereby permitting the formation of a successional forest.
characterized by shrub and herbs. After the deforestation, the erosion process stimulated the leaching and ultimate loss of soil nutrients.\textsuperscript{12}

We can infer from Goudie\textsuperscript{13} and Sauer\textsuperscript{14} that the diffusion of the use of fire might well have contributed to the formation of savannas. In that sense the savanna should be defined as a flat region covered with grass and shrubs. Several savannas have been identified in the area surrounding the San Juan Bay. The littoral areas of Bayamón river, the sectors known today as Sabana and Sabana Seca in Toa Baja, have been identified as Savannas since historical times.\textsuperscript{15}

The impact of the Indian population in animals contribute perhaps to reduced mammal species such as the sea cow or Manatee, several species of chiroptera such as Monophyllus frater, Stenodermus rufus and Phyllonecteris major, the insectivora mammal known as Nasophontes edithae, the rodents popularly known as hutías or Isolobodon portoricensis and other rodents such as Elas nodoutomys obliguus, Heptaxodon bidens, Heteropsomys insulans and Homopsomys antillensis. They also contributed to the extinction of Acratocuus odontrigonus and Acractonus major, of the Edentata mammal group.\textsuperscript{16} Although the Indian diet consisted also of fish, birds, snails, insects and reptiles, mammals were perhaps the most affected.

Big game hunting was not practiced in Puerto Rico due to the absence of large animals; on the other hand, Indian activities concentrated in small game hunting, making intensive use of this resource.\textsuperscript{17}

In recent excavations done in a limestone mound known as Monte Canejas, located southwest of San Juan Bay (Fig. 3-1), Gus Pantel\textsuperscript{18}
discovered the possible use of land snails (Caracolus Sp.) as a food source by the Indians. He also found remains of mangrove oyster, marine mollusk, crab, hutías, birds, lizards, fish and turtles.

Fishing activities in the San Juan Bay area have been proven by the archaeological discovery of a fishing village located in Puerta de Tierra sector, in the southeastern portion of the San Juan Islet (Fig. 3-1). 19

As Sauer 20 indicated, the coastal environment constituted an excellent habitat for human population. In coastal areas man has the opportunity to satisfy food needs, to obtain the raw materials needed, and to move from one area to another by water. As Irving Rouse 21 presented, Indians began to populate Puerto Rico from the coast to the interior. Therefore, this fact explains the prolonged exploitation of the coastal resources in Puerto Rico, more than any other type of environment.

Based on the studies done in this area, it can be assumed that the Indians extracted sand for polishing their stones and objects, and they obtained cobbles and pebbles from the riverine areas to make their tools. Also, clay was taken from the alluvial deposits located in the southeastern part of San Juan Islet and from the riverine areas. Using these materials they made the pottery found later in the excavation of "El Convento" 22 and in "San José" church. 23 The Indians exploited intensively the nearby mangrove zone of San Juan Bay for food resources and ceramic purposes, as is proven by the indigenous ceramic of Monte Canejas. 24

By the reconstruction of the archaeological sequence in the San Juan Bay area, Table 3-3, it is possible to visualize the temporal and
### TABLE 3-3

<table>
<thead>
<tr>
<th>Site</th>
<th>Date</th>
<th>Cultural Group</th>
<th>Ceramic Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monte Canejas</td>
<td>1300-1492 A.D.</td>
<td>Taínos (Chicoide-Esperanza type)</td>
<td>Shards are coarse and soft, fracture coarsely, granular redish brown in color.</td>
</tr>
<tr>
<td>Puerta Tierra</td>
<td>600-800 A.D.</td>
<td>Arawak Epi-Salaoid (late cuevas-early ostiones) type</td>
<td>Fine and hard but do not ring clearly, surface smooth and finished: break easily fractures firms and granular, fracture color medium brown tinged with red.</td>
</tr>
<tr>
<td>El Convento</td>
<td>100-350 A.D.</td>
<td>Igneri (saloid-Hacienda Grande Type)</td>
<td>Fine and hard, well made, ring like porcelain when struck with metal, hard to fracture firm and finely granular with colors brown to ivory/chocolate tinge.</td>
</tr>
<tr>
<td>San Jose Church</td>
<td>-</td>
<td>Igneri (saloid-Hacienda Grande Type)</td>
<td>same as El Convento</td>
</tr>
</tbody>
</table>

Reference: Gus Pantel, Agammenon, *Cultural Resources Survey of Fort Buchanan Military Reservation* (San Juan, Prepared for the Interagency Archaeological Service-Atlanta, 1982). 1-110

Reference: De Hostos, Adolfo, *Historia de San Juan Ciudad Murada* (San Juan, Instituto de Cultura Puertorriqueña, 1966) 7.

Reference: Pons de Alegria Mela, *Igneri ceramic from the Convent or Santo Domingo* (M.A. Thesis State University of New York, Buffalo, 1973) 186-188.

spatial dimension of the Indian impact in San Juan Bay area. According to the archaeological evidence, the most primitive cultural group established in the San Juan Bay area is represented by the Igneri. This culture, established throughout the Islet of San Juan, made intensive use of clay, sand, shells, and rocks, obtained from the areas surrounding the bay, for their pottery.

The groups that came later, Arawak and Taínos, affected the area of Puerta de Tierra and Caparra, respectively (Fig. 3-1). Both groups seem to have made intensive use of the coastal resources available, particularly the raw material necessary for their utilitarian and decorative objects and the food sources required by their diet.

The ecological impact of the Indian society in the San Juan Bay area is correlated with the quantity and density of the population settled in the region during pre-Hispanic times. Apparently, the only unsettled areas were represented by the swampy and mangrove regions surrounding the bay. According to a report prepared by the Corps of Engineers,25 the immediate lowland area surrounding Rio Piedras, Puerto Nuevo and Quebrada Margarita seems to have been of limited aboriginal use. However, the Fort Buchanan and Caparra areas were highly populated. As Anderson26 mentioned, one of the reasons for establishment of the town of Caparra by the Spaniards, was the presence of the Indian labor force, obtainable from nearby areas.

There is historic evidence in the "Probanza de Juan González" that corroborated the existence of an Indian settlement of this region. According to the testimony of Andrés López and Francisco Rodríguez, the area occupied by Caparra was previously settled by several Indian villages.27
When the Spaniards came, they redistributed the Indian population of Caparra through different repartimientos. Although the number of Indians assigned to the Caparra area is not known, we can conclude that this region probably absorbed most of the Indian redistribution. In 1509 more than 5,500 Indians were redistributed by the repartimiento of Juan Cerón. The last repartimiento was in 1515 and the total Indian redistribution was about 4,000.²⁸

It is natural to expect a larger concentration of Indians in the area of Caparra after the Spaniards arrived. The Indian labor force was used for mining, agriculture and building Caparra. Probably several thousand Indians were used for these activities. Based on this argument, we can assume a large Indian population before and after the Spaniards arrived in Caparra.

As we see throughout this section, the Indians used the ecological habitat immediate to the San Juan Bay area according to their capacity and needs; nevertheless, the impact of Indian society never reached that of later occupants. Although Indians made important ecological and geographic changes, these modifications never disrupted the habitat of the bay area as happened later. As Spencer indicated, "a small contemporary society possessing only a low level culture of slight technological power must still live close to nature and accept aspects of control from the physical environment".²⁹
CHAPTER III

FOOTNOTES

1 Acevedo Labor, Gómez, and M. Ballesteros, Culturas Indígenas de Puerto Rico. (Madrid, Imprenta Samaran, 1975), 36.


3 Gómez, op. cit., 47, Carib Indians were only located at the eastern coast of Puerto Rico.


7 The conuco provided crops for two or three years without a need for constant care. These mounds resisted wind and water erosion and provided an extensive harvest to support a large population. See Carl O. Sauer, The Early Spanish Main (Los Angeles, University of California Press, 1966), 68.

8 Oviedo, 1944, op. cit., Vol. 2, 175-177, 185, 195.

the manioc based economy of the Tainan Indians of Trinidad, she estimated that manioc in the form of Cassava bread, comprised about 60 to 70% of the diet. Other crops, including maize and beans provided less than 5%, fishing, including the gathering of shellfish, accounted for about 20%, and hunting provided 4 to 5% of all food products.

Some studies have been done related to this subject, most of which are quoted in this section. However, no major study has been done related to the Indian influence in the relief and coastal configuration of the region. Significant archeological studies are needed for the finding of Indian major engineering construction, such as irrigation channel, and the location of Indian agricultural plots.


12 Ibid., 41.


15 Goudie, op cit., 41. There is a big controversy if the savannas have been formed under human or natural (climatic, edaphic) processes. Our appreciation in this matter can be summarized in the idea that savannas can be formed in a variety of circumstances, where either man or nature could be the main factor or where both could be considered equally important.


19 De Hostos, Adolfo, *Historia de San Juan Ciudad Murada*, (San Juan, Instituto de Cultura Puertorriqueña, 1966), 18.


23 Álegria, Ricardo, "Igneric Excavation at San José Church", *Personal Communication*, (San Juan, Puerto Rico, 1982).


26 Anderson de Córdova, Karen, "Caparra", Cultural Resources
Reconnaissance of Five Projects in Puerto Rico, (U.S. Army Crops of

27 Ibid, E-2.

28 Ibid, E-6.

29 Spencer, J. E. and W. L. Thomas, 19 , Introducing Cultural
CHAPTER IV
THE SAN JUAN BAY AREA DURING THE COLONIAL PERIOD

The Town of Caparra
(1508–1520)

When Juan Ponce de León visited the San Juan Bay area in 1508 he discovered an extensive plot of land, rich in natural resources and enclosed by a large and well protected bay which was excellent for port facilities and commercial development. This area also included an abundance of streams and apparently great quantities of gold. For these and other reasons, Ponce de León named this area Puerto Rico, or Rich Port.¹

According to a historical reference Ponce de León established his first temporary camp in the area known today at Punta Cataño.² Because of the site was a poor one, he decided to move his camp to the southwestern corner of the bay, an area he later called Caparra.³

The transformation of the land began in the San Juan Bay area once it was settled, approximately one league (4 km) from the coast⁴ (Fig. 4-1). The urban section of the town included the church, the hospital, Ponce de León's house, a smelting house, the thatch and wood houses of the Spanish settlers, and a main plaza or square.⁵

The main advantages of the Caparra site were the flat expanse of land with ample water and lumber resources, proximity to the bay despite intervening swampy terrain, proximity of major river beds, natural protection from enemy attacks, and the possibility of using the Indian labor force from the surrounding area.⁶

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Fig. 4-1. Map of the San Juan Bay Area by Rodrigo de Figueroa in 1518. Source: Historical Archive of Puerto Rico.
During the first years of colonization, the most important economic activities were mining, agriculture and livestock farming. Gold mining was practiced in the river and creek valleys located in the southwestern part of Caparra particularly in the Sibuco and Toa rivers areas. The gold mining began in 1510, lasted until 1536, and produced about four million "pesos" in total value.7

Ponce de León intensified the agricultural production. He established three small farms close to San Juan Bay, in Guaynabo, Bayamón, and Caparra. The last one had about eight thousand cultivated mounds or "conucos".8 Livestock raising began in Caparra at the time of it's founding.9 Several cattle ranches or "estancias"10 were established in the area immediate to Caparra.11 Here large portion of the land particularly on the eastern side of Caparra, was used for growing wild cattle. The "estancias" also raised poultry and horses.

The settlement of Caparra was controlled by laws passed in 1512 and 1513. In 1512, Governor Moscoso established in his civil law that anyone with a farm costing more than 2000 pesos had to build a stone house, and that anyone who used Indian labor had to plant the following within two years: four trees of peaches, apples, pomegranate, pears, apricot, and walnut.12 In 1513, Ferdinand V promulgated the "Ley Primera" which granted titles to land tracts upon compliance with the 1512 requirements concerning residence and cultivation.13

The Caparra settlement period resulted in several natural modifications. Some of these modifications were the clearing of land, the construction of roads, houses, buildings, and port facilities.
Other changes included the extraction of minerals, increased use of the soil, the introduction of new flora and fauna such as coconut palm, coffee, sugarcane, horses, and goats.

With the establishment of Caparra the Spaniards constructed the pier named "Desembarcadero" in the area today called Pueblo Viejo Bay. They also began the construction of a pathway from this pier to Caparra. All the ships which stopped in San Juan at that time were supposed to bring a large amount of stone for this pathway construction. The road remained impassable until 1518, when Rodrigo de Figueroa visited Caparra and described the pathway as muddy and swampy. A second pier was constructed later at the mouth of the Puerto Nuevo river. This new pier was also connected to Caparra by a pathway. This second pathway was also described as muddy and swampy. At the Puerto Nuevo river pier the ships had more accessibility to the coast and also the transportation from the pier to Caparra was made easier through the use of a second channel flowing into the Puerto Nuevo River.

In 1518 the population did not exceed 175 Spanish inhabitants. Virtually the entire population was of European origin because, by this time, much of the Indian population had been significantly reduced and the large black influx did not begin until seven years later.

With only this number of people relatively small changes seem to have taken place in the Bay area. The most important changes occurred in terms of land clearing and grazing. The wood used for the buildup of Caparra came from the surrounding areas. Farming and ranching activities also perpetuated the clearing of large plots of land.
The Caparra settlement existed only until 1519 because the Spanish Crown ordered the population to transfer to the Islet located at the eastern side of the Bay. As early as 1514 the Caparra population requested permission from the Spanish government to transfer the city. The new commercial and administrative development as well as the poor site conditions of Caparra were the reasons for this change. In 1518, after surveying the San Juan Bay area, Rodrigo de Figueroa recommended the movement of the city. His reasons for recommending the transfer included the unhealthy and poor environmental conditions of the area, as well as the isolation and difficulty transporting the products from the bay to the settlement. The San Juan Islet, according to de Figueroa, had a much better location with good soil and trees.23

The natural and cultural conditions of the San Juan Bay area, as found by Rodrigo de Figueroa, are depicted in his 1518 map (Fig. 4-1). The Caparra settlement (No. 17), called on the map the City of Puerto Rico, was located behind a mangrove forest. The map also shows the location of a beach in the southern portion of La Puntilla (No. 7) and the swampy section of the San Juan Islet (No. 8), as well as the location of the outlets of Puerto Nuevo (No. 16), Bayamón (No. 20) river. The "Desembarcadero" is represented in the southwestern portion of the bay, under the name "Puerto Viejo".

Besides these features, Rodrigo de Figueroa's map includes some of his recommendations, particularly those that refer to the San Juan Islet where he wanted to locate the city. He also suggested that the port be located on the western coast of the city. Before moving the city, de Figueroa recommended the construction of two causeways, one
from the eastern section of the Islet to the mainland (Fig. 4-1, No. 12, 13) and a second one through the Martin Pena channel. The movement of Caparra to the Islet took place between 1519 and 1522. By this time, de Figueroa's recommendations had already been achieved.24

Land Use and Land Conversion
(1520-1899)

The ceremony for the inauguration of the new city was on June 24, 1520, and the official inscription was on August 28 of that year.25 In its first year, the city consisted of 170 residents, 14 religious, 120 houses made of stone, wood and straw, a cathedral and the monastery of Santo Domingo. In 1523, Ponce de León's son-in-law built the first significant civil building called La Casa Blanca.26 (Fig. 4-2). In 1530, the settlement area included a hospital called La Concepción, the churches of San José and Ermita de Santa Bárbara, a town hall, or "Cálibdo", and a General Studies University which was founded in the Monastery of Santo Domingo.27

The land surrounding the urban area was used for agricultural purposes. Although the Caparra region was partially abandoned by 1525,28 some farming and ranching activities still remained in the area in 1530.29 By this time, sugarcane had already been introduced to Puerto Rico.30 Caparra was the only place around the bay where sugarcane was produced, and with only a few slaves it provided the city with its needs.31 Even though the size of the cane fields around Caparra is not known, it can be safely assumed that the cane area had to be relatively large in order to support the existing population.32

The southeastern and southwestern section of the bay were essentially

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Fig. 4-2. La Casa Blanca. Constructed in 1523. Source: Photo courtesy Historical Archive of Puerto Rico.
unsettled, and were used principally for wild cattle grazing, horse and pig raising.33

The San Juan Islet settlement continued to grow, although slowly, throughout the 16th century. In 1530 the city of Puerto Rico passed through a series of economic and social crises brought on by the high taxes imposed by the Spanish crown, constant attack from the French and Carib Indians,34 high unemployment, debt among property owners, and lack of social and health services. By around 1568, the city contained no more than two hundred houses, two squares and four or five streets.35

By the end of the 16th century, the city included, besides the military constructions, more than 300 houses. This urban growth was perceived by Layfield when he visited the city in 1598 (Fig. 4-3).36

The Spanish white population of the city never passed the thousand mark in the 16th century (Table 4-1). After transfer to the Islet in 1522, the city of Puerto Rico only had 175 white inhabitants.37 The 1531 census revealed a population of 265 white Spaniards as well as an Indian a population of 1106 natives were registered in San Juan. Since some 1846 Negroes were registered for the same period, the total population of the San Juan area in 1531 was 3217 inhabitants.38

The number of Negroes began to increase after 1533 when the sugar industry registered its great expansion. Between 1521 and 1551 about 1050 negroes were introduced. In 1598, 200 more were added for working in the military projects.39 The non-white population was concentrated in the "bujios" surrounding the city. One of these
Fig. 4–3. The City of San Juan at the end of the 16th century.
Source: Coll y Toste, Lealtad y Heroísmo de la Isla de Puerto Rico, 1897.
<table>
<thead>
<tr>
<th>Year</th>
<th>Spanish Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1515 (Caparra)</td>
<td>175</td>
</tr>
<tr>
<td>1521</td>
<td>320</td>
</tr>
<tr>
<td>1527</td>
<td>516</td>
</tr>
<tr>
<td>1529</td>
<td>480</td>
</tr>
<tr>
<td>1530</td>
<td>344</td>
</tr>
<tr>
<td>1535</td>
<td>500</td>
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<tr>
<td>1548</td>
<td>500</td>
</tr>
<tr>
<td>1556</td>
<td>650</td>
</tr>
<tr>
<td>1571</td>
<td>1,000</td>
</tr>
<tr>
<td>1575</td>
<td>1,000</td>
</tr>
<tr>
<td>1582</td>
<td>864</td>
</tr>
</tbody>
</table>

slums appeared at the northern part of the city in 1529 according to a sketch drawn by Ramírez de Arellano (Fig. 4-4).

After 1530 the Spanish population tended to increase and became stable as a result of agricultural developments. In 1571 the city had 1000 Spanish inhabitants, but after 1575 the Spanish population decreased again to 800. This decrease was a result of critical economic conditions prevailing on the Island. These conditions were the result of abandonment of the Island by Spain and the lack of local capital resources.

The 17th century was characterized as a period of slow economic development. The most important activities of this century were the construction of various forts in the area surrounding the Bay and the construction of the city wall.

Although there were not many resources available in 1602, administrators began the construction of the new City Hall and then, in 1608, they built the city hospital which was named "Hospital del Rey". The urban core area then consisted of about 300 houses, 120 "bohíos" or thatch houses, El Morro Castle, the Dominican Convent and the governor's house. Various pathways connected the city with its suburban areas.

In 1602, the most important economic activity in the San Juan Bay area was cattle raising. Several cattle farms had been established near the southern border of San Juan Bay. These farms are illustrated on the 1632 map (Fig. 4-5). The immediate area of San Juan City was also used for cattle raising, particularly the section, later called Puerta de Tierra, located at the eastern edge of the city.
Fig. 4-4. The city during 1529. Source: Rafael Ramírez de Arellano. 
La Capital A Travers de los Siglos, 1950.

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Fig. 4-5. The San Juan Bay Area in 1632. Source: María de los Angeles Castro. Arquitectura en San Juan de Puerto Rico, Siglo XIX, 1980.
middle of the century vegetable and fruit farming was added to the
cattle raising at Puerta de Tierra.\textsuperscript{45}

Second in importance was sugarcane production. In 1625 sugar
mills were working in the Condado and Caparra areas.

In 1615 a storm hit the area and contributed to the deterioration
of economic conditions in San Juan city. Ten years later, when the
population recovered from the difficulties of the previous years,
Bodounio Enrico, a Dutch general, attacked the city and damaged its
most important buildings. Among the most affected were La Fortaleza
and the Cathedral, but he also burned the library of Bishop Bernaldo
Balbuena, and more than 46 wood and 52 stone houses were destroyed.\textsuperscript{46}
After this attack the population reacted by requesting that the
government construct a wall which would surround and protect the city
area.

The only significant building construction for the rest of the
17th century was the reconstruction of the Cathedral in 1646, the
building of the San Francisco Church in 1651, and the construction of
the Dominican nun's convent, beginning in 1651.\textsuperscript{47}

By 1604 only 1,600 "vecinos" and a population of 2,000 Negroes
and mixed individuals lived in the city.\textsuperscript{48} The total population in
1640 was around 5,000 persons. The majority of this population was
composed of Spaniards, "Criollos" or native born Spanish, black slaves
and a small minority of Italians and Portuguese.\textsuperscript{49} The white Spanish
population of San Juan registered in 1673 was 300 people.\textsuperscript{50} Due to
the difficult situation of the Island, the government recommended the
introduction of several families from the Canary Islands.\textsuperscript{51} In 1695
the first Canaries families arrived in San Juan.\textsuperscript{52} This contributed
to later agricultural and population expansion. By 1698 the white population was estimated as being 1,100 persons.  

Large urban expansion began in the eighteenth century with the construction of military structures. Many blacks came to work and were established in the areas surrounding the city. In 1714 the governor gave permission to a small black community to establish a camp in the area between "Puerta de Tierra" and the San Antonio bridge. This black community was later transferred to the area called "Cangrejos", today Santurce, where they established a black community joined with another black group that was formed of people who were running away from the other Antilles. 

In 1714 the main road or "Camino Real", was already constructed, extending from Puerta de Tierra to the San Antonio Bridge. Outside the San Juan Islet, it went as far as the Cangrejo community (Fig. 4-6) and Rio Piedras town which was founded in that year.

The first half of the eighteenth century saw the consolidation of agricultural activities in the San Juan Bay area. Various "hatos" and "estancias" appeared in that period and served as a basis for the formation of a new urban nucleus, an example of which was the new urban center of Rio Piedras, Guaynabo and Bayamón.

In 1750 crops and cattle continued to be the most important agricultural activities in San Juan Bay. By this time various "hatos" were selling at auction in Palo Seco, Martin Pena and Pueblo Viejo. The southwestern region of the Bay supplied the food needed in San Juan city.

Land reform developed after the 1750s. A new economic orientation and land distribution system was achieved by the
government. Since then farming has been oriented toward the growing of sugarcane. In 1757 the "hatos" were demolished in "Cangrejos" forming new "estancias" which were oriented to the crops of vegetables and fruits. Some of these "estancias" also cultivated sugarcane. However, the area most affected by sugarcane cropping was that of the southwestern region of the Bay, particularly the sector behind the swampy region of Cataño, Palo Seco, and the region behind the Caparra and Puerto Nuevo mangrove.

In 1775 sugar production was the most lucrative economic activity in Puerto Rico. Obviously, the San Juan Bay area was affected by these circumstances. In 1799 Ledru described the sugarcane industry in the Estancia San Patricio. According to his description, the industry was based on the use of black labor. The factory included 4 buildings; the first was used for squeezing the cane, the second for the sugar cane deposit, the third included the kettles, and the fourth was used as a storage house and rum distillery.

After 1750 the city began to live on a "welfare" condition which extended until the end of the Colonial Period. Besides the military construction, two new hospitals were built in 1776 and 1798. In 1784 the government began paving San Juan streets and by the end of the century the custom house was already built in the area of La Puntilla. A second preliminary structure was also established in that sector which later came to be a military arms deposit named "El Arsenal". Two churches were constructed in this century: "Capilla del Cristo" and "Capilla de los Franciscanos".
San Juan was described by Abbad y Lasierra in 1782. According to his book:

"the city has 6 streets which run from north to south and 7 streets from east to west. None have stone pavements. The construction of the houses varies according to the social class of its inhabitants. The wealthier homes are made of stone masonry covered with shingle, and some even had a terrace roof. Black people's homes are made of boards and beams. The roof is made of 'thatch' called 'yaguas'. The only source of light is a low and narrow door. These types of houses are called 'bujíos'. The houses of this type are on the city edge, although inside the city wall, they can be considered slums, or 'arrabales'. Most of them include a back yard or kitchen garden. At this time the total population is about 6,005 persons. The community made a concerted effort to construct public buildings. The Cathedral is the only parish church of the city and is very ornate. Close by are the ruins of two other buildings. They are believed to have been the Episcopal Palace and the Seminary. The main square has a spacious plaza with the city's most beautiful buildings. Surrounding the 'Hospital del Rey' there is nothing else but a group of houses that had been successively joined. The most useful and well constructed building is the hospital 'Nuestra Señora de la Concepción'... There is one convent of the Franciscan order and another of the Dominique as well as one of the Carmen Calzado order of nuns. The Governor's palace is an antique fort that existed over the inlet or "Caleta de San Juan". Its name is 'Real Fortaleza de Santa Catalina'.

The urban changes between 1782 and 1797, when Ledru described the city, do not seem to be significant, since both descriptions are very similar. A clear idea of the urban expansion of the city during that period is presented in Fig. 4-6.

The towns located in the suburban region of San Juan continued to develop and grow after the 1750s. Most of the growing black population concentrated in these areas. By the end of the 18th century there were various black communities located between the Santiago city door and La Puntilla, and in the area of Palo Seco. In 1782, Abbad described the black community of "Cangrejos" as being a
town dedicated to fishing, agriculture and cattle. The foundation of that settlement went back to 1760.

The 19th century represents the golden century of Puerto Rican socio-cultural and economical development. Although this recent development affected in some way the towns outside of the San Juan region, it was basically concentrated on San Juan Bay area. The 19th century economy was based on the free interchange of agricultural products and the sugarcane crop, which was the most profitable product of the time. The recent urban and economic expansion of the city was the result of the application of post 1863 Spanish political liberalism in Puerto Rico. The port was open to national and foreign ships; taxes were reduced to facilitate the international traffic and the development of commerce and industry. As a result of this policy, the San Juan Bay area's importance as an urban and commercial center of Puerto Rico was strengthened.

The urban expansion was due to the black and Canary population coming after 1814 to work on the sugarcane plantations. At the same time there was some rural to urban migration occurring. By 1845, there were between 12,000 to 14,000 persons in San Juan and its surrounding area.

The developed area of San Juan extended toward the southeastern part of the city. In 1805 the governor Toribio Móntes ordered the construction of 12 barracks in the area of Puerta de Tierra, which existed until 1819 when they were destroyed by a hurricane. In 1804 a battery was established in La Puntilla, also known as "La Marina," to protect the Bay from enemy attacks. Both of these structures were the first houses and buildings established in these areas.
Throughout the century, the area of "La Puntilla" included the "Arsenal", the storage building called "Almacenes de depósitos" and the "Casa de Empleados". Also located in the immediate area was a jail called "Correccional de Vagos de la Puntilla". During 1847 the construction of a group of masonry buildings was begun; they were burned in 1854. In 1878 about 98 wood houses existed in the area of La Puntilla. These houses existed until the end of the 19th century.

The area of Puerta de Tierra included, by the end of the 19th century, a catholic church, an asylum building, the building of the Ateneo Puertorriqueño constructed in 1876, the train station and a small settlement submitted. Fig. 4-7 shows the southeastern expansion of La Puntilla and Puerta de Tierra.

Inside the wall, the expansion of the city was also significant. In 1814 the new cemetery of the city, "María Magdalena de Pazzis", was inaugurated. The old cemetery, located behind the Cathedral, was abandoned by this time. In 1820 the public lighting system was inaugurated. By this year the paving of the streets was already finished, but the original stone pavement was replaced by cobblestone paving in 1833. Most of the poor people's homes had disappeared by 1845 when Pedro Tomás de Córdova visited the city. After describing its structures, houses and buildings, he concluded that:

"The height of the city, its straight streets of equal width, the cobblestone paving and shining sidewalk, the regularity, candor, and system, the breezes that refresh without obstacle, its spacious walls and wonderful castles, form a marvelous picture, making it one of the most beautiful settlements in America."

The urban expansion outside the San Juan Islet spread widely after 1850. Besides the small settlement of Puerta Tierra and the town of Cangrejos, two new towns, Cataño and Palo Seco, appeared in
Fig. 4-7. Map prepared by Manuel F. Castro, 1862. Source: María de los Angeles Castro, Arquitectura en San Juan de Puerto Rico, Siglo XIX, 1980.
the surrounding area of San Juan Bay. Both towns consolidated throughout the century as a major agricultural settlement. The Cataño area specialized in sugarcane, cattle, and coconut production, and the Palo Seco area specialized in fishing and coconut cultivation. 

Apparently the railroad system, built in 1880, was responsible for the suburban expansion of the region. The train traveled through San Juan to Cangrejos, known at this time as Santurce, and as far as Rio Piedras following the main road (Fig. 4-8). Together with the train system a carriage system was established along the same route. The train extended from San Juan as far as the area of Bayamón and Cataño.

The symbol of the last urban expansion of the city was the eastern wall demolition (Fig. 4-9). Since 1880 the population was requesting this demolition from the government because of the explosive urban expansion within the city. The plans for widening the city were submitted by the municipal architect Pedro Cobreros in 1881. After sixteen years the government made the final decision to demolish one of the most important Hispanic symbols: the eastern section of the wall and the city land door.

Part of the restoration project of the periphery of the city was the construction of two strolls. The first one was named "Covadonga" or "Paseo de Puerta de Tierra". In 1854 the second avenue, called "Paseo de la Princesa", was finished. A large line of trees covered the edges of this "paseo" (Fig. 4-10). Between this avenue and the southern section of the wall was a botanical garden, constructed during these years.

The main square of the city was also restored. The "Plaza de Armas" was paved in 1841 and reconstructed several times throughout
Fig. 4-8. The San Juan-Río Piedras Train.

Fig. 4-9. The Santiago City door. Source: Photos courtesy of the Historical Archive of Puerto Rico.

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Fig. 4-10. Paseo de la Princesa. Photo courtesy of Historical Archive of Puerto Rico.

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the century; being finally restored in 1859. The "Plaza de Santiago" was converted into the head square of the Covadonga Avenue. It was restored in 1866. Another square paved in 1868 was the Santo Domingo Square, located at the northern side of the Dominic Convent.81

When the 19th century ended the city had already registered a large urban transformation; however, this was only a sign of what would happen later. The big changes were still to come.

Military Structures

After 1530 the most important role played by the San Juan Bay area was that of the military center. As a result of the frequent English, French, and Dutch attacks on the city, the northeastern section of the bay was transformed into a military stronghold consisting of forts and walls.

After 1529, when the Carib Indians attacked the city for the first time, the government ordered the construction of a fort near the entrance channel to the bay.82 The actual construction of that fort did not start until 1537 and was finished in 1540.83 "La Fortaleza", the name used for this fort, was the first of all the military structures build around San Juan Bay. After "La Fortaleza" was built many people considered that it had been badly located. For that reason the fort was never used as a main defense post. In 1570 it was converted into the official residence of the governor; so it has remained until today.

The Spanish, recognizing the strategic position of Puerto Rico, planned that a second military structure was to be built later in an isolated spot in front of the bay. The construction of "El Morro" was
started in 1539. In 1554 it was just a small bulwark, and in 1589 a new section was added. The fort was completed by 1642.84

The major fortifications of the sixteenth century were almost completed by 1591. A small fort near San Antonio bridge was built at that time and was given the name of "El Boquerón" or "San Gerónimo". In addition, two stockades also existed; "La Perla" on the northern coast of San Juan city, and "El Cañuelo", located on a rock close to Isla de Cabras.85

In the first quarter of the 17th century all the forts and stockades started in the previous century were finished except for a small spot in the area of "La Puntilla".86 No significant forts were constructed in the next quarter of this century. However, the most conspicuous military work of the colonial period was done at this time, that is, the construction of the city wall. In only ten years, 1631-1641, the city was almost surrounded by this marvelous work of engineering which was 25 feet high and 18 feet wide. The city wall was not completed until 1771 when the San Cristóbal Castle was finished.87

Military constructions reached a turning point during the second half of the 18th century. Between 1750-1800 more military structures were constructed than in all the periods before. The "San Cristóbal" Castle was finished by 1771. With the coming of the engineer O'Reilly (1760-1770) the defense lines were finished, the southern section of the city wall reconstructed, and El Morro Castle enlarged. O'Reilly recommended the construction of the "San Gerónimo", "Miraflores", and "El Arsenal" bastions.88
A detailed description of all the military structures constructed in the second half of the 18th century has been presented by Zapatero. The work includes the reform of "El Morro" and "San Cristobal" castles. Most of the military works done after 1775 were concentrated on the eastern side of the city. This obviously was its weakest section.

Due to the state of war between Spain and England, it was necessary to reinforce the eastern point of the Islet. A group of small forts were constructed in the section of Puerta de Tierra and on the northern coast of the San Juan Islet. These included the following forts; "La Princesa", "El Espigón", "San Carlos", "El Abanico" and "Santa Teresa".

The San Gerónimo Castle was rebuilt in 1783; twelve military posts were established in the area within the San Gerónimo fort, the Escambrón beach and the San Antonio bridge. A powder warehouse was established behind the San Gerónimo fort and various lines of defense of military curtains were established between the northern coast and the San Antonio channel. The first of these lines ran from El Escambrón beach to the San Antonio bridge. The second ran from the Escambrón swamp to the San Antonio channel, and a third curtain, located at the eastern half of the Islet, ran from the northern coast to the San Antonio channel (Fig. 4-11). The only structure being rebuilt outside the eastern area was the small fort located in the area of "La Marina", restored in 1783.

When Abbad y Lasierra visited the City in 1782 he observed the golden age of the military constructions, exclaiming:

"the most magnificent and wonderful that exits in this city are the fortification works."
Fig. 4-11. Map showing the location of the Military Structures in the San Juan Islet during 1847. Source: María de los Ángeles Castro, Arquitectura en San Juan de Puerto Rico, Siglo XIX, 1980.
In 1783, when Juan Francisco Mestre finished the military works designed by O'Reilly, the San Juan Bay area and the San Juan Islet in particular had been converted into a military post.

The 19th century was a relatively peaceful period for San Juan city. The construction of urban buildings and the commercial expansion of the city substituted the previous military emphasis. Since then the military structures remained in the San Juan Bay area as a remembrance of its early history.

Nevertheless, the emphasis on the military function of the bay constituted the main events that took place during the colonial period and was responsible for important modifications of its natural landscape.

**The Port of San Juan**

When urbanization extended to the San Juan Islet, in 1520 a new pier was constructed on the western side of the main plaza. Throughout the 16th century the port served as a center for the urban expansion of San Juan. According to Castro de Dávila the city started to grow close to the city gate ("Puerta del Puerto de San Juan") around the Cathedral and Santo Domingo Square (Fig. 4-3).

Apparently, the location of the port in that area corresponded to the recommendation made by Rodrigo de Figueroa in 1518. The importance of the port was based on the fact that it was the only place designated by the "Casa de Contratación" in Seville as the legal port trade with the island. A total of 47 ships called there in 1527.

According to the maps representing this period (Fig. 4-12), the western and eastern areas of "La Puntilla" were used as provisional...
Fig. 4-12. San Juan and its Main Port in the 17th century. Source: Historical Archive of Puerto Rico.
ports. Possibly this area was used to store merchandise and equipment, as it was later.

During the 17th century the commercial activities of San Juan were reduced significantly. The taxes assigned by the Spanish crown were too high and, therefore, only a few ships stopped there in the middle of that century. As Vilar indicated, the only excitement occurred when an unexpected galleon arrived at the port. Even so, in 1698 the port that registered most commercial traffic in Puerto Rico was San Juan.

During this time the piers located in the eastern area of "La Puntilla" began to be used as well, especially after the southwestern section of the city wall and the door called "San Justo" were finished.

Although there are not many contemporary descriptions of the San Juan port, the information available describes it as probably being the most important center in the city. According to Ramírez de Fuenleal, by 1529, the city of San Juan completely depended on provisions imported through its waterfront. In 1582 the port was described as being strong and impregnable. Juan de Laet described the port in 1640 in this way:

"...its port, at the same time that it is spacious, it is protected from the winds and the enemy's invasion."

In 1782 Abbad y Lasierra related more details about the western and eastern ports. He wrote:

"On this western side of the wall are the doors of San Juan and San Justo. The first leads to the San Juan inlet, and this one is the most used to enter and get out by sea to the Island. The second port included the pier and the custom house, which were close to the two docks with its piers for the king's boats, as well as
one extraordinary warehouse of the black company, made of wood inside the water."  

Based on Abbad's description it is possible to deduce that the western port was more important than the eastern port throughout the first two centuries of the colonial period; but later, with the increasing commercial activities and port facilities, the eastern port became more important. By 1805 the western port was completely abandoned because it apparently was in bad condition. A new pier was constructed close to the old western one, but it was only used for the transportation of agricultural products and fish coming from the area of Bayamón river and Palo Seco, where a pier was already constructed for these particular purposes.

In 1816, 378 ships, including the coasting trade ships called at the port of San Juan. When Tomas de Cordova observed San Juan in 1845, he described the eastern port as being the most important commercial area of the city. He explained that this pier was surrounded by a group of storehouses, commercial buildings, houses and other port facilities.

Close to the western pier, or the old San Juan port as it was known after 1850, slums were formed after 1835 (Fig. 4-7), thereby deteriorating even more the immediate area of this port, and thus its importance.

The last description of the port of San Juan was made by Manuel Ubeda y Delgado in 1898. He described the eastern port as being a pier constructed of stone with three stone stairs used for shipment. Close to this pier was a wooden shed. Surrounding the pier on the western side was the custom house and in the eastern side the warehouse known as "Depósito Mercantil" (Fig. 4-13).
Fig. 4-13. Map of the Port of San Juan in 1891. Source: María de los Ángeles Castro, The Place of San Juan de Puerto Rico Among Hispanic American Cities, 1936.
The period between 1850 and 1899 was a time of extensive port facility construction. More than 80 projects were constructed according to the documents of the Fund of Public Work in the Historical Archive of Puerto Rico. These projects are included in Table 4-2. This table shows the year of the project, its file and record number in the Puerto Rican Historical Archives, and a general description of the project.

Among the works done during this period were the construction of wood houses, warehouses, cabins, sheds, docks, dikes, piers, ramparts, levees, moles, coal deposits, and trail facilities. It also included the filling and dredging of the immediate port area and the cutting of the vegetation, particularly the mangrove areas (Fig. 4-13).

"Junta de Obras del Puerto" was the institution in charge of the structure construction and work permits of the port of San Juan. In 1886 and 1889 they authorized the widening of the eastern pier, the dredging of its area and the construction of the northern section earthworks. In 1897 they ordered the widening and dredging of the piers, the construction of a new pier close to the train station, the construction of a group of storagehouses between the piers and the train station, the construction of another storagehouse in the area of "Isla Grande", the landfilling in the coastal area of "La Marina" and the reconstruction of Isla de Cabra's pier.

Some of these works can be appreciated in the 1896 map (Fig. 4-14). As can be seen, the most affected area was the southeastern section of San Juan. Other important features were: "La Carbonera", located in the southeastern section of the city, the train station,
## TABLE 4-2

Port facilities constructions 1838-1900 in the San Juan Bay Area

<table>
<thead>
<tr>
<th>Year</th>
<th>File</th>
<th>Record</th>
<th>Project Description or Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>1838</td>
<td>95</td>
<td>5 Extention and widening of San Juan eastern pier</td>
</tr>
<tr>
<td>2.</td>
<td>1848</td>
<td>96</td>
<td>9 Data related to the construction of the eastern pier of San Juan</td>
</tr>
<tr>
<td>3.</td>
<td>1855</td>
<td>97</td>
<td>11 Construction of a dwelling ground in front of the southern storehouses of La Marina</td>
</tr>
<tr>
<td>4.</td>
<td>1858</td>
<td>6</td>
<td>3 The dredging of San Juan Bay</td>
</tr>
<tr>
<td>5.</td>
<td>1858</td>
<td>2</td>
<td>1415 A carbon deposit established by José María Cartagena</td>
</tr>
<tr>
<td>6.</td>
<td>1866</td>
<td>98</td>
<td>468 Cleaning of the western port sinkhole</td>
</tr>
<tr>
<td>7.</td>
<td>1867</td>
<td>98</td>
<td>470 Restauration of the western port</td>
</tr>
<tr>
<td>8.</td>
<td>1869</td>
<td>7</td>
<td>347 Information about the dredging of San Juan port</td>
</tr>
<tr>
<td>9.</td>
<td>1870</td>
<td>98</td>
<td>966 Storehouse construction and east pier prolongation</td>
</tr>
<tr>
<td>10.</td>
<td>1872</td>
<td>101</td>
<td>351 Restauration of the eastern pier</td>
</tr>
<tr>
<td>11.</td>
<td>1873</td>
<td>101</td>
<td>60 Possible extraction of rock material from Cabras Island to be used in the pier's restauration</td>
</tr>
<tr>
<td>12.</td>
<td>1875</td>
<td>139</td>
<td>877 Drainage of the Custom house area</td>
</tr>
<tr>
<td>13.</td>
<td>1882</td>
<td>166</td>
<td>1734 Construction of a wood pier in the Cataño beach by Don Ramón Valdés</td>
</tr>
<tr>
<td>14.</td>
<td>1883</td>
<td>139</td>
<td>28 Don Manuel Godinez began to dry the mangrove located east of the capital</td>
</tr>
<tr>
<td>15.</td>
<td>1884</td>
<td>139</td>
<td>12 Don Anastacio Vargas began to fill a ground plot #14 in the area of La Carbonera</td>
</tr>
<tr>
<td>16.</td>
<td>1884</td>
<td>8</td>
<td>4 Real order for dredging the San Juan Bay</td>
</tr>
<tr>
<td>17.</td>
<td>1884</td>
<td>103</td>
<td>34 An iron pier constructed by the Puerto Rican Maritime Corp.</td>
</tr>
<tr>
<td>18.</td>
<td>1886</td>
<td>104</td>
<td>402 Restauration of a private pier in the Island of Mata Redonda</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Year</th>
<th>File</th>
<th>Record</th>
<th>Project Description or Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.</td>
<td>1886</td>
<td>9      5</td>
<td>The second dredging of the San Juan Bay area</td>
</tr>
<tr>
<td>20.</td>
<td>1888</td>
<td>106    8</td>
<td>Restablishment of the Arsenal Masonry pier</td>
</tr>
<tr>
<td>21.</td>
<td>1888</td>
<td>139    57</td>
<td>Landfill of the area behind ground plot #14 in La Carbonera</td>
</tr>
<tr>
<td>22.</td>
<td>1890</td>
<td>140    81</td>
<td>Selling of the land filled behind ground plot #14 in La Carbonera</td>
</tr>
<tr>
<td>23.</td>
<td>1890</td>
<td>74     91</td>
<td>Storehouse construction in the area of La Marina</td>
</tr>
<tr>
<td>24.</td>
<td>1890</td>
<td>14     175</td>
<td>Acquired material for rampart construction</td>
</tr>
<tr>
<td>25.</td>
<td>1891</td>
<td>2      100</td>
<td>Elimination of cabins close to the eastern pier of San Juan</td>
</tr>
<tr>
<td>26.</td>
<td>1892</td>
<td>141    208</td>
<td>Landfill the eastern side of the eastern piers</td>
</tr>
<tr>
<td>27.</td>
<td>1892</td>
<td>166    1734</td>
<td>Permission by Mr. Paul Van Syker for the construction of a wood pier in Cataño beach</td>
</tr>
<tr>
<td>28.</td>
<td>1892</td>
<td>19     122</td>
<td>The dredging of San Juan Bay</td>
</tr>
<tr>
<td>29.</td>
<td>1892</td>
<td>19     216</td>
<td>Dredging activities on the norther side of Isla de Cabras</td>
</tr>
<tr>
<td>30.</td>
<td>1892</td>
<td>20     124</td>
<td>Channel construction on the norther side of El Cañuelo</td>
</tr>
<tr>
<td>31.</td>
<td>1894</td>
<td>136    156</td>
<td>Widening of the eastern pier shed</td>
</tr>
<tr>
<td>32.</td>
<td>1894</td>
<td>2      229</td>
<td>Don Antonio Rivera constructed a floating coal deposit</td>
</tr>
<tr>
<td>33.</td>
<td>1894</td>
<td>23     147</td>
<td>Some possible dredging of the &quot;Largo&quot; sandbank</td>
</tr>
<tr>
<td>34.</td>
<td>1894</td>
<td>142    289</td>
<td>Establishment of a site for the mining of coal deposits in the eastern side of San Juan pier</td>
</tr>
<tr>
<td>35.</td>
<td>1894</td>
<td>142    144</td>
<td>Good use of mangrove cut vegetation in Santa Catalina and Portugues Channel</td>
</tr>
<tr>
<td>36.</td>
<td>1895</td>
<td>142    175</td>
<td>Land clearing in the area of San Patricio</td>
</tr>
<tr>
<td>37.</td>
<td>1895</td>
<td>142    171</td>
<td>Land clearing of the mangrove areas</td>
</tr>
<tr>
<td>38.</td>
<td>1895</td>
<td>23     172</td>
<td>The dredging of the Cataño channel</td>
</tr>
<tr>
<td>Year</td>
<td>File</td>
<td>Record</td>
<td>Project Description or Subject</td>
</tr>
<tr>
<td>------</td>
<td>------</td>
<td>--------</td>
<td>--------------------------------</td>
</tr>
<tr>
<td>39.</td>
<td>1896</td>
<td>142</td>
<td>247 The widening of San Juan city</td>
</tr>
<tr>
<td>40.</td>
<td>1897</td>
<td>142</td>
<td>401 Destruction of the east rampart</td>
</tr>
<tr>
<td>41.</td>
<td>1897</td>
<td>142</td>
<td>201 Land plot distribution in the east rampart</td>
</tr>
<tr>
<td>42.</td>
<td>1897</td>
<td>74</td>
<td>12 The construction of the warehouse &quot;Deposito Mercantil&quot;</td>
</tr>
<tr>
<td>43.</td>
<td>1898</td>
<td>30</td>
<td>375 Description of the material dredge</td>
</tr>
<tr>
<td>44.</td>
<td>1900</td>
<td>89</td>
<td>22 San Juan Bay sounding</td>
</tr>
</tbody>
</table>

Source: Historical Archives of Puerto Rico, Fund of Public Works, Series of Ports and Piers, San Juan, Puerto Rico.
Fig. 4-16. Map showing the widening and extension of the Port Works in 1896. Source: María de los Ángeles Castro, Arquitectura en San Juan de Puerto Rico, Siglo XIX, 1980.
located within "La Carbonera", and the extension of the earthwork projects.

By the end of the 19th century the port area was submitted to restrictive conservational laws. All construction was regulated, waste disposal was prohibited and all port facility destruction was to be repaired by the person who caused the harm. These restricted conditions gave architectural uniformity to the port area. At the beginning of the 20th century the port was the major center of San Juan city, and therefore, of the Island of Puerto Rico (Fig. 4-15).

The Natural Landscape of the San Juan Bay Area

The bay discovered by the Indians and colonized by the Spaniards with the conspicuous force of the Negroes and "criollos", has significantly changed through time. Fortunately, many persons have noted these changes for posterity.

According to the 16th century descriptions, the bay area was a typical estuarine system characterized by extensive areas of mangrove, marsh and hardwood vegetation, wide beaches, extensive sand dunes, eolianites, sand reefs, sandbanks, tidal channels, lagoons, and river mouths (Fig. 4-16). In 1519, Rodrigo de Figueroa drew the first map pictures of the bay area, and simultaneously registered the first change in the natural landscape.

Right next to the Condado lagoon (Fig. 4-16) was a coastal area covered by mangrove. The northwestern side of this mangrove included a narrow but elongated peninsula, ending at the middle of the lagoon, exactly where a sand bank was located. A large section of beach rock covered the northern part of the Condado peninsula.
Fig. 4-15. Photo of the Port of San Juan at the beginning of the 20th century. Source: Courtesy of the Historical Archive of Puerto Rico.
Figure 4.16 Natural Landscape of the San Juan Bay in 1508
The southern section of the San Antonio channel consisted of two extensive mangrove islands ("Isla Grande" and "Isla Miraflores") and one mangrove peninsula. All three were separated by several narrow channels and a large inlet (Ensenada de Miraflores). The area located on the back part of Isla Miraflores consisted of peat deposits. From this point until the Martín Peña channel the bay comprised a narrow line of sand deposits behind which was located another large mangrove forest.

The area surrounding the Martín Peña channel consisted of a dense mangrove forest which extended west into the back section of "Punta Cataño". Several small tidal channels and creeks were located within this region as well as various haystack hills ("San Patricio", "Monte Canejas") that were located on the back side of this forest. The shoreline included a wide sand beach with dunes extending from the Martín Peña to the Caparra Port. The Martín Peña channel and Puerto Nuevo river were the major sediment outlets for the formation of this beach system. A system of consolidated sand dunes formed a long ridge along the coast of Caparra's port. A small beach covered the littoral line between the port of Caparra and the southern border San Fernando channel, which served as the division line between the mangrove and marshland vegetation. A small peat area was also located between the two areas.

In 16th century, the natural landscape of San Juan Bay could be divided into four major physiographic regions: (1) the San Juan Islet, (2) the area extending from the San Antonio channel to the Martín Peña channel; (3) the area extending from Martín Peña to San Fernando channel; and (4) the area extending from Punta Cataño to Palo Seco,
including the sand reef called "Isla de Cabras" and "Las Cabritas" (Fig. 4-16).

The San Juan Islet then constituted of an elongated cemented sand dune protected by a line of sand reefs in the north, of which the most significant one was "Peñón de San Jorge". The Islet's irregular coast was characterized by the formation of small sand beaches and a cliff, the latter being the highest point on the western side of the Islet. The cliff originated in the area of the present location of "La Perla" and surrounded the western point up to the port of San Juan. In this area the cliff receded, permitting the formation of a sand beach in front of the old port. This beach extended to the south, forming a deposit surrounded by a mangrove forest ("La Puntilla"), which ended in the area where the eastern pier was constructed. An elongated mangrove forest originated at this point, covering the entire southern shoulder of the San Juan Islet and abutting it southeastern edge.

The eastern coast of the Islet was characterized by a combination of marshland and beach deposits. A beach rock was located on the northeastern point of the Islet (Punta El Escambrón). Its inner part was covered by hardwood forest.

The San Antonio channel separated the Islet from the mainland. It was relatively narrow and shallow, being also connected to the Condado lagoon. A wide sand bank appeared in the middle of these two water bodies.

The most impressive beach system consisted of the area extending from Punta Cataño to Palo Seco ("Playa de Cataño"). In this region the beach was more than 120 feet wide (40 meters) in some sections. The area behind the beach, excepting the southern section of the
Fig. 4-17. San Juan Bay and its surrounding areas in 1678, according to Luis Venegas Osorio. Source: Juan Manuel Zapatero, La Guerra del Caribe en el Siglo 18, 1964.
river, was basically covered by marsh vegetation. Various small tidal channels connected this swampy area with the bay. The peninsula of Palo Seco represented an elongated river mouth spit covered with grass and some mangrove vegetation on its southern edge. Several sand reefs were exposed to the surface forming a north-south line in front of the Palo Seco area. Located in the opposite direction were Isla de Cabras and "Las Cabritas".

The bay has been described as being shallow and narrow during the first century of colonization and this condition remained basically unchanged until extensive dredging of the bay in the second half of the 19th century. The average depth was 10 feet (3 meters), and reached a maximum depth of 20 feet (6.10 meters) in the central channel and a minimum of 1 foot (0.26 meters) on the coastal border. The bay contained numerous sand banks and tidal channel system exposed during the low tide period. The best known of these sand banks were "Bajo Largo" located in the middle of the bay, "Bajo de la Puntilla", "Bajo del Condado", "Bajo Punta Larga", and "Bajo de Cataño". Large submarine sand deposits occurred in the southern part of "Isla de Cabras", in the eastern section of Palo Seco and in the northern end of Cataño beach.

The main bay channel was the central one; however, due to the sediment load carrying capacity of the rivers and channels surrounding the bay, this channel was narrow and shallow, with extensive sand shoals always causing difficulties for incoming ships. The bay had a second channel, called "El Cañuelo", located between "Isla de Cabras" and the tip of "Palo Seco". This channel was narrower and less deep than the channel at the main entrance.
None of the 16th, 17th or 18th century documents about San Juan have provided us with a complete description of the bay area; however, incomplete description of some of the areas are rather common. Rodrigo de Figueroa characterized the Islet as being topographically smooth, with good soil and covered with a solid crown forest. He perceived the area of Caparra as being swampy, humid and wild. In 1598, Layfield described the bay Islet as being covered by mostly evergreen forest, "as rare that will confuse any botanical professor of England", he concluded. In 1640 Juan de Laet described the same forest as dense and impenetrable.

In 1782 Abbad y Lasierra described the bay area in more detail; "La bahía es bastante capaz, de buen fondo y resguardada: la lengua de tierra que llaman La Puntilla, se avanza en al agua y la divide por el medio, dejando formadas dos ensenadas bastante capaces en que pueden fondear navios de línea. La entrada del puerto necesita de algún cuidado por un peñasco que sale debajo del agua. Los escombros de las fábricas de las casas, que llevan las lluvias por falta de policía, han deteriorado bastante la bahía. En lo menos hondo de ella hay muchos manglares que cubren el agua, y una hermosa isleta que llaman Miraflores...".

He also described the area of San Gerónimo and Cangrejos "...el de San Gerónimo que defiende la boca de comunicación que tiene el mar de afuera, con la Bahía en esta parte, y aun que solo puedan pasar lanchas, por los arrecifes que la cubren, siempre es la parte mas expuesta... Desde aquí (Puente de San Antonio) empieza a disfrutarse la frondosidad de los arboles y praderas de que está cubierta la Isla... a distancia de legua y media de la ciudad encontramos el pueblo de Cangrejos... El territorio que goza es una península, que forma el mar de afuera, el de la Bahía de Puerto Rico, y el caño de Martín Peña, que saliendo a la bahía va a encontrarse con la boca de Cangrejos... Parte del terreno es arregadizo... Las inmediaciones de los caños nombrados, están cubiertas de mangles.".

The first scientific exploration of the San Juan bay area was done by a group of French natural historians in 1797 under the
leadership of Pierre Ledré. Their studies mainly concentrated in classifying the natural vegetation of the area. Good descriptions remain of the southern section of the bay and El Condado sector. According to Ledru, the banks of the Puerto Nuevo river were swampy areas covered by ferns, lianas and red mangrove. The area next to the "Hacienda San Patricio", where they stayed for more than two months, was covered with grass. Close to San Patricio Ledré discovered a creek (probably "Quebrada Margarita") which was covered by ferns (Polipodium arboreum, P. spinosum), according to his own description.

In his trip to "Boca de Cangrejos", Ledré described the area of El Condado as being sandy and covered with "acacias" (mimosa), coco plums (Chrisobalanus icaco), "pajuiles" (Anacardium occidentale) and other shrubs. The dimensions of the bay, according to Ledru, were 3 1/2 maritime miles long and 4/5 of a mile wide. The channel was able to handle between 300-400 ships and had a depth of 2 to 7 French fathoms.

The most complete description of the natural landscape in the San Juan bay area was made during the colonial period by Pedro Sánchez de Toca in 1890. His description included the most important features of the area surrounding the bay, as well as its bathymetry and bottom conditions (Fig. 4-20). He described the area in the following way:

"The port of San Juan includes in the north one Islet, in which its southwest end is separated from the coast by a narrow channel ("San Antonio") that holds a bridge. In its southern and eastern sections, the port is protected by a low mangrove forest and in the west by "Isla de Cabras" and "Las Cabritas" and a shallow water sandbank. Isla de Cabras and "Las Cabritas" are four small islets that include two isolated rocks in the extremes. Over "Isla de Cabras" are several buildings and in front of its northeastern point ships
Fig. 4-20. Bathymetric map of San Juan Bay, 1888. Source: United States Marine and Naval Division.

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ran aground in the night. The southern Islet, called "El Cañuelo, includes a bulwark for defending the western side of the port. The pass between "El Morro" and "Isla de Cabras" has a sand bank, making dangerous the entrance of any ship that drafts more than 22 Spanish feet (6.13 meters). The general direction of the pass is toward the southeast. This pass is surrounded by a series of sandbanks that extend from "El Morro" to "La Puntilla". These sandbanks are called "Santa Elena" or "La Laja", "San Agustín" or "El Tunante" and "Los Alfeniques". The sandbanks are identified by buoys painted an aluminum color. There are also buoys in the "Yufri", "Anegado" and "Punta Larga" shoals. The interior port is located at the northeastern side of "La Puntilla" and it is the most comfortable and protected for commercial ships. Its boundaries are; to the west, "El Arsenal"; to the north, the Custom house and the piers, the Puerto Rican Ship Vapor Company; to the east, "La Isla del Carbón" and a section of "Isla Grande"; and to the south, the northern section of "Punta Largo" sandbank. In 1884 ships of 22 feet (6.13 meters) of draft, entered to this protected port, but after the dredging extended to the Yufri sandbank, ships that drew 23.8 feet (6.63 meters) could enter. In the same channel at the western side of "Puerta de San Juan" it was possible for ships of 27.4 feet (7.63 meters) of draft to enter. The place used to stop the boats that stayed in the bay was the channel formed by "Yaboa", "Anegado" and the "Yufri" sandbanks, located south of "Punta Larga" shoal. The ships reconstruction was done on the northeastern side of the port where a repair dock existed. A coal deposit was there and this coal was shipped immediately through flatboats. The national warships got their water from the Arsenal cisterns, but during the dry period they took their water from the waterspring in "Miraflores" or from the Bayamón river. During the high tide the sea rises about 1.6 feet (0.44 meters)."

Hurricane Impact on Landscape Changes

Undoubtedly one of the main agents changing the natural and cultural landscape of the San Juan bay area were hurricanes. Evidently these tropical storms caused a lot of destruction and harm to the city of San Juan and its population. The strength of these climatic events must have had an effect on the biogeography, geomorphology, and ecology of the bay.
According to a description given by Herrera and Córdova, hurricanes were among the most feared enemies of the islanders. The impact of this type of phenomenon was such that a witness said:

"Vino a esta ciudad halló todos los navíos en el puerto estaban al través y perdido uno de ellos, desfondado, y los otros encayados en tierra y se hicieron pedazos... Estaban todas las haciendas de los vecinos de esta ciudad quedan destruídas, sin quedar en ellas conucos ni bohíos y que ha visto este testigo que los montes estan rajados y caídos."

During the Caparra period two minor storms hit the San Juan bay area. The first occurred in August of 1508 and the second in July of 1515. No major damage was noted. In 1526 a storm destroyed the crops, houses, and buildings of the city of San Juan. Five successive storms struck the San Juan area in 1530, leaving the population in the most miserable of conditions.

Two other hurricanes hit the island in 1537, destroying all the cultivated land and drowning a large number of people. A third storm hit the city in 1546, destroying part of "La Fortaleza". This series of storms created an erosion problem in the cliff where "La Fortaleza" was built. A large wall was constructed to stop the erosion and to control the strong waves that hit the cliff. Landslides also occurred in the area around the San Antonio bridge.

Three other minor hurricanes occurred in Puerto Rico after 1550: the first in August 1568, the second in August 1573, and the third in September of 1573. No evidence exists about the effect of those storms in the San Juan bay area. There seems to have been very little impact on the city of San Juan, its population, and the bay.

The harm caused by the hurricanes was one of the principal reasons for some of the poverty in San Juan throughout the 17th
The first hurricane of this period hit the city in 1615, devastating the city, and causing extensive damage to the port area. Another strong hurricane occurred in 1626 destroying the roof of the Dominique Convent. Several other minor hurricanes were registered in 1641 and 1657, 1673 and 1695, when a storm demolished the Cathedral's roof.

Twenty-three hurricanes struck the San Juan bay area during the 18th century. The most dangerous were "Santa Rosa" in 1730 and "Santa Rosa II" in 1738. "Santa Elena" in 1751 and "San Augustín" in 1772 were probably the most furious hurricanes of the century. More than 35 storms were recorded during the 19th century, of which "Santa Ana II", in 1825, and "San Narciso", in 1867, affected the bay area considerably. The first destroyed the San Antonio bridge and the poorest slums of the city, and also sank all the boats in the bay. The second significantly affected the bay area, a witness said:

"the bay was a real catastrophe, the hurricane destroyed the forest and it sank under the waters." Other strong 19th century hurricanes were "San Agapito" in 1807, "San José" in 1816, and "San Mateo" in 1819. The rest of the hurricanes were considered minor storms; however, their cumulative effect in the changing of the landscape in the San Juan bay area must necessarily be considered important, though we cannot measure them, even in a qualitative sense.

**Human Impact on Landscape Change**

Man probably had a more significant impact on the landscape of the San Juan bay area than hurricanes, throughout the colonial period. During this epoch man not only cleared the land for urban purposes,
but also filled and dredged some areas according to his needs. Through material extraction, man started some erosional problems and probably changed the natural sedimentological pattern of the bay.

The construction of urban and military structures claimed the clearing of vegetation. The dredging and filling of the land as well as the construction of the main road in 1551 eliminated large sections of the Islet's vegetation. Obviously the land claimed for urban and agricultural expansion were main factors in the land clearing process of this century.

Natural vegetation was substituted by the introduction of new species of plants. Some, especially coconut and sugarcane, formed part of the bay landscape by the end of the 16th century, when Layfield wrote:

"Dentro y alrededor de la población hay una gran cantidad de palmas de coco, las que además, de su excelente fruto dan un aspecto poético al paisaje." Since the Caparra period, laws were passed that required the introduction of European trees like pears and peaches.

The expansion of the city required the dredging and filling of some swampy areas immediate to the Islet. The construction of the San Antonio bridge required a stone filled platform, whereas the construction of the Aguilar waterspring needed some dredging. The filling of land was expected on the southern edge of the city as a result of the expansion of the city wall.

The extraction of land material was one of the most frequent human impacts in the bay area. Part of the development of Caparra included the use of material such as stone and sand extracted from the coastal areas of the bay. The same was true when the new city was
Built in the San Juan Islet. Large amounts of construction material used in the buildings of the San Juan military structures came from the bay. Considering the dimensions of the development process of San Juan throughout the colonial period, land material extraction must be considered an important impact.

The quality of the environment was not healthy. The city of San Juan did not have a municipal sewage system and residents disposed of their wastes in the street. A small stream and ditch were the only natural drainage systems of the city of San Juan. The stream ran by the foot of the hill of the Islet, collecting the waters and discharging them into the main channel of the bay somewhere near "La Fortaleza". The ditch ran from the northern section of the Islet to the southern part and into the bay. Both the stream and the ditch were eventually converted into channels. This way of waste disposal represented a health hazard as well as a source of pollution for the bay and the adjacent area. Abbad y Lasierra described this problem in 1782 in the following manner:

"The house debris, carried by the rain-water has significantly deteriorated the bay."

There seems to have been some thought concerning air quality. A city ordinance specified that all commercial activities dealing with odor-producing products had to be close to the bay so that the winds could clear the air quickly and residents were not exposed to such unpleasantness.

The introduction of dogs was an important factor in changing ecological relations in the San Juan bay area. Dogs contributed to the extermination of coastal crabs which were abundant in the mangrove forests.
Many of these disruptions of the environment happened in earlier centuries. In 1660 the forest area between the San Antonio bridge and "Puerta de Santiago" was cleared; particularly, the area was used for the construction of the main road and some military structures. According to the description of Diego Torres Vargas in 1647, large amounts of wood were obtained from the bay area for house construction.

The city had problems of urban concentration in this century. The construction of the city wall limited its expansion. As a consequence, the outside area of the wall was populated by slums where people lived in poor environmental conditions. Problems with the drainage system persisted in this century.

Some landscape changes occurred, again as a result of the ongoing human activities. A new human landscape was developing as the result of agriculture, cattle, urban and military activities in the area. By the second half of the 17th century some areas outside the San Juan Islet were already significantly altered. The nearby village of Palo Seco was modified by the construction of ranches used by the Negroes arrived. During this time the first considerations were discussed for widening the bay in order to expand it and make it into a better commercial port. The arrival of the engineer Churruca in 1780 responded in part to this idea. He constructed the first precise map of San Juan bay (Fig. 4-23) in which he also described the most important points and the natural condition of San Juan bay. After his studies, Churruca recommended the dredging of the bay, a project seriously considered by the end of the century.
Economic progress does not necessarily imply good environmental conditions, but the principle held true in the 19th century for San Juan bay. It was in this period that the deforestation process reached its maximum. The establishment of the coal industry in the San Juan bay coastal area eliminated large amounts of natural vegetation. The mangroves were perceived as an obstacle for the recent urban development and also as a source of air pollution caused by the unpleasant odors expelled. A good documented example of the mangrove elimination is the authorization to Manuel Adel in 1873 to clear and fill a mangrove area in Cataño beach. Inevitably the land was conceded to the person that filled the mangrove. One year later the landowner was supposed to begin a major construction project in the recent landfill. This process occurred very often and was the major cause of vegetation elimination in the surrounding area of San Juan Bay.

The major port works took place after 1888 with the filling of the eastern pier area, the construction of La Carbonera rampart and other minor fillings in Cataño (Table 4-2, numbers 21, 22, 24, 25, 40, 41).

Dredging activities began about 1858. The only dredging activities that involved all of the bay were the 1884, 1886 and 1892 dredgings. The 1890s dredgings were different from the initial ones because of the machinery involved. Other areas of dredging were the Cataño and El Cañuelo channels.

The construction of port facilities had an important impact on the coastal morphology of the area. By the end of the century there were about 8 piers, including eastern and western piers, Cataño, "Isla..."
Fig. 4-24. Distinctive features of the San Juan Bay Area, 1896.
Source: María de los Angeles Castro, Arquitectura en San Juan de Puerto Rico, Siglo XIX, 1980.
de Cabras", "Mata Redonda" and "Miraflores". \(^{140}\) In 1873 a duct was constructed in the San Antonio channel. In this area a rampart and various levees were also constructed. \(^{141}\) "La Carbonera", the most famous of the ramparts built in the bay, was used for transporting coal. Others ramparts were constructed close to the eastern pier. Even in areas as far as "Martín Peña" coastal facilities were constructed. \(^{142}\)

Some basic sanitary problems were solved by the end of the 19th century. Since 1800 the garbage have been deposited in a dump located in "La Puntilla". A second dump, located in "Puerta de Tierra", was also used. A drainage system was constructed by 1844, thereby improving the condition of the city, but deteriorating the ecological conditions of the bay. \(^{143}\)

Although the quality of the sanitary conditions improved, in comparison with the previous century, the general environmental quality by 1880s has been described as poor. \(^{144}\)

When the century was over there was no doubt about the human influence changing the nature of the San Juan Bay area.
CHAPTER IV

FOOTNOTES


2 Rouja, Vicente, "La Ciudad de San Juan Bautista 1508-1521", Revista Angela Luisa, (November, 1971), 59.

3 Figueroa, Loida, Breve Historia de Puerto Rico (Rio Piedras, Ed. Edil, 1979), 52.

4 One "legua legal" was equivalent to 4.2 km and a "legua comun" to 5.5727 km. The present location of Caparra is about 2.7 km (1.7 miles) from the "Puerto Viejo" coast. For further explanation see Roland Chardon, "The Linear League in North America", Annals of the Association of American Geographers (Vol. 70, No. 2, 1980), 129-153, and "A Quantitative Determination of a Second Linear League Used in New Spain", Professional Geographer, (Vol. 32, No. 4, 1980), 462-466.

5 Of all these structures today remains only Ponce de León's House.


The term "Estancia" refers to a multicrop farm. The nature of such farms are well described in Eugenio Fernandez Méndez, *Crónicas de Puerto Rico*, (Rio Piedras, Ed. Universitaria, 1973), 277.

Rouja, Vicente, op. cit., 59.

Zeno Vasquez, Francisco M. *Historia de la Capital de Puerto Rico*, (San Juan, Ed. Gobierno Municipal, 1959), 45.


Zeno, Francisco M., op. cit., 22.

Ibid., 45.


Coll y Toste, Cayetano, op. cit., Vol. 3, 111.

Ibid, 115.
By this time the city was known as "Ciudad de Puerto Rico", the name that was used until mid 1550s when by a Real decret, the name was changed to San Juan.

26 Tió, Aurelio, "El San Juan de los Ponce de León", Revista del Instituto de Cultura Puertorriqueña, (Vol. 52, 1971b).

27 Dooley, Eliza B., Old Churches of San Juan, (San Juan, Imprenta Venezuela, 1935), 21; Rafael Ramírez de Arellano, La Capital a Través de los Siglos, (San Juan, 1950), No pagination.

29 Brau, Salvador, op. cit., 62.


33 Morales Carrión, Arturo, op. cit., 155.

34 Murga Sanz, Vicente, op. cit., 44.

35 Anonymous, *Descripción de la Ciudad de Puerto Rico Siglos XVI y XVII*, Revista del Instituto de Cultura Puertorriqueña, Vol. 53, 1971, 78; Rafael Ramírez de Arellano, op. cit.,

36 Anonymous, *Descripción de la Ciudad de Puerto Rico*, op. cit., 80; Rafael Ramírez de Arellano, op. cit.,

37 Rodríguez Morales, Luis, op. cit., 62.

38 Anonymous, *Descripción de la Ciudad de Puerto Rico*, op. cit., 77.


41 Real Díaz, José, *Cartas del Cabildo de San Juan Bautista de Puerto Rico*, (San Juan, Ed. Municipio de San Juan, Instituto de Cultura Puertorriqueña, 1968), 122, 125, 148.

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42 Zeno, Francisco M., op. cit., 117; Adolfo de Hostos, 1948, op. cit., 51.
43 de Hostos, Adolfo, Crecimiento y Desarrollo de la Ciudad de San Juan, (San Juan, Ed. Departamento de Intrucción Pública, 1957), 7.
44 Coll y Toste, Cayetano, op. cit., Vol. 12, 130; Salvador Brau, op. cit., 88.
45 de Hostos, Adolfo, 1948, op. cit., 18; María de los Angeles Castro, op. cit., 54.
48 de Hostos, Adolfo, 1957, op. cit., 6; "Vecinos" is the Spanish word for family chief. Using an average of 3.5 members per family, we can conclude that 1,600 vecinos were equivalent to 5,600 persons.
50 Blanco, Tomas, Prontuario Histórico de Puerto Rico, (San Juan, Ed. Biblioteca de Autores Puertorriqueños, 1955), 34.
52 Real Díaz, Jose, op. cit., 192.
54 Coll y Toste, Cayetano, op. cit., Vol. 9, 122.
55 "Hatós" refers to cattle farms, the best example known in the San Juan Bay area is "Hato Rey", which remembers that at one time this land belonged to the King or "Rey" of Spain.

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56 Rodríguez Morales, Luis, op. cit., 9.
57 Coll y Toste, Cayetano, op. cit., Vol. 9, 377.
60 Ledrú, André Pierre, *Viaje a la Isla de Puerto Rico en el Año de 1797*, (San Juan, Imprenta Militar, 1863), 50.
61 Castro, María de los Ángeles, op. cit., 238.
62 Ibid, 79.
63 Abbad y Lasierra, Fray Iñigo, *Historia Geográfica Civil y Natural de la Isla de San Juan Bautista de Puerto Rico*, (Río Piedras, Ed. Universitaria, 1959), 99-107; Fray Iñigo Abbad y Lasierra, "Diario del Viaje a la América", *Boletín de la Academia Puertorriqueña de la Historia*, (Vol. 18, 1977), No pagination; Fray Iñigo Abbad y Lasierra, "Descripción de la Ciudad de Puerto Rico en el Siglo XVIII", *Revista del Instituto de Cultura Puertorriqueña*, (Vol. 53, 1971), 43-47. The term "bujío" means a thatch house and the term "arrabal" means a slum area. The fragment of Lassierra's description has been translated by the author of this dissertation.
In 1814, about 80 persons arrived in San Juan from the Canary Islands.

Beauchamp, Torres, Plan Maestro de Puerta de Tierra, (San Juan, Ed. Torres Beauchamp Marvel y Asociados, 1980), 11.

Zeno, Francisco M., op. cit., 86-87, 287; Torres Beauchamp, op. cit., 12; María de los Angeles Castro, op. cit., 369.

de Hostos, Adolfo, 1948, op. cit., 440; María de los Angeles Castro, op. cit., 166-169.

de Hostos, Adolfo, 1948, op. cit., 425; Francisco M. Zeno, op. cit., 452.


Coll y Toste, Cayetano, op. cit., Vol. 9, 24; Translation by the author.


This name was given in honor to the Count of Santurce, who established the train system, and was one of the first rich persons settled in the area.

Castro, María de los Angeles, op. cit., 374-379.

Ibid, 202-203.

Ibid, 204-212.


Silen, Juan Angel, op. cit., 41-42; Eugenio Fernández Méndez, 1971, op. cit., 140.

Zapatero, Juan Manuel, La Guerra del Caribe en el Siglo XVIII, (San Juan, Instituto de Cultura Puertorriqueña, 1964), 63; Fray Iñigo Abbad y Lasierra, 1971, op. cit., 57. The French had already attacked and burned the settlement of San German various times and the British had approached the southern coast of Puerto Rico in 1585. The first British attack occurred on November 22, 1595, under the command of Sir Francis Drake. His fleet left San Juan Bay in the early morning of November 27. The British attacked a second time on June 16, 1598, this time under the leadership of Sir George Clifford, Count of Cumberland. He succeeded in taking the city; however, an epidemic of dysentery killed over 400 men and forced the rest of the invading forces to leave the city of San Juan on August 24, 1598. Before departing they sacked and robbed the city. For further details see: Tomás Blanco, Los Tres Ataques Británicos a la Ciudad de San Juan Bautista de Puerto Rico, (San Juan, Talleres Tipográficos de Centeno Fernández y Co., 1947), 23-61; Juan Manuel Zapatero, op. cit., 61-62.

Vilá Vilar, Enriqueta, op. cit., 108. It was called "El Revellín de la Puntilla".

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The construction of San Cristóbal Fort began in 1697. For further details on the city wall see Cayetano Coll y Toste, op. cit., Vol. 10, 124-126.


88 de Córdova, Pedro Tomás, op. cit., 40-51.

89 Zapatero, Juan Manuel, op. cit., 317-409.

90 Abbad y Lasierra, Fray Iñigo, 1971, op. cit., 43-47.

91 Castro, María de los Angeles, "The place of San Juan de Puerto Rico Among Hispanic American Cities", Revista Interamericana, (Vol. 6, No. 2, 1976), 164.

92 Stetson, George E., San Juan, Puerto Rico: A Case Study of Evolution and Functional Role of a Primate City, (Ann Arbor, Michigan, University Microfilms International, 1976), 67; The attribute of being the only legal port remained until the 19th century.

93 de Hostos, Adolfo, Historia de San Juan Ciudad Murada, (San Juan, Instituto de Cultura Puertorriqueña, 1966), 263; Enriqueta Vilá Vilar, op. cit., 122.

94 Canto, Angel López, op. cit., 277.

95 Anonymous, "Descripción de la Ciudad de San Juan Siglos XVI y XVII", op. cit., 76, 79, 81.

96 Abbad y Lasierra, Fray Iñigo, 1971, op. cit., 47.


98 Ibid, 309.

99 Coll y Toste, Cayetano, op. cit., Vol. 9, 23.

100 Castro, María de los Angeles, 1980, op. cit., 187.

102 Anonymous, *Junta de Obras del Puerto de San Juan*, (San Juan, Tipografía del Boletín Mercantil, 1887), 3-4, 6.

103 Ibid, 1857, 18, 19, 22, 25-26, 94.

104 Anonymous, *Reglamento Para la Conservación y Policía de los Muelles y de su Zona de Servicio en el Puerto de San Juan de Puerto Rico*, (San Juan, Ed. Imprenta del Gobierno de Puerto Rico, 1896), 1-3.

105 Anonymous, "Descripción de la Ciudad de Puerto Rico Siglos XVI y XVII", op. cit., 75-76, 80-81.

106 Abbad y Lasierra, Fray Inigo, 1971, op. cit., 47.

107 Abbad y Lasierra, Fray Inigo, 1977, op. cit., no pagination.


109 Ibid, 55.


Translation by the author.

112 de Herrera, Antonio, op. cit., 39; Pedro Tomás de Córdova, op. cit., 179.

113 Sanz, Vicente Murga, op. cit., 229.


115 Murga Sanz, Vicente, op. cit., 160, 271, 278.


120 de Hostos, Adolfo, 1957, op. cit., 4; Vicente Rouja, op. cit., 60.

121 Anonymous, "Descripción de la Ciudad de Puerto Rico Siglos XVI y XVII", op. cit., 80.

122 Vásquez, Francisco M. Zeno, op. cit., 45.
123 de Hostos, Adolfo, 1948, op. cit., 31-32.
124 Perea, Juan Augusto, op. cit., 160.

127 Abbad y Lasierra, Fray Iñigo, 1971, op. cit., 47.
130 de Hostos, Adolfo, 1948, op. cit., 18.
131 Anonymous, "Descripción de la Ciudad de Puerto Rico Siglos XVI y XVII", op. cit., 82.

133 Coll y Toste, Cayetano, op. cit., Vol. 9, 122.
135 Wadsworth, Frank H., op. cit., 43.
136 Lynn, A., Informe Sobre el Sistema Higienico de la Población de San Juan, (San Juan, Imprenta del Municipio de San Juan, 1880), no pagination.
137 Coll y Toste, Cayetano, op. cit., Vol. 12, 149.
138 Puerto Rican Historical Archive (P.R.H.A.), *Fund of Ports and Piers*, San Juan, a) file 139, record 57; b) file 140, record 81; c) file 14, record 175; d) file 142, record 401; e) file 142, record 201.

139 P.R.H.A., *Fund of Ports and Piers*, San Juan, a) file 95, record 5; b) file 96, record 9; c) file 101, record 351; d) file 136, record 156; e) file 98, record 470; f) file 104, record 402; g) file 166, record 734; h) file 101, record 60.


141 P.R.H.A., *Fund of Ports and Piers*, San Juan, a) file 142, record 401; b) file 142, record 201; c) file 140, record 81.


143 de Hostos, Adolfo, 1948, *op. cit.*, 428-429.

144 Lynn, A., *op. cit.*, [Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.]
CHAPTER V

The Pre-Modern Period

(1900-1939)

Land Conversion

The 1900-1939 urban development of San Juan affected, in particular, the areas of Puerta de Tierra, Santurce, and El Condado. By 1900 Puerta de Tierra consisted of a group of houses constructed along the main road.\(^1\) The exclusive area of Santurce consisted of a group of "chalets", located also along the same road.\(^2\) El Condado reached its most significant development after 1920 when the Benn brothers urbanized the area behind the Condado peninsula.\(^3\) The same situation occurred with Hato Rey, Cataño and Palo Seco. All these areas were connected by a train system that ran from the old section of San Juan and passed through Puerta Tierra, Santurce, Hato Rey, Caparra, Bayamón and Cataño (Figures 5-1 and 5-2).

As can be seen in Figure 5-2 the 1900-1939 urban development of San Juan was concentrated in the Santurce region, forming a new urban nucleus. The urban extension of this region was favored by the construction of various hospitals, parks, and schools. Since the beginning of the 20th century the Puerto Rico Railway and Light Company had its office in Santurce, thus contributing to the economic expansion of this sector (Fig. 5-3). By 1930 an exclusive high class urbanized development was constructed and called "El Hipódromo".\(^4\)

The area of Puerta de Tierra also increased its construction throughout this period, the most important included a jail, the child shelter building, the YMCA (Fig. 5-4), the Asylum and "El
Fig. 5-1. Santurce and Puerta de Tierra, from San Cristóbal Castle, at the beginning of the 20th century. Source: Historical Archive of Puerto Rico.
Figure 5-3: Santurce in 1919. Source: Historical Archive of Puerto Rico.
Fig. 5-4. Map showing the land belonging to the Y.M.C.A. and Ateneo Puertorriqueño during 1914.
Source: Historical Archive of Puerto Rico.
Since the beginning of the century two heavy industries were established in the area, a fertilizer plant and the Standard Oil Company. A tobacco and cigar industry were also established where today the Puerto Rican Historical Archive is located.

The Hato Rey urban belt expanded from the Martín Peña bridge to the area of Rio Piedras. By 1939 this area had two race tracks as a symbol of its recent urban development. A new urbanized area named "Roosevelt" was already in construction (Fig. 5-2).

Excluding the urban, mangrove and swampy areas, the remaining land was used for agricultural purposes. Most of it was used for the growing of sugar cane, particularly on the southwestern side of the bay. The area west to Hato Rey was used for cattle pasture and mixed agriculture, mainly coconut, pineapple and citrus. Since 1902 a significant portion of land in the San Juan Bay area belonged to the United States Federal Government. These areas were reserved for the construction of military structures or port facilities.

The population of San Juan grew significantly after 1920. The 1910 census registered a total of 48,716 persons in the San Juan area. By 1930 this population had increased to 114,715 and by 1940 the capital city had 169,249 inhabitants. Most of the population was concentrated in the area of the San Juan islet and Santurce. Both centers functioned as independent urban nuclei. San Juan represented the main administrative and port center while Santurce represented the industrial and residential heart. Both were significant commercial centers.
"Arrabales" or Slums

The most important urban development during the 20th century has been the slum areas or "arrabales". Although these areas had their origins in the colonial period, they reached their maximum development after 1900. By the first decade of the 20th century there were several slums located in the area of Puerta de Tierra. These were known as "Hoyo Frío", "Miranda" and "Sal Si Puedes". Another slum, "La Perla", existed outside the northern wall of the city of San Juan. During subsequent decades the slum areas increased considerably, concentrating in the mangrove and swamp public areas where the cost of land was extremely low.

As a result of the proliferation of slums the government enforced several laws concerning construction activities and also destroyed or moved some of them. The area most affected by this policy was Puerta de Tierra. By 1924 the government began moving the people from Puerta de Tierra slums to "Tras Talleres". Some of the neighbors from the slums of Puerta de Tierra were accommodated in "El Falansterio", a new type of public residential building complex. By 1938 the biggest slum of Puerta de Tierra, called "San Ciprián", had already disappeared.

Several factors contributed to the development and increasing number of slum areas. These include the concentration of administrative activities in the San Juan area and the recent industrial developments in Puerta de Tierra and Santurce. However, probably the most important factor was the breakdown of the agricultural economy of Puerto Rico, particularly with regard to coffee and tobacco production. The consequences of these factors was a massive post-1930 migration from rural to urban areas. Several
Fig. 5-5. Development of the land gained to the sea in Puerta de Tierra, 1931.
Source: Historical Archive of Puerto Rico.
migration waves appear to have supplied the major population of the slums.

Santurce's new economic importance was also a determining factor in the increasing development of the slums. According to 1940 aerial photographs, the peninsula of Santurce was almost surrounded by a slum belt. The largest concentration of poor houses were in the northern section of the Martín Peña channel, on the southern edge of El Condado lagoon and in the southeastern part of Isla Grande.

The area of Cataño also registered an important population growth as a result of the formation and increased number of shantytowns. After 1930 various "arrabales" were formed along the Cataño-Bayamón road. 12

The Port of San Juan

The port construction work continued with the coming of the Angloamericans to Puerto Rico. In 1904 a street along the rampart area of the main piers was constructed, 13 by 1908 the "Carbonera" (Fig. 5-6) and "Las Goletas" piers were already leveled, 14 and in 1915 the shed, located at the eastern point of "La Carbonera", was constructed. 15

San Juan Bay has been described by Ward 16 as being the most important commercial port of the island and the only harbor on the north coast that affords protection in all weather. He continued describing the port with the following words:

"The harbor is about 3.5 miles long in a southerly direction and has a width of 1 to 2 miles, but, as there are very extensive shoals, less than 4% of the harbor area is available for anchorage of deep-draft vessels. At the time of American occupation, the depth in the main entrance channel was 25 (English) feet (7.62 meters) at mean low water and had a minimum width

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Fig. 5-6. La Carbonera embankment, 1911. Source: Historical Archive of Puerto Rico.
Fig. 5-7. La Puntilla at the beginning of the 20th century. Source: Historical Archive of Puerto Rico.
of about 400 feet. In the harbor, a proper depth of 24 feet or more existed in an area of about 92 acres. There are 6 piers with aggregate berthing space of about 6,530 feet, and bulkhead wharves of an aggregate length of about 3,750 feet (Fig. 5-8, No. 1-6). Of the above piers, four very in width from 80 to 120 feet and in length from 410 to 530 feet and are provided with iron cover sheds, with vessel berths on either side 20 to 28 feet deep. Of the other two piers, one has 330 feet frontage on the channel with dredged ships on the east and west sides of 20 and 28 feet deep, 600 and 450 feet long, respectively. The bulkhead wharves build by the Insular Government have an aggregate length of about 3,700 feet, with iron sheds for the storage of perishable freight (Fig. 5-8, No. 9-10). A bulkhead, privately owned, 420 feet long, has a depth of about 26 feet. All of the above terminals have railroad connections. Three of them, the coal dock, Pier no. 6 and the San Antonio dock, have mechanical equipment and the latter is equipped with a precooling plant for fruit. A bulkhead in front of the old customhouse (Fig. 5-8) is used by local vessels of shallow draft; and three piers within the old navy yard are used, one by the Marines, one by the Lighthouse Department, and the third by the Engineering Department. The lighthouse service has constructed a concrete bulkhead along the southeasterly front of its reservation. Terminal facilities have been increased as the area of deep water has been extended, thus giving an easier outlet to the staple products of the island such as sugar, coffee, tobacco and fruits.

As for port activities, Ward mentioned that the commerce of San Juan consisted of the receipt of foodstuffs, textiles, coal, building material, machinery, fertilizer, and the shipment of sugar, fruit, tobacco and coffee. These commodities were carried in 1844 vessels of 4,439,328 registered tonnage. The Cataño and Palo Seco ferry handled considerably smaller package freight. The Cataño ferry reported 1,967,387 passengers carried in 1929, and the Palo Seco ferry 38,895.17

**Natural Landscape and Human Impact**

Many of the natural conditions of the San Juan bay area are presented in the 1912 map (Figure 5-9). This map shows several

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Fig. 5-8. U.S. Board of Engineers, port and terminal facilities at the Port of San Juan.
maritime and land features of the bay, including bathymetry, shoals, channels, coastal landforms, swamps, mangroves, beaches, reefs, river mouths, spits and lagoons. It also shows the area affected by human activities, particularly the areas where the vegetation has been replaced by urban or agricultural land uses.

According to this map most of the San Juan Islet was already built up. The southern Islet boundary was filled and only a small part of the mangrove vegetation remained. This mangrove extended from the Puerta de Tierra inlet to the San Antonio Bridge. The "Escambrón" area contained a swamp separated from the sea by a beach and protected by a line of flat platform reefs.

A coconut farm was established at the eastern tip of the Condado Peninsula. This area was later used for the construction of the Borinquen Park. Most of the original vegetation on the southern edge of the Condado lagoon had been eliminated for the establishment of other coconut farms. The only mangrove area that was left around the lagoon was the northeastern point.

To this date the mangrove area located south of the San Antonio channel remained untouched. However, the urban expansion of Santurce extended over these areas, claiming the mangroves located west of the Santurce Peninsula.

In other portions of the southwestern part of the bay, the vegetation was also cleared for the cultivation of coconut, sugarcane, fruits, or for cattle pasture. These areas included the margins of the Puerto Nuevo river, the area surrounding Monte Canejas and Caparra, the littoral of Bayamón river mouth, and the area surrounding
Catano and Palo Seco. Most of the rest of these areas remained barren or wild.

In terms of the bay's bottom, the largest channel was the entrance one, with a maximum depth of 25 feet (7.62 meters). The area between "El Morro" and "La Puntilla" had an average of 10 feet in depth. It also included two important shoals, "Santa Elena" and "San Agustin". The section between "La Puntilla" and "Punta Largo" shoal had a waterway of 29 feet in depth. The San Antonio channel extended easterly forming a narrow, shallow canal, with depth ranging between 5-16 feet. A branch of this channel extended south between Isla Grande and the eastern mangrove peninsula, to form the Miraflores bay (Fig. 5-10). This small bay had a depth ranging from 13-15 feet in its deepest areas and 1 foot in the shallow areas.

A sand shoal extended south from the western point of the Condado peninsula to the San Antonio bridge (Fig. 5-9). The average depth of this shoal was about 2 feet. The center part was the deepest section of the Condado lagoon, with a depth of 21 feet. The lagoon also included a north-south channel, extending from the San Antonio bridge to the San Geronimo Fort. A second waterway, the San Antonio, extended west of the Condado Peninsula; neither of these two channels had a depth of more than 9 feet.

The southern portion of the bay, which included the area south of the line of Miraflores Island and Punta Catano, contained a sand bank belt, which diminished in depth as it approached the coast (Fig. 5-10). This included the Miraflores and Capitaneja shoal, located southwest of Miraflores Island; the Mojiganga bank, located east of
Puerto Nuevo river mouth, and the Great bank, located southeast of Cataño.

Four significant shoals were located in the central part of the bay named Punta Largo, Yaboa, Anegado and Largo. The depth of these shoals did not exceed 6 feet in the deepest areas and one foot in the shallow parts.

The maritime section between Punta Cataño and Isla de Cabras was a relatively shallow water section (Fig. 5-10). Three levels of sand deposits could be distinguished. The first extended from 1 to 6 feet (0.30 to 1.83 meters) in depth, the second from 7 to 12 feet (2.13 to 3.65 meters) and the third from 13 to 18 feet (3.96 to 5.49 meters). The only shoals of this region were the Tablazo, with a depth of 12 feet (2.13 meters), and the Cabras shoal, with a depth of 3 feet (0.91 meters). A small platform reef line was located east of Punta Palo Seco, with an average depth of 6 feet (1.83 meters).

The Martín Peña channel mouth had a depth ranging from 8 (2.43 meters) to 17 feet (5.18 meters). The deepest part of the Bayamón River mouth was about 7 feet (2.13 meters). The San Fernando channel had a similar depth.

With the dredging works of 1939, the San Antonio channel was dredged to a depth of 30 feet (9.14 meters), the Bar channel (part of the entrance channel) was dredged to 38 feet (11.58 meters) and a width of 800 feet (243.9 meters). The Anegado or entrance channel was dredged to 30 (9.14 meters) feet and with a width of 300 feet (91.5 meters). The total anchorage area of the bay had a width of 92 to 329 acres.
Comparison of aerial photographs taken in 1923 and 1939 with the 1912 map above showed that between these dates all the mangrove areas located north and of the southern San Antonio channel were filled. In particular, the mangrove area of the Puerta de Tierra was filled by the shantytowns - the result of a then extant government policy establishing that any person who had a mangrove land plot was supposed to improve its condition by filling and drying the land.\textsuperscript{18}

The price of the land was higher after the improvements. As an example, the 1929 costs of a square meter of land in the area of Puerta de Tierra and Isla Grande was 2 dollars before and 6 dollars after the landfilling.\textsuperscript{19}

In the case of Puerta de Tierra, as happened in other sectors of the San Juan Bay area, the landfilling process that began in the shantytowns was completed with the deposition of the bay's dredge sediments. Due to the proximity of the slums with these dredging deposit sites, the people suffered the consequences of mud flooding.\textsuperscript{20}

The greatest landfilling occurred between 1920 and 1939 in the mangrove areas located south of the San Antonio channel Isla Grande, Miraflores, and a mangrove peninsula were filled. Since then, the newly filled areas have collectively been called Isla Grande. This zone was filled with deposits coming from bay dredging activities. By 1939 the construction of Isla Grande Airport was already in progress.

Some other small areas were filled for specific purposes. For example, the widening of Ponce de Leon Avenue (formerly main road) in 1932,\textsuperscript{21} the construction of Muñoz Rivera Avenue in Puerta de Tierra,\textsuperscript{22} of San Antonio and Ashford bridges,\textsuperscript{23} and the new Martín Peña
The southern point of the Condado lagoon was filled for the construction of small private piers and cabins.

Most of the landfilled areas were used for urban purposes. The rapid urban expansion of San Juan forced the government to auction the only land available: swamps and mangroves. The sole commitment of the landowner was to improve, by drained, and filling the land. All kinds of justifications were given for getting a plot of a mangrove land and then filling it.

The ideal plan was to drain and fill most of the mangrove areas surrounding the bay. The first goal was to dry all the mangrove areas along both sides of the San Antonio and Martín Peña channels, second to dry the mangrove area of "Las Monjas", located in the sector of Hato Rey, and third, desiccate a portion of land located between Cataño, Bayamón and San Fernando channel.

While in some sections the land was transformed by landfilling, in other sectors the main landform changes occurred as a result of the extraction of land materials. Sand was the most common material extracted, and the most popular areas for obtaining it were the Condado beaches and lagoon, the areas surrounding the Capitol building, Santurce, La Marina, and Cataño beach. By 1928 the sand extraction represented an environmental problem in Santurce. Grass and ground were also other land materials frequently extracted.

Except in the slums, hygienic conditions of the city improved. Urban expansion outside the limits of old San Juan decreased its overcrowding problem. The city had a rubbish dump, located far away from the urban centers.
Apparently there were certain problems with the quality of the water in the Martín Peña channel, caused by the discharges into the channel of the Rio Piedras sewer system.\textsuperscript{31}

The major hygienic problems were concentrated in the slum regions where, besides the suffering caused by the dredging activities, people lacked light, fresh air, running water and a sewer system.
CHAPTER V
FOOTNOTES

1 Beauchamp, Torres, Plan Maestro de Puerta de Tierra, (San Juan, Ed. Torres Beauchamp, Marvel y Asociados, 1980), 2.


3 "From the Wild of Cataño to the Wild of El Condado", San Juan Star (March 10, 1974); 6.

4 Pérez Chanis, Efrén op. cit., 8.

5 Vásquez, Francisco M. Zeno, Historia de la Capital de Puerto Rico, (San Juan, Ed. Gobierno de la Capital, 1959), 220; Torres Beauchamp, op. cit., 14; "El Falansterio Quedará Terminado", El Mundo, (March 5, 1937), 1, 16; "Los Proyectos de la PRRA para Eliminar Arrabales", El Mundo, (July 1, 1936), 8.


7 Coll y Toste, Cayetano, Boletín Histórico de Puerto Rico, (San Juan, Tipografía Cantera, Vol. 12, 1914), 302.

8 Beauchamp, Torres, op. cit., 12.


10 Historical Archive of Puerto Rico, (H.A.P.R.), Fund of Public Works, Series of Public Property, Subseries: San Juan-Santurce, line: 124, Box 253, (December 22, 1938), G.F. 735, Santurce No. 62.


13 H.A.P.R., Fund of Port and Piers, file 83, record 5.

14 Ibid; file 113, record 37.

15 Ibid; file 138, record 5.


17 Ibid; 1982.

18 H.A.P.R., Fund of Public Works, Series Public Property, Subseries, San Juan-Santurce, line 124, Box 253, (July 5, 1935), G.F. 646, Santurce no. 62.

19 Ibid; subseries, San Juan-Puerta de Tierra, line 124, Box 248, (November 1929), G.F. 535, P.T. 62.

20 El Mundo, January 17, 1924, op. cit., 1, 6; "No se Debe Demorar más el Auxilio a los Barrios Inundados", El Mundo, (April 16, 1939), 5, 12.


22 Beauchamp, Torres, op. cit., 14.

24 H.A.P.R., Fund of Public Works, Series Public Property, Subseries San Juan-Santurce, line 124, Box 251, (1928).

25 Ibid, Box 253, (September 8, 1936), G.F. 656, Santurce no. 62, Box 253, G.F. 646, Santurce no. 62.

26 Ibid, Box 252, (June 30, 1922), G.F. 670 Santurce no. 62. Mr. W. D. Noble, member of the British consulate, bought a 5 acre plot of mangrove land located in Miraflores. The plot was sold for $4,061.00 with the commitment that the land be dried within four years or it would revert to the government of Puerto Rico.

27 "La Bahía de San Juan, La Desecación de los Manglares", El Mundo, (October 25, 1920), 3.

28 H.A.P.R., Fund of Public Works, Series Public Property, Subseries San Juan-Santurce, San Juan-Puerta de Tierra, line 124, Box 247, 251.

29 Ibid, Box 251.

30 Ibid; Box 239, 251.

1940 marked the beginning of a period of major geographical transformation in the San Juan Bay area. Several factors contributed to the creation of the appropriate environment for this transformation, first, the emergence of the commonwealth government and "Operation Bootstrap", whose main objectives were to promote political and economic development in Puerto Rico, and second, the reorientation of the economy to commerce, tourism, and industry. The combination of these two factors made the San Juan Bay area an important port of the United States.

The 1940 urban decline of the old San Juan was the result of the urban rising growth of Santurce. While the government was constructing new hospitals and governmental facilities in Santurce, building restoration was the only urban activity in the old San Juan.¹

Besides the urban nucleus of San Juan and Santurce and the relatively small, but important, center of Puerta de Tierra, Palo Seco, Cataño and Hato Rey, a new concept of urban development appeared: the Roosevelt, Puerto Nuevo and Bay View developments (Fig. 6-1). The first was started in 1940 and the other two after 1947. All represent the concept of urban "Satellite Centers" developed by private companies.²
Fig. 6-1. Original plan design of the Puerto Nuevo, Caparra Terrace, and Caparra Heights developments, 1925. Source: Historical Archive of Puerto Rico.
In 1950, Santurce had become the most important urban center of the metropolitan area (Fig. 6-2). With the construction of new roads the shift in population growth to new areas such as Puerto Nuevo, Roosevelt and Rio Piedras was more evident. Central Avenue (Jesus T. Piñero) was the main corridor between Caparra, Puerto Nuevo and Rio Piedras; Roosevelt avenue served as the main road between the Roosevelt, Puerto Nuevo, Puerto Nuevo Norte and Villa Borinquen residential areas. Ponce de León and Kennedy (Road no. 2) avenues remained as the main roads, the former connecting San Juan and Rio Piedras, and the latter, San Juan and Bayamón.

The urban expansion of Cataño spread toward the southern side of the main plaza, where the sectors called Sabana y Amelia developed. Both were built along the Road No. 24, which connected Cataño with Road No. 2. Urban growth in Cataño, Sabana y Amelia, and the margin of Martín Peña channel was caused by the rural-urban migration of workers.

A clear spatial urban stratification began at that time and continued throughout the 1960s. On one hand the private urbanization projects for median income class increased, while on the other, the low income housing were tripled. Throughout the 1950s, some areas, such as El Condado Peninsula, began to develop as exclusive residential urban sectors, while the coastline of Martín Peña was lined with slums. Other medium low class to medium high class developments appeared, including San Patricio, Caparra Height, Baldrich, Garden Hill, and Villa Caparra.

In some cases principal roads were used as axes for lineal urban development, as occurred in Caparra along Road #2. In other cases the
developments were separately formed based on nuclei, following the "Satellite Center" pattern. Some new sections were added to the already existing developments. Most of these were built by the end of the 1960s. For example, Baldrich could be described as a prolongation of Roosevelt, and Los Caobos as the prolongation of Caparra Height.

After 1960 urban expansion reached the southwestern section of the Bay, where sufficient new land existed for this purpose. By this time the urban expansion of San Juan and Santurce had reached its maximum built up area and the Hato Rey eastern expansion was limited by the San José lagoon. At the beginning of 1970 the following developments had been created; Las Vegas, Levittown, Villa España and Jardines de Caparra.

San Juan's peripherical urban expansion was partly a response to the urban deterioration of Santurce and San Juan themselves. This expansion began in 1960 and was spread by the construction of new highways and expressways that linked the main urban center with the suburbs. The 1970s marked the turning point of this process with the construction of Las Americas, De Diego and Baldorioty de Castro expressway. The first links San Juan and Santurce with the southern section of the city, the second with the western side, (Bayamón, Cataño, and Toa Baja), and the third with the eastern town of Carolina.

The urban development attained by the metropolitan area of San Juan after 1975 took place in the outer limits of the San Juan Bay area, mainly in Bayamón, Carolina and Guaynabo (Fig. 6-3). The last urban project within the San Juan Bay area was the "Vista del Morro", constructed in 1976 in the southern section of Palo Seco península.
In 1950 the construction of the Hilton Hotel began, and by 1960 the residential area of the Condado Peninsula was already replaced by hotels and condominiums. The construction of high rise buildings increased after 1970. Some traditional residential areas, such as Miramar and Santurce, have been replaced, since then, by buildings designed for residential, commercial, private enterprise or public service usage.

The reconstruction of old structures is an urban process that has been occurring along with new construction. Because San Juan Islet represented the oldest area and because of its conspicuous value, this zone has been experienced much urban renewal since 1940, a process which has transformed old San Juan into the main center of culture and tourism of Puerto Rico. Most of the restored buildings have been used for purposes different from what they were originally designed. That is why, from a typical residential and service region old San Juan has been converted into a tourism oriented area, characterized by night clubs, restaurants, and commercial stores.

Some historical buildings have been completely destroyed under the pretext that they were in poor condition. According to government sources, 90.8% of the buildings were deteriorated in 1967. As a result, in 1969 the government ordered the demolition of the Spanish buildings located between San Sebastián, Sol, and Tanca streets. This practice has continued throughout the 1970s and into the 1980s. One of the structures demolished in 1982 was "Colegio San Idelfonso".

Since 1956 the government planned to destroy the historical buildings of La Puntilla. In 1964 the housing department, known as "CRUY" ("Centro de Renovación Urbana y Vivienda"), insisted on the
renovation of the area after destroying the buildings. The decision became reality in 1965, only after public protest. In 1975, after destroying the historical buildings, CRUV began the construction of 400 apartment complexes. The project was inaugurated in 1978 and the new constructions were built preserving the same architectural colonial style of the old San Juan.

In the last few years a large developmental housing project, called "Nuevo Centro de San Juan", has been initiated. Since 1975 the government has considered the idea of developing a large medium class residential project in the area along the Martín Peña channel. This area would include parks, theatres, restaurants and scenic views. This project includes, according to the 1979 plans, the relocation of about 5,000 families living in the area, the dredging of Martín Peña channel, and the preservation of a 200 meter line for recreational purposes. If this project becomes a reality, it would transform the geographical nature of the largest and only remaining open space in the San Juan Bay area.

Land Use Changes

The orientation towards an industrialized economy was the main reason for the post-1940 land use changes in the area surrounding the San Juan Bay. Although the land was owned by three different landowners (federal government, insular government, and private owners), the industrialization process mainly concerned public lands. By 1940 about 20% of the land in the San Juan Bay area belonged to the federal government. This land was reserved for the construction of port and military facilities. The land classified as public or belonging to the insular government comprised about 60% of the total
land. However, this particular land was considerably reduced as a result of its intensive use for urban and industrial purposes.

The planning board (Junta de Planificación) has established a system based on regional specialization of land use. The result of their policy was the "multinucleus" urban model, whereby the old San Juan has been converted into a cultural and historical tourist center. Santurce has specialized in commerce, Hato Rey represents the financial nucleus, Cataño and Puerto Nuevo, the port's focal points, El Condado, the tourist center; the other sectors represent residential or recreational cores. The specialization of the land use has increased since 1970.

Although many of the sectors have been oriented toward this pattern of land use, others have spontaneously specialized in one particular economic activity based on private initiative. Whether by planning or other mechanisms all areas in the San Juan Bay area have undergone significant land use transformation in the last forty years.

In 1940 the San Juan Islet represented the main governmental, commercial, and port center of the San Juan metropolitan area. Since then the area includes important governmental buildings such as the Capitol, La Fortaleza, and the Supreme Court. More recently the tesure office or "Hacienda" and the Department of Natural Resources have been added. The San Juan Islet also included the main sector of the municipal government concentrated around Plaza de Armas or Baldorioty de Castro. In the 1940s the facilities of Muñoz Rivera Park were constructed. During the 1950s began the construction of the Caribe Hilton Hotel as well as the southeastern structures, which

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today house the U.S. Environmental Protection Agency and The Army Corp of Engineers.

The Islet has always included a high percentage of federal lands, such as "El Morro", "San Cristobal", U.S. Coast Guard, the U.S. Naval Station in Puerta de Tierra, and the Navy residential area near San Gerónimo Fort. Some of the original federal land holdings have been given to the insular government for restoration, including the area of "Casa Blanca" and Fort Brooke.

Throughout the modern period, the slum sectors of "Puerta de Tierra" have been transformed into a different type of residential sector characterized by public housing and multifamily buildings. Its southern edge has been used for port and other transportation facilities as well as for construction of institutional buildings.\(^\text{13}\)

The San Juan Islet and its two main sectors, the old San Juan and "Puerta de Tierra", are now undergoing urban renewal. For example, "El Escambrón" has been restored and represents the main recreational area of the San Juan Islet. The same has occurred with the piers. When the commercial activity became oriented toward "Puerto Nuevo", the old San Juan piers were partially abandoned. Then the government restored two of them for tourist purposes.

The Condado Peninsula was not an urbanized area in 1940. By this time the area represented the favorite vacation place for the people coming from San Juan as well as the rest of the island and other countries. The construction of various hotels, including the "Hotel Condado" in the northern section of the Condado lagoon began in 1950. In contrast, the southern border of the lagoon was made up of slums. However, a reorientation of this area towards tourism has, since 1960,
seen the original slum areas replaced by hotels, stores and other
types of tourist facilities.\textsuperscript{14}

By 1940 the area of Isla Grande (Fig. 1-2) represented the
principal center of aerial transportation of Puerto Rico. This
attribute belonged to Isla Grande airport until 1960 when the new
facilities of Isla Verde International Airport were opened to the
public. Besides the airport administration and airplane facilities,
part of Isla Grande has been used by the U.S. Naval Reserve.

More recently the Isla Grande airport has been used by private
flight school companies. Some of the old buildings have been
reconstructed and used for governmental offices. Meanwhile, the port
structures located in the northwestern side and the docks located at
the southern corner of the island are still used for commercial
facilities and tourism respectively. Both structures were constructed
by the end of the 1960s.

Miramar and Santurce remained a homogeneous compact area. The
only perceptive changes have been in its building structures. Since
1940 Miramar has been an exclusive residential sector changing after
1965 with the construction of tall residential buildings and hotels.
Before 1960 Santurce was characterized by mixed land use with
residential sectors mixed with commercial, industrial and public
service buildings. After 1960, however, most of the residential areas
were replaced by new condominiums, government offices, and commercial
stores. This phenomena has been observed along Ponce de León,
Fernández Juncos and De Diego avenues.

In the last decade, and resulting from the formation of new urban
centers, the importance of Santurce as the main core of the
metropolitan area has been noticeably reduced. This has caused the
deterioration of urban blocks and the abandonment of houses as well as
entire buildings. In an attempt to revitalize the area new roads
and buildings have been constructed recently. These include a section
of the "De Diego Expressway", the "Minilla" tunnel, and the "Bellas
Artes" building.

The northern margin of Martín Peña channel was the ideal region
for the formation of shantytowns. The area belonged to the insular
government and contained mostly swamps and mangroves. By 1950 all the
northern edge of the channel was covered by "arrabales". In the
1960s the Urban Renovation Program began to eliminate some of these
slums and by 1970 the east and west slum section of the channel were
already eliminated; between 1970 and 1982 the last remaining
shantytowns were eliminated.

With the elimination of the "arrabales", new construction has
appeared in its substitution. In 1979 the facilities of Parque
Central and Parque Ecuestre were constructed. More recent is the
construction of a new residential complex called "Parque Centro", and
the construction of the "De Diego Expressway".

The southern edge of Martín Peña has been a wild mangrove region
since 1940. However, at its eastern point is located the only shanty-
town that exists today around the Martín Peña channel, called "Tokío".

Originally Hato Rey was an open space dedicated to pasture land
and agricultural production. The main urban center was along the
Ponce de León and Muñoz Rivera Avenue. Between 1940 and 1960 the
sector consolidated as an important residential center with the
Roosevelt and Baldrich developments.
In 1970 Hato Rey was converted into the financial center of San Juan. The typical one-story structure was substituted by high-rise buildings and the traditional residential streets were rezoned into commercial. Today, Hato Rey is one of the most modern zones of San Juan.

Due to its proximity, Puerto Nuevo has been affected by the same factors as Hato Rey. In 1940 this sector was basically barren land dedicated to pasture and fruit trees. This region has consolidated as a typical residential zone, with the exception of the main avenues, where the houses have been replaced by commercial stores. Puerto Nuevo has the most modern port structures of Puerto Rico. By 1962, the edifices belonging to the "Centro de Obras Públicas", "Planta de Tratamiento de Aguas" and the "Bechara Industrial Zone" were built.

Another typical residential sector is Caparra (Fig. 1-2). Since the construction of San Patricio, each new urban development was constructed with the idea of sustaining more social exclusivity. Originally the area was an agricultural region. Part of this land includes the San Patricio military reserve and the San Patricio hillstack mount. Some of the new developments have been surrounded by "barriadas" that persisted until recently, as in "Jardines de Caparra" and Garden Hills. The principal commercial center is located in the Roosevelt-Kennedy intersection and is named San Patricio shopping center. As occurred in Hato Rey and Puerto Nuevo, the buildings along the principal avenues are being transformed from residential to commercial. This process is evident in the Roosevelt and Central avenues as well as in Road no. 2 and Escorial Street.
The area of Buchanan (Fig. 1-2), which was underdeveloped, was converted in 1950 into the largest military reserve in the San Juan Bay area. All this land has been used for the construction of buildings and other types of military facilities, including a large recreational section built by 1970. A heavy industry section was built nearby in Puerto Viejo Bay in 1962. This portion included the Army Terminal pier, the oil storage tank, an electric generation plant and various warehouses. The northern side of Monte Canejas was an extractive area used by the heavy bottling and cement industries. Both closed operations in 1977.

Sabana y Amelia have been, since their origin before 1940, two residential areas for low income families. Separated from Cataño by the San Fernando channel, the area has grown toward the south covering an originally extensive mangrove swamp. The southern point of the sector was filled between 1950 and 1960 for the purpose of building various rice mills and two piers. In 1968 the slum known as Vietnam was formed. Located in the northeastern point originally this area was a large mangrove swamp, and was filled after 1960. Construction of Road 165 limited the southern expansion of Sabana y Amelia. However, the area surrounding this road has been filled by private companies for the construction of warehouses. Although the housing quality has improved, Sabana, as well as Amelia, has to renew their urban appearances. The fact that they are located close to one of the major centers of pollution explains, in part, the urban deterioration problem existing in this sector.

The town of Cataño has not benefited very much from the industrial development in the area. By 1940 the urban density of the
town could be classified as medium (1132 persons per square mile); however, through time the density has increased considerably (3780 persons per square mile in 1970). The original downtown area has been the main commercial, service and financial center. To this core other new sectors have been added, including "La Puntilla de Cataño".

The Bay View development (Fig 1-2) was originated from the purpose of middle class residential use. This area has not undergone significant changes since its formation, with the exception of housing reconstruction and the building of Road no. 165 in the 1970s. Besides the residential housings, the most important structures are the Bay View cemetery and buildings that, at present, are used for the Francisco Oller and Onofre Caballeira schools.

At the beginning of 1940 the Palo Seco peninsula was a wild area covered by pastures, coconut palms and mangrove vegetation. The only urban area was the village of Palo Seco. A small cemetery was located outside the urban area. Late in the decade the land surrounding the town was used for the growing of minor crops, fruit and coconuts. By 1950 the Bacardí Distillery was already established, but the largest development of the area occurred in the late 1950s with the construction of Palo Seco thermoelectrical plant and the new site of the Bacardí Distillery. By this time the agricultural activity in the area was already abandoned, and the industrial area has continued growing throughout the last decades, presently representing 75% of the land area.

After being filled in 1948, Isla de Cabras was connected to the mainland by a causeway. In 1962 the Island had coconuts and grass vegetation, but since the early 1970s the island was converted into a
recreational center. However, the only structures located on it are "El Lazareto" and "El Cañuelo" ruins, which were constructed during the Spanish colonial period, a shooting club, and a police headquarters constructed recently.

The sector named "Palmas" is the largest geographical unit of the western side of San Juan Bay (Fig. 1-2). This region was originally an agricultural zone used mainly for sugarcane, fruit trees, and pastures. A large section of this area was covered by wetlands, particularly the area belonging to "Las Cucharillas" swamp and the margin of Bayamón river. Three slum areas were formed by 1950: "Juana Matos", "Las Cucharillas" and "Puente Blanco". But by 1962 "Las Palmas" industrial zone and the warehouses located at Road no. 869 had been established. At this time the construction of the petrochemical complex located south of the present De Diego expressway was begun. All these industrial complexes doubled their size through the 1960s. By late 1968 a large development called "Las Vegas" was constructed. Since then the "Vista del Morro" development and two high-rise residential building have recently been erected.

The Levittown sector was, in 1940, a zone used for the cultivation of citrus, coconuts, and sugarcane. The area was at that time a plantation called "El Plantaje", made up by various small "haciendas". Through the 1950s Levittown was the principal producer of orange and grapefruit of San Juan. There was a relatively small airport located at the western bank of Bayamón river, which was used for the transportation of these products. The only land connection was through Road no. 862, which linked Levittown with Sabana Seca.
However, by 1962 this area was connected to Palo Seco and Cataño through Road no. 165.

The total geographical transformation of Levittown occurred in 1962, when the land was sold to the "Levi Company of New York", and the Levittown Lakes development was constructed. Since that time urbanization has spread toward the southwest. "Levittown" was probably the last project in the San Juan Bay area, belonging to the category of "Satellite Cities".

The transformation of the land in the San Juan Bay and its surrounding area has been described in some detail in the previous pages. These changes can also be presented in tabular form by composing percentages of land use as in Table 6-1. These percentages were obtained from planimetric measures taken from maps and calculated in terms of 10 basic categories: agriculture, forest use, water resources, wetland, residential, recreation, public facilities, commercial, industrial, non-productive sectors, transportation and communication. The maps were constructed from aerial photographs taken in 1940, 1951, 1962, 1971 and 1979, following the land use classification system from the Department of Natural Resources of Puerto Rico. This classification is presented in Table 6-2.

The land use percentage data presents many interesting patterns. The data prove the general principle that the decrease in agriculture has been proportional to the increase of the built up area. Therefore, the fact that the urbanized area has tripled in the last forty years has been the main reason for the virtual disappearance of agriculture. However, forest and wetland areas which were deeply affected during 1940-1970 are now presenting some signs of recovery,
### TABLE 6-1

Land Use Changes (%) in the San Juan Bay Area

**1940-1980**

<table>
<thead>
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<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>1. Agriculture</td>
<td>16%</td>
<td>14%</td>
<td>10.7%</td>
<td>9.2%</td>
<td>2.1%</td>
</tr>
<tr>
<td>2. Forest</td>
<td>9%</td>
<td>8.5%</td>
<td>4.3%</td>
<td>2.5%</td>
<td>4.8%</td>
</tr>
<tr>
<td>3. Water</td>
<td>4%</td>
<td>3.8%</td>
<td>3.2%</td>
<td>3.3%</td>
<td>3.6%</td>
</tr>
<tr>
<td>4. Wetland</td>
<td>13%</td>
<td>7.8%</td>
<td>7%</td>
<td>6.5%</td>
<td>11.5%</td>
</tr>
<tr>
<td>5. Residential &amp; Urban</td>
<td>20%</td>
<td>24%</td>
<td>27%</td>
<td>29.3%</td>
<td>29.6%</td>
</tr>
<tr>
<td>6. Outdoor Recreation</td>
<td>3%</td>
<td>2.8%</td>
<td>3%</td>
<td>3.7%</td>
<td>2.8%</td>
</tr>
<tr>
<td>7. Public Facilities</td>
<td>10%</td>
<td>10.1%</td>
<td>10.4%</td>
<td>10.5%</td>
<td>11.9%</td>
</tr>
<tr>
<td>8. Industrial &amp; Commercial</td>
<td>1.4%</td>
<td>6%</td>
<td>10.2%</td>
<td>14.7%</td>
<td>13.9%</td>
</tr>
<tr>
<td>9. Non Productive-Extractive</td>
<td></td>
<td>7.3%</td>
<td>4.3%</td>
<td>2.2%</td>
<td>2.1%</td>
</tr>
<tr>
<td>10. Communications &amp; Transportation</td>
<td></td>
<td>7.5%</td>
<td>11.7%</td>
<td>16.7%</td>
<td>17%</td>
</tr>
</tbody>
</table>

**Sources:** Department of Natural Resources, Section: Inventory of Natural Resources, San Juan, Puerto Rico, and Land Use Maps 1940, 1951, 1962, 1979.
Table 6-2 Land Use Classification System

<table>
<thead>
<tr>
<th>AGRICULTURE</th>
<th>WILDLAND</th>
<th>COMMERCIAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC</td>
<td>Non-merchant Swamp</td>
<td>Cc</td>
</tr>
<tr>
<td>AP</td>
<td>Scrub, heavy wetland</td>
<td>Cc</td>
</tr>
<tr>
<td>AG</td>
<td>Salt water marsh</td>
<td>Cc</td>
</tr>
<tr>
<td>AT</td>
<td>Fresh water marsh (green)</td>
<td>Ch</td>
</tr>
<tr>
<td>AU</td>
<td>Coffee</td>
<td></td>
</tr>
<tr>
<td>AV</td>
<td>Intensive Comm. Crops</td>
<td></td>
</tr>
<tr>
<td>AH</td>
<td>Small Holder (planted)</td>
<td></td>
</tr>
<tr>
<td>AO</td>
<td>Citrus plantation</td>
<td></td>
</tr>
<tr>
<td>AP</td>
<td>Banana plantation</td>
<td></td>
</tr>
<tr>
<td>AW</td>
<td>Inactive Agriculture</td>
<td></td>
</tr>
<tr>
<td>AX</td>
<td>Active (C,T,G,H,F,I,J,K,L)</td>
<td></td>
</tr>
<tr>
<td>BY</td>
<td>Pow Wow</td>
<td></td>
</tr>
<tr>
<td>FB</td>
<td>Pine, woody growth</td>
<td></td>
</tr>
<tr>
<td>FJ</td>
<td>Light, scattered crown</td>
<td></td>
</tr>
<tr>
<td>FS</td>
<td>Solid crown cover</td>
<td></td>
</tr>
<tr>
<td>FP</td>
<td>Public Forest</td>
<td></td>
</tr>
<tr>
<td>WE</td>
<td>Controlled, fresh water area</td>
<td></td>
</tr>
<tr>
<td>WU</td>
<td>Rivers, streams (50' x width)</td>
<td></td>
</tr>
<tr>
<td>WJ</td>
<td>Tilth Channel</td>
<td></td>
</tr>
<tr>
<td>WK</td>
<td>Managed, protected</td>
<td></td>
</tr>
<tr>
<td>WP</td>
<td>Marine Nature</td>
<td></td>
</tr>
<tr>
<td>WI</td>
<td>Lagoon, 3.0 acres</td>
<td></td>
</tr>
<tr>
<td>WH</td>
<td>Water- fresh water pond</td>
<td>3.0 acres</td>
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<table>
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<tr>
<td>WU</td>
<td>Rivers, streams (50' x width)</td>
<td></td>
</tr>
<tr>
<td>WJ</td>
<td>Tilth Channel</td>
<td></td>
</tr>
<tr>
<td>WP</td>
<td>Managed, protected</td>
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<tr>
<td>WP</td>
<td>Marine Nature</td>
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</tr>
<tr>
<td>WI</td>
<td>Lagoon, 3.0 acres</td>
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<tr>
<td>WH</td>
<td>Water- fresh water pond</td>
<td>3.0 acres</td>
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<tr>
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<tbody>
<tr>
<td>Tu</td>
<td>Sup, Hwy (4 lanes)</td>
<td></td>
</tr>
<tr>
<td>Ty</td>
<td>Railroad freight yard</td>
<td></td>
</tr>
<tr>
<td>To</td>
<td>Commercial dock facilities</td>
<td></td>
</tr>
<tr>
<td>Tp</td>
<td>Developed Harbor</td>
<td></td>
</tr>
<tr>
<td>Tn</td>
<td>Non-Dock facilities</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
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<table>
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<tr>
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<th>PASTURE</th>
<th>COMMERCIAL</th>
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<tbody>
<tr>
<td>D7</td>
<td>Hay, farm crops</td>
<td></td>
</tr>
<tr>
<td>D7</td>
<td>Tobacco</td>
<td></td>
</tr>
<tr>
<td>D7</td>
<td>Dairy farm crops</td>
<td></td>
</tr>
<tr>
<td>D7</td>
<td>Specialty farm</td>
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<td>D7</td>
<td>Nursery</td>
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</tr>
<tr>
<td>D7</td>
<td>Beach</td>
<td></td>
</tr>
<tr>
<td>D7</td>
<td>Poultry farm</td>
<td></td>
</tr>
<tr>
<td>D7</td>
<td>Farmstead</td>
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<tr>
<td>D7</td>
<td>Water</td>
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</tr>
<tr>
<td>D7</td>
<td>Land</td>
<td></td>
</tr>
<tr>
<td>D7</td>
<td>Pond, less than 3 acres</td>
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</tr>
<tr>
<td>D7</td>
<td>Control structure, gate</td>
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<td>D7</td>
<td>Water well</td>
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<tr>
<td>D7</td>
<td>Pumping station</td>
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<tr>
<td>D7</td>
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</tr>
<tr>
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<tr>
<td>U1</td>
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<td></td>
</tr>
<tr>
<td>U1</td>
<td>Commercial</td>
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<table>
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<th>URBAN &amp; RESIDENTIAL</th>
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<tr>
<td>U1</td>
<td>Single dwelling, outsiders</td>
</tr>
<tr>
<td>U1</td>
<td>Density area</td>
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<tr>
<td>U1</td>
<td>Small holder (1-3 acres)</td>
</tr>
<tr>
<td>U1</td>
<td>Presence of high-rise office</td>
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<tr>
<td>U1</td>
<td>Previous infrastructure</td>
</tr>
<tr>
<td>U1</td>
<td>Radio station/transformer</td>
</tr>
<tr>
<td>U1</td>
<td>Airports</td>
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<tr>
<td>U1</td>
<td>Lighthouse</td>
</tr>
<tr>
<td>U1</td>
<td>Commercial radio station</td>
</tr>
<tr>
<td>U1</td>
<td>Radio, TV tower</td>
</tr>
<tr>
<td>U1</td>
<td>Offstreet parking</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>COMMERCIAL</th>
<th>TOTAL</th>
<th>町</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>Hotel, motel</td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TRANSPORTATION</th>
<th>WATER</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>Water pipe line</td>
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<tr>
<td>P1</td>
<td>Dike, sea wall</td>
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<td>P1</td>
<td>Beach</td>
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<td>P1</td>
<td>Offstreet parking</td>
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<tr>
<td>P1</td>
<td>Harbors</td>
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<td>P1</td>
<td>Water</td>
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<tr>
<td>P1</td>
<td>Water</td>
</tr>
<tr>
<td>P1</td>
<td>Offstreet parking</td>
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<table>
<thead>
<tr>
<th>POLITICAL DIVISIONS</th>
<th>TRANSPORTATION</th>
<th>WATER</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Primary multipurpose</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Secondary multipurpose</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Secondary</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Percentage of</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Secondary multipurpose</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Secondary</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Percentage of</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>See above map</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Primary roads</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Interchange</td>
<td></td>
</tr>
</tbody>
</table>
both have increased by more than 1% during the 1970 to 1980 period. The large increase in the urban and industrial areas occurred primarily between 1950 and 1970, now both categories tend to be stable. The urban area stabilized at 30%, and the industrial and commercial at 14%, of the total land use.

The data also reflect that recreational land use has not increased in proportion to urban expansion; in most cases its percentage decreased. The total percentage represented by this use has been about 3%. This is not the case with the transportation and communication facilities which increased in proportion to the urban use. It seems that the most important factors in the development of the urban infrastructure of San Juan Bay have been the development of industry and transportation instead of residence services.

Also it is important to notice that what was called non-productive land in 1940 has been used recently for transportation and urban purposes at a growth rate of 2%. This increase shows the need for land in this region and the intensive use of the presently existing land.

It is important to stress that this pattern refers only to the San Juan Bay area as defined in this study. The general pattern for the San Juan metropolitan area could be completely different from the ones previously described.

The Slum or "Arrabales" Areas

The turning point of the rural-urban migration in San Juan was by 1950, when 18% of the urbanized area of Santurce, and 8% in the San Juan Islet, were considered slums. In 1940 slum houses covered the central and southern portion of Puerta de Tierra, the northern section
of Old San Juan city, the southeastern point of El Condado lagoon, the northwestern and northeastern extreme of Constitution bridge, part of the northern edge of Martín Peña channel and the sector of Sabana y Amelia. In 1950 the largest "arrabal" section was the northern margin of Martín Peña channel, which included houses built on the water. During 1950-1960 new slums were formed in Tokio, El Monte, Puente Blanco, Juana Matos and Las Cucharillas.

An interview with Mrs. Lydia González Colón reflects the living conditions of the slum population. She lived in a slum called "Hoare" between 1943 and 1951. According to her information, most of the resident population came from the interior mountain towns of Puerto Rico such as Morovis, Orocovis, Ciales and Jayuya. The first step after arrival was either to purchase a house or build one with any available wood. The cost fluctuated between 140 and 200 dollars. Built on beams buried in the mud, the house was then constructed 2-4 feet over the water level. However, during high tide most of the floor got wet. Separate houses were connected with small wood bridges, which were also connected to a main bridge extending to dry land. In each two bedroom house lived between 6 to 7 persons. Most of the people worked in Abarca, a metallurgy plant, or in Compañía de Gas, Ventura Rodríguez & Sons, or in Railgold Brewery. Others might have a small clothing store or "bazar", shoemaking, or barber shop. Drinking water was obtained from outside the slum and the toilets discharged directly into the water under the house. Each had electricity which cost about 25 cents per month.

After 1948 the population of Hoare began to fill the swamp with garbage coming from Abarca. In 1951 the San Juan mayor continued the
landfill works, and that same year the population was transferred to
different places; Mrs. Colón was sent to the San José public residence
area. The government paid 700 dollars for her Hoare house after
finding her a plot of land in San José, where she has been living
since that time.

This description presents the general pattern of the people
living in the slum. After living in poor conditions and filling the
land, they were transferred to a different public residential area.

The social dynamism of the "arrabal" permitted speculation with
the land through the buying and selling of land plots. Due to the
public policy of selling the mangrove areas, many persons took
advantage of buying the land, filling it and then selling for a
profit. This complex phenomenon contributed to the formation of
social strata among the slum people, distinguishing the owner from the
renters, "wet" slum people from "dry" ones.

Since the government initiated its campaign of slum clearance
through urban renovation, 85% of the "arrabales" have been eliminated,
and their population transferred. A 1941 decree proposed to eliminate
inadequate housing in San Juan, but because of the failure of this
order, the government declared in 1950 that land occupied by the slums
would be for public use, and thereby was justified any slum transfer
or elimination. For example, Hoare and El Fanguito were eliminated
to give way to the construction of Muñoz Rivera and Kennedy Avenue
intersection, and the eastern slum of El Condado lagoon was wiped out
when the Baldorioty Avenue was built.

Between 1970 and 1980 all the northern slum line of Martín Peña
channel was eliminated in order to build the recreational facilities
of "Parque Central", "Parque Ecuestre" and the condominium project of
"Parque Centro". Today the only shantytown left in Martín Peña area
is Tokio. But, outside this area, Juana Matos, Puente Blanco and Las
Cucharillas are still left. Some of these slum areas could be
considered "barrios" now, which means that these people have, in some
way, improved their living conditions. The terms "barrio" usually
refers to an area where public and social services are generally
provided.

Since 1950 the slum population was transferred to public housing
projects or "Caseríos". This explained the creation of "San José",
"Luis Lloréns Torres" and "Nemesio Canales" in the 1950s. Such
public projects continued throughout the 1960s, especially in Cataño,
where three "caseríos" were constructed.

The largest population relocation was that of the people of the
Martin Peña sector. About 5,000 persons lived in the area in 1969;
none remain today, at least in its northern edge. But the present
relocation is different in that the people are not transferred to a
"caserío", but to a rural area or to a "municipio" located in the
suburbs. For example, the Buenos Aires slum, located in the northern
central part of Martín Peña, was relocated, and the majority of its
population was transferred to places like Levittown, Río Piedras, Toa
Baja, Toa Alta, Bayamón, Carolina, Cataño, Vega Alta, Trujillo Alto
and Vega Baja.

From different interviews, it became apparent that the
elimination of some slums has contributed to the growth of others.
For example, Tokio has grown more rapidly in the last decade than in
the previous years, as also happened with Vietnam, located in Sabana y
Amelia. Perhaps some of the growth of these slums is a response to the increase in population coming from other "arrabales" and from other countries, particularly the Dominican Republic.

The general pattern of the rural-urban migrant has been to move from the coffee or tobacco areas to a slum area in San Juan. From here he moved to a public housing project, then to a low cost development. The second generation will probably move to a middle class development. This process has led to a chain of residential moves among the different social classes existing in San Juan, whereby one development invaded by a lower class, "pushes" the people living in that development to move elsewhere. A similar successive residential mobility is observable in condominiums. Although there are no specific data on this phenomenon in Puerto Rico, a comparable situation has been recognized in cities of the United States.

Population

The total population of the metropolitan area of San Juan in 1940 was 218,198 inhabitants and 882,515 in 1980, thus the metropolitan population has quadrupled since 1940 (Table 6-3). The area had an increase of more than 175,558 inhabitants between 1940 and 1950, 146,400 persons (1950-60), 231,161 (1960-70) and 111,198 persons from 1970-1980.

It is evident that all the metropolitan "municipios" have registered a high population increase during the modern period. However, within the metropolitan area itself some sectors have been losing population while other metropolitan sectors gain. For example, between 1940 and 1960 San Juan lost about 24,500 inhabitants, while
Rio Piedras gained 97,665 persons; part of this increase represents the population lost by San Juan.

The general pattern of population growth in the San Juan area is presented in Table 6-3. This data present the decline of San Juan city, which contributed to the post-1960 expansion of Rio Piedras. Bayamón Guaynabo and Carolina have experienced a tremendous increase in population after the 1960s. By 1980 Cataño and San Juan were the only "municipios" in the San Juan Bay area that lost population. Most of this population has migrated to other metropolitan municipios, such as Bayamón or Carolina.

The same pattern can be observed when we compare some central sectors in the San Juan Bay area against peripheral sectors (Table 6-4). Old San Juan, as well as Santurce, has been losing population since 1950. However, the peripheral areas of Levittown, Caimito, and Cupey have been gaining population, especially in the last decades. When Hato Rey was located in an area that was considered peripheral between 1960 and 1970, it increased in population; now, during the 1980s, even though its location is considered central, it is losing population. Palo Seco is an exceptional case. Being considered an old populated area the sector has not offered any attraction for present increase in population.

What these data and pattern suggest is that the metropolitan population is progressively moving to the peripheral areas of San Juan, leaving the central ones for the later development of commerce, banking and institutional public services.

The movement of the population to the periphery presents problems, especially regarding transportation. The daily migration to
TABLE 6-3
Population Growth in the Municipalities Surrounding the San Juan Bay Area
1940-1980

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<tr>
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<tbody>
<tr>
<td>San Juan</td>
<td>169,247</td>
<td>224,767</td>
<td>200,274</td>
<td>141,285</td>
<td>110,989</td>
</tr>
<tr>
<td>Rio Piedras</td>
<td>19,935</td>
<td>132,438</td>
<td>*230,103</td>
<td>*306,440</td>
<td>*320,097</td>
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<tr>
<td>Cataño</td>
<td>7,924</td>
<td>9,182</td>
<td>19,764</td>
<td>26,459</td>
<td>26,243</td>
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<tr>
<td>Carolina</td>
<td>5,363</td>
<td>5,041</td>
<td>23,094</td>
<td>94,271</td>
<td>159,055</td>
</tr>
<tr>
<td>Guaynabo</td>
<td>1,128</td>
<td>2,157</td>
<td>25,190</td>
<td>55,310</td>
<td>76,378</td>
</tr>
<tr>
<td>Bayamón</td>
<td>14,596</td>
<td>20,171</td>
<td>41,731</td>
<td>147,552</td>
<td>189,753</td>
</tr>
<tr>
<td><strong>Metropolitan Area</strong></td>
<td>218,198</td>
<td>393,756</td>
<td>540,156</td>
<td>771,317</td>
<td>882,515</td>
</tr>
</tbody>
</table>


* Since 1960 the data of Rio Piedras was obtained from the original sector boundaries because since then Rio Piedras has been integrated to San Juan.

** Only includes the above municipios.
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</thead>
<tbody>
<tr>
<td>Old San Juan</td>
<td>34,381</td>
<td>29,760</td>
<td>22,095</td>
<td>13,053</td>
<td>9,886</td>
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<tr>
<td>Santurce</td>
<td>133,091</td>
<td>195,007</td>
<td>178,179</td>
<td>128,232</td>
<td>101,103</td>
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<tr>
<td>Hato Rey Norte</td>
<td>-</td>
<td>8,282</td>
<td>-</td>
<td>18,525</td>
<td>15,909</td>
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<tr>
<td>Cupey</td>
<td>3,413</td>
<td>4,125</td>
<td>-</td>
<td>14,496</td>
<td>27,171</td>
</tr>
<tr>
<td>Caimito</td>
<td>3,115</td>
<td>4,588</td>
<td>-</td>
<td>9,412</td>
<td>15,939</td>
</tr>
<tr>
<td>Levittown</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>17,079</td>
<td>31,613</td>
</tr>
<tr>
<td>Palo Seco</td>
<td>904</td>
<td>840</td>
<td>-</td>
<td>489</td>
<td>439</td>
</tr>
</tbody>
</table>

the central core of San Juan is now higher than ever before, most of the people living in Carolina, Bayamón, or Guaynabo move daily to Santurce, San Juan, or Hato Rey to work or to obtain any public or private service.26

This trend continues in the 1980s, as does the rural-urban migration. But now the latter migration is more perceptible in the middle class and specialized workers who move to the city looking for a government or private-sector jobs, or for higher education. The city continues to be the main center of economic activities. This means that most of the services and opportunities are concentrated here. As this condition continues, more and more people will be coming to San Juan, not only from the rest of the island, but also from other countries.

The Port of San Juan

According to a 1941 description27 the installation of warehouses, terminals, railroad and related equipment provided the port of San Juan with the necessary furnishings to handle the greatly increased traffic and commerce of the city.

At the time there were six piers (Fig. 6-4). Pier No. 1 had 495 feet (15 meters) in length and was 98 feet wide (30 meters). It also had a depth alongside of 30 feet (9 meters) and a berthing capacity of 990 feet. Pier No. 2 had 420 feet (128 meters) in length and 100 feet (30 meters) in width. It had 30 feet depth alongside and 1200 feet of berthing capacity. Both were located at the end of Tanca Street.

Pier No. 3 was the most modern pier in Puerto Rico. It had a length of 395 feet (120 meters) and a width of 120 feet (37 meters). The depth alongside was 30 feet and the berthing capacity 771 feet.
(232 meters). Pier No. 5 had a length of 480 feet (146 meters) and a width of 86 feet (26 meters). The depth alongside was 30 feet and its berthing capacity 900 feet (274 meters). Pier No. 6 was divided into two sections. Section B had 243 feet (74 meters) by 312 feet (95 meters) and Section C had 294 (90 meters) by 80 feet (24 meters). The depth alongside was 30 feet and its berthing capacity 2100 feet (640 meters).

The San Juan port also had two insular bulkheads located along the San Antonio channel. The first one had a length of 830 feet (253 meters) and 35 feet (11 meters) in width. The second had a length of 2130 feet (649 meters) and 65 feet (20 meters) in width. Both had a depth of 30 feet and railway connections for general shipment.

Three docks were already constructed in 1941 and one more in planning for the near future. The San Juan dock company had a length of 372 feet (113 meters) and a width of 33 feet (10 meters). The San Antonio dock had a length of 600 feet (183 meters) and a width 330 feet (101 meters). The Pyramid dock had 397 feet (121 meters) in length and 64 feet (19 meters) in width. All had railroad, fuel oil connections and water supply. Although by this time it was only projected, after being constructed the Graving dock would have a length of 720 feet (219 meters) and a width average of 100 feet (30 meters).

In addition to the above, there were several landings in the western side of the harbor, a bulkhead in front of the Custom House and three piers in the area of La Marina.

The fuel oil was supplied by three petroleum companies; the West India Oil Co., The Texas Company, and the Shell Company. Both Bunker
Oil and Diesel were available through the facilities of the Shell Company at pier 5, Pyramid dock and the government extension wharves.

Sucesores de Abarca was the only marine repair plant. It was equipped to make repairs to steel vessels, engines, boilers and dynamos. The Porto Rico Coal Company operated a cooling station for the handling of steamer requirement. The plant included a storage dock of 10,000 tons of coal.

No significant port construction was developed between 1941-1952. The port activities were concentrated in the southern side of San Juan Islet until 1958 when Governor Luis Muñoz Marin authorized 3 million dollars for the construction of a new port in Puerto Nuevo Bay. Since 1952 new port facilities were being constructed outside the San Juan Islet. By this time 2 sheds were already constructed in Puerto Nuevo for sugar shipping and one more was in construction in Isla Grande. The Army also had constructed 2 piers in Puerto Viejo Bay.

The new port project for Puerto Nuevo was known "Projecto del Mercado y Puerto de Puerto Nuevo" (Fig. 6-5). It includes the diversion of Puerto Nuevo River, the bay dredge, the filling of the land, and the construction of 2 piers, one dock, and warehouses. The total area covered about 98 acres. The project works began in 1962, and in 1963 the first pier with a modern handle shipping system was inaugurated. The construction of piers in this area continued slowly throughout the late 1960s and 1970's. However, a large infrastructure of warehouses, administration offices, parking, roads, and sea walls were developed. Other port facilities constructed outside the Puerto Nuevo Bay included the two piers build in 1962 in Sabana for the rice mill companies. In 1964

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Figure 6-5

[Diagram of San Juan Harbor, PR, with various annotations and measurements.]

PROJECT: An entrance channel 38 feet deep and 800 feet wide across outer bar to channel head (about 1,200 feet), with 45-foot depth over a 500-foot width within the channel. A mid-channel 16 feet deep and 1,200 feet wide at the entrance to the inner harbor (about 4,000 feet from head); an inner harbor area 30 feet deep over about 500 acres, including: a channel along southwest side of that area 16 feet deep, and 800 to 1,000 feet wide in continuation of the 38-foot entrance channel and extending to the intersection of Graving Dock and Army Terminal Channels, and with an approach channel 38 feet deep and 600 feet wide in San Antonio Channel and an area 35 feet deep, 300 to 1,000 feet wide, and 2,000 feet long in San Antonio Channel, a channel 38 feet deep and 1,000 feet wide in the inner harbor of Army Terminal, with a turning basin of 1,000 feet wide and 2,000 feet long in front of the dock, a channel 30 feet deep and 600 feet wide from the inner harbor to Graving Dock, with a turning basin of same depth 1,000 feet wide and 2,000 feet long in front of the dock, a channel 30 feet deep and 300 feet wide between Army Terminal and Graving Dock (Puerto Nuevo Channel), a new approach channel 36 feet deep, 1,500 feet wide, and 3,200 feet long off the southwestern side of Isla Grande, removal to depth of 8 feet of Anegada, Large, and Capitana Shoals.

MEAN TIDAL RANGE: 1.1 feet

EXISTING PROJECT

SAN JUAN HARBOR, P.R.

SCALE IN FEET

DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA
6-30-75

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the Isla Grande Terminal was inaugurated. These facilities include various piers, docks and buildings. In 1976 the Puerto Rican Maritime Company announced an investment of more of 1 million dollars for pier improvement in Puerto Nuevo.

With the port activities oriented to Puerto Nuevo and other areas, the San Juan islet piers were partially abandoned. It was then the government decided to acquire some of them and to reconstruct them for touristic purposes. The reconstruction of Pier No. 1 began in 1971 and it was inaugurated in 1972. Its tourist facilities included an administrative office, waiter areas, and a souvenir store. Piers 3 and 6 have been recently habilitated for tourist business; meanwhile, the others have been eliminated.

In 1980 the facilities of San Juan port could be considered one of the most modern in the world. The berthing facilities are shown in Table 6-5. All these facilities have made of San Juan a world port in terms of commercial and tourist traffic. Tables 6-6 to 6-7 present an idea of the increasing importance of San Juan port in terms of the general cargo and tourism. The general pattern is that in the last two decades the cargo handling has doubled. In 1976 the port occupied the second place in the Americas in terms of ship movement and in 1982 it was considered the 8th port in importance in the world in terms of tonnage.

Natural Environment and Human Impact

The urbanization and industrialization process have been the main factors in the clearing of vegetation. The built up portion of the San Juan Bay area has increased from 38.4% in 1940 to 75.2% in 1980

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### TABLE 6-5

Summary of Existing San Juan Harbor Berthing Facilities

<table>
<thead>
<tr>
<th>Pier Designations</th>
<th>Cargo Handled</th>
<th>Channel Location</th>
<th>Available Vessel Berths</th>
<th>Storage-Marshaling Areas (Sq. Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cruise ship passengers</td>
<td>San Antonio</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Ferry terminals</td>
<td>San Juan commuters</td>
<td>San Antonio and Isla de Cabras</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Cruise ship passengers</td>
<td>San Antonio</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>Cruise ship passengers</td>
<td>San Antonio</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>Vessel tending</td>
<td>San Antonio</td>
<td>1</td>
<td>25,000</td>
</tr>
<tr>
<td></td>
<td>(water, etc)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Conventional general cargo</td>
<td>San Antonio</td>
<td>3</td>
<td>176,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>40,000</td>
</tr>
<tr>
<td>9</td>
<td>Conventional general cargo</td>
<td>San Antonio</td>
<td>3</td>
<td>134,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>40,000</td>
</tr>
<tr>
<td>10</td>
<td>Tug and barge terminal</td>
<td>San Antonio</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>11</td>
<td>Conventional general cargo</td>
<td>San Antonio</td>
<td>1</td>
<td>100,000</td>
</tr>
<tr>
<td>12</td>
<td>Conventional general cargo</td>
<td>San Antonio</td>
<td>1</td>
<td>15,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>37,000</td>
</tr>
<tr>
<td>13</td>
<td>Conventional general cargo</td>
<td>San Antonio</td>
<td>1</td>
<td>28,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>55,000</td>
</tr>
<tr>
<td>14</td>
<td>Conventional general cargo</td>
<td>San Antonio</td>
<td>1</td>
<td>40,000</td>
</tr>
<tr>
<td>Navy Frontier Pier</td>
<td>Conventional general cargo</td>
<td>San Antonio</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Channel &amp; Extension</td>
<td></td>
<td></td>
<td>450,000 (approx.)</td>
</tr>
<tr>
<td>Pan American Dock</td>
<td>Conventional general cargo</td>
<td>San Antonio</td>
<td>2</td>
<td>32,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>240,000</td>
</tr>
</tbody>
</table>

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
<table>
<thead>
<tr>
<th>Pier Designations</th>
<th>Cargo Handled</th>
<th>Channel Location</th>
<th>Available Vessel Berths</th>
<th>Storage-Marshaling Areas (Sq. Feet)</th>
<th>Transit</th>
<th>Open</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isla Grande Lo/Lo Trailer Ship Terminal</td>
<td>Container cargo</td>
<td>San Antonio</td>
<td>2</td>
<td>0</td>
<td>1,800,000</td>
<td></td>
</tr>
<tr>
<td>Isla Grande Ro/Ro Trailer Ship Terminal</td>
<td>Container cargo</td>
<td>Graving Dock</td>
<td>2</td>
<td>0</td>
<td>870,000</td>
<td></td>
</tr>
<tr>
<td>15 &amp; 16</td>
<td>Dry docks</td>
<td>Graving Dock</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Sabana Pier</td>
<td>Bulk grains</td>
<td>Army Terminal</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>San Juan oil refinery berth</td>
<td>Petroleum</td>
<td>Army Terminal</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Army Terminal Pier</td>
<td>Petroleum &amp; conventional general cargo</td>
<td>Army Terminal</td>
<td>2</td>
<td>50,000</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Navy Oil Pier</td>
<td>Petroleum</td>
<td>Army Terminal</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>A &amp; B</td>
<td>Petroleum &amp; conventional general cargo</td>
<td>Puerto Nuevo</td>
<td>2</td>
<td>102,000</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Ro/Ro container cargo</td>
<td>Puerto Nuevo</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Conventional general cargo</td>
<td>Puerto</td>
<td>1</td>
<td>0</td>
<td>100,000</td>
<td></td>
</tr>
<tr>
<td>E, F, G, H, J, K &amp; L</td>
<td>Container cargo</td>
<td>Puerto Nuevo</td>
<td>7</td>
<td>0</td>
<td>4,312,000</td>
<td></td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Pier Designations</th>
<th>Cargo Handled</th>
<th>Channel Location</th>
<th>Available Berths</th>
<th>Storage-Marshaling Areas (Sq. Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>Conventional general cargo (especially Canadian lumber)</td>
<td>Puerto Nuevo</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>653,400</td>
</tr>
<tr>
<td>Dynamite Pier</td>
<td>Dynamite and other Class A explosives</td>
<td>Isla de Cabras</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

Source: Corps of Engineers, General Design Memorandum on San Juan Harbor, 1981.
TABLE 6-6
Estimated General Cargo Movements Through San Juan Harbor

<table>
<thead>
<tr>
<th>Year</th>
<th>Population (1,000's)</th>
<th>General Cargo Movements (Excluding Dry Bulk) (1,000 Tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>x</td>
<td>y</td>
</tr>
<tr>
<td>1960</td>
<td>1,539</td>
<td>1,947</td>
</tr>
<tr>
<td>1961</td>
<td>1,582</td>
<td>1,822</td>
</tr>
<tr>
<td>1962</td>
<td>1,626</td>
<td>2,241</td>
</tr>
<tr>
<td>1963</td>
<td>1,668</td>
<td>2,108</td>
</tr>
<tr>
<td>1964</td>
<td>1,716</td>
<td>2,492</td>
</tr>
<tr>
<td>1965</td>
<td>1,761</td>
<td>3,033</td>
</tr>
<tr>
<td>1966</td>
<td>1,787</td>
<td>3,231</td>
</tr>
<tr>
<td>1967</td>
<td>1,810</td>
<td>3,520</td>
</tr>
<tr>
<td>1968</td>
<td>N/A</td>
<td>4,287</td>
</tr>
<tr>
<td>1969</td>
<td>N/A</td>
<td>4,074</td>
</tr>
<tr>
<td>1970</td>
<td>1,853</td>
<td>4,739</td>
</tr>
<tr>
<td>1971</td>
<td>1,964</td>
<td>4,867</td>
</tr>
<tr>
<td>1972</td>
<td>2,002</td>
<td>5,586</td>
</tr>
<tr>
<td>1973</td>
<td>2,040</td>
<td>6,057</td>
</tr>
<tr>
<td>1974</td>
<td>2,077</td>
<td>7,021</td>
</tr>
<tr>
<td>1975</td>
<td>2,115</td>
<td>5,789</td>
</tr>
<tr>
<td>1976</td>
<td>2,153</td>
<td>5,254</td>
</tr>
<tr>
<td>1977</td>
<td>2,191</td>
<td>4,843</td>
</tr>
</tbody>
</table>

Projections* x¹ y¹

<table>
<thead>
<tr>
<th>Year</th>
<th>Population (1,000's)</th>
<th>General Cargo Movements (Excluding Dry Bulk) (1,000 Tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>x</td>
<td>y</td>
</tr>
<tr>
<td>1980</td>
<td>2,478</td>
<td>8,543</td>
</tr>
<tr>
<td>1985</td>
<td>2,790</td>
<td>10,812</td>
</tr>
<tr>
<td>1995</td>
<td>3,282</td>
<td>14,398</td>
</tr>
<tr>
<td>2005</td>
<td>3,752</td>
<td>17,825</td>
</tr>
<tr>
<td>2015</td>
<td>4,262</td>
<td>21,544</td>
</tr>
<tr>
<td>2025</td>
<td>4,772</td>
<td>25,263</td>
</tr>
<tr>
<td>2035</td>
<td>5,282</td>
<td>28,982</td>
</tr>
</tbody>
</table>

* Population projections past the year 2000 were extrapolated from the Puerto Rico Planning Board projections.

Source: Corps of Engineers, General Design Memorandum on San Juan Harbor, 1981.
### TABLE 6-7
Past and Projected U.S. Population and San Juan Cruise Ship Passenger Data (x 1,000)

<table>
<thead>
<tr>
<th>Year</th>
<th>U.S. Population</th>
<th>Total Cruise Ship Passengers into San Juan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>x</td>
<td>y</td>
</tr>
<tr>
<td>Data:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965</td>
<td>194,300</td>
<td>96.0</td>
</tr>
<tr>
<td>1966</td>
<td>196,600</td>
<td>103.6</td>
</tr>
<tr>
<td>1967</td>
<td>198,700</td>
<td>119.9</td>
</tr>
<tr>
<td>1968</td>
<td>200,700</td>
<td>122.5</td>
</tr>
<tr>
<td>1969</td>
<td>202,700</td>
<td>136.6</td>
</tr>
<tr>
<td>1970</td>
<td>204,900</td>
<td>163.8</td>
</tr>
<tr>
<td>1971</td>
<td>207,100</td>
<td>261.2</td>
</tr>
<tr>
<td>1972</td>
<td>208,800</td>
<td>344.3</td>
</tr>
<tr>
<td>1973</td>
<td>210,400</td>
<td>411.1</td>
</tr>
<tr>
<td>1974</td>
<td>211,900</td>
<td>415.6</td>
</tr>
<tr>
<td>1975</td>
<td>213,600</td>
<td>412.3</td>
</tr>
<tr>
<td>1976</td>
<td>215,100</td>
<td>445.1</td>
</tr>
<tr>
<td>1977</td>
<td>217,700</td>
<td>453.3</td>
</tr>
<tr>
<td>1978</td>
<td>219,500</td>
<td>484.2</td>
</tr>
<tr>
<td>Future Projections:</td>
<td>1985</td>
<td>233,580</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1995</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2005</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2015</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2025</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2035</td>
</tr>
</tbody>
</table>

Source: Corps of Engineers, General Design Memorandum on San Juan Harbor, 1981.
while the vegetation cover has decreased from 26% in 1940 to 19.9% in 1980 (Table 6-1).

Although in the last decade the vegetational areas around San Juan Bay have been slightly increasing, the total recovery has not reached the 1940 percentage. This apparent recovery occurred when the slum areas were eliminated, thus permitting the vegetation to grow. But now the vegetation that grew in the former slum areas is being eliminated again for the construction of new buildings.

In 1940 the mangrove lands were being sold at public auction, as it is documented in the Historical Archive of Puerto Rico. For example, a 1940 document read:

"the law authorized to divide and sell the mangrove located south of the Bayamón Cataño road for 10 dollars each land plot of 500 square meters... To all persons that have improved or dried a mangrove in Cataño would be given land ownership, without need of paying, because then it would be considered the improvement of the land as the payment. All persons who buy a 500 square meter mangrove plot will have to fill it and construct houses. The person that in 5 years does not dry the land will lose the property... The land would be allowed to be used only for house construction and the person has to plant no less than four trees, any person that has an income of more than 2,500 dollars annually would not be allowed to buy a parcel."  

As it is evident in this document the selling of mangrove plots was one mechanism used for locating the migrating population arriving in San Juan. So the reduction of mangrove areas was proportional to the increase in migration. This explains why a large reduction of mangrove occurred between 1940 to 1960.

The extensive destruction of the mangrove during the last 20 years has been caused by the construction of port, industrial and government facilities. The most typical example is the elimination of 102 acres of mangrove for port facilities in Puerto Nuevo, the earth
filling of Isla Grande, and the filling of the Hato Rey mangrove area after its having been used for a dump.

By 1970 most of the mangrove areas of Cataño were already eliminated, while in some other areas, like Martín Peña, it was beginning to recover, and so continues today.

A different form of human influence has been the substitution of the natural tropical vegetation by a new cultural one. The introduction of cultural vegetation has been promoted, especially during the last decade. As an example, a total of 7,964 trees of different species in the San Juan Islet were introduced in 1975.36

Other species have invaded the region naturally by the sea or air, as is the case of the well diffused Australian Pine, that today, is concentrated in "El Escambrón" and in the southern border of Cataño.

The earthfilling works has been a major cause for relief changes in the San Juan bay area. Some of them have been developed under governmental initiative, others by individual or group effort. The first large landfilling project was Isla Grande (Fig. 6-5). After being started in 1922 the total filling of the peninsula was not completed until 1950. Landfilling work was combined with the dredging projects of 1922, 1930, 1935, 1940 and 1945 with the sediments obtained from the dredging activities being deposited in Isla Grande. Some other landfilling material, such as limestone, was brought from the neighboring areas. The first step in the Isla Grande landfilling was the connection of Isla Grande mangrove island to the mainland eastern mangrove peninsula. Then after 1940 both were connected to "Miraflores", another mangrove island, located in the south.
Some other large governmental landfilling projects included the connection of Isla de Cabras to the mainland in the 1940s, and the landfilling of a swamp in Cataño for the construction of the air base of Buchanan. During the 1950s the southern coastline of the Condado lagoon was filled for the construction of the Baldorioty de Castro Avenue. In 1960 the northern side of the lagoon was filled for the building of hotels and other touristic facilities.\(^{37}\)

Another wetland filled by the government was Puerto Nuevo. Since 1961, they began to deposit dredge material in this mangrove area. The process included drainage, drying, and earthfilling with mud, sand, and rocks. This landfill reached a height of 10-12 feet.\(^{38}\) By this time the coastal area of Sabana was also filled.

When the Army Terminal channel was dredged in 1962 the sediments were deposited at the eastern side of Palo Seco peninsula. A year later a new peninsula or spit had already formed.\(^{39}\)

The most recent government landfill was the area of the "Municipal Dump", in Puerto Nuevo-Hato Rey. In 1960 about 100 acres were filled along the Kennedy avenue, and today more than 150 square acres are in the process of being filled in this area.\(^{40}\) The last documented landfill is the one authorized by the government in 1976, which included the total earthfilling of the slum "Juana Matos".\(^{41}\)

Equally significant as the governmental landfilling projects has been the earthfilling done by the slum communities. These ones were filled with all kinds of garbage, rocks, wood, coconut husks, and soils. Wooden bridges were constructed to facilitate the work, which usually lasted three to five years. The process was communally
organized, though sometimes the government contributed by transporting filling material.

The slum communal process caused the landfilling, by 1980, of the following sectors: the northern edge of Martín Peña, the southeastern portion of Isla Grande, south central border of Puerta de Tierra, the area covered by Sabana y Amelia, Tokío, and a portion of Juana Matos and Puente Blanco slums.

The most important dredging works of the last forty years are summarized in Fig. 6-5. The result of these dredging activities is the construction of five channels within the bay, with an average depth of 30 to 45 feet and a width of 600 to 800 feet. A new dredging project, which was submitted by the Corps of Engineers in 1981, would increase the depth and width of the existing channels. Details of this project are also included in Figure 6-5.

Some of the channel surroundings have also been dredged. In 1969 San Fernando and La Malaria channel were dredged and cleaned. The 1976 and 1978 dredging works of San Juan Bay included the dredging of the Martín Peña channel mouth. The last dredging cycle began in 1980, and the purpose was to maintain regular depth of the bay channels. In contrast to previous dredging practice, the dredged materials are now deposited in the open sea.

Although dredging activities have affected the bay water quality, they have had little impact compared to other sources of water pollution.

As a result of industrial discharges have been many fish kills in the bay. In 1958 the Bacardí distillery was accused of killing fish with its polluted discharges. Recently the main discharges have
been linked to oil and gasoline products. In 1969 Esso Standard Oil, Cataño Borge, Compañía del Caribe Nitrógeno, and Autoridad de las Fuentes Fluviales were accused by the federal government of polluting the water.\textsuperscript{45}

Disasters by petroleum spread in 1976\textsuperscript{46} and the industrial discharge of 3000 gallons of gasoline in 1979\textsuperscript{47} have continued to aggravate the water pollution problem in San Juan Bay and the disruption of biota.

Two critical areas, in terms of water pollution, were Condado lagoon and Martín Peña channel, both of which were affected by sewage discharges. In 1974 the Junta de Calidad Ambiental (Environmental Quality Board) of Puerto Rico ordered the closing of Condado Beach. One year later the beach and the lagoon were cleaned up.\textsuperscript{48} However, today, problems with illegal sewage discharges still occur. On the other side, the Martín Peña the water quality has been considered unfit for any human use for a long time.

The ecological environment of San Juan Bay has deteriorated to such a degree that, during 1971, the total estimated cost for achieving a normal environmental state was more than one thousand million dollars.\textsuperscript{49} Of course, with these high costs, the most sensible action would be to prevent any future environmental disruption.
CHAPTER VI

FOOTNOTES

1 Anonymous, Informe 1941-42 y 1942-43, (San Juan, Ed. San Juan City Manager, 1943), 9-10, 57. Among the most important restoration projects are the renewal of Baldorioty de Castro and Colon squares, the rehabilitation of the "Cabildo" and the widening of some streets.

2 "57 Residencias más en la Barriada Roosevelt", El Mundo, (December 7, 1942), 10; "Primeras 500 Casas de Puerto Nuevo", El Mundo, (June 28, 1948), 7; "Han Terminado 1600 casas en Puerto Nuevo", El Mundo, (October 14, 1948), 4. In 1942, 57 houses were in plan to be constructed in "Roosevelt". In 1948 about 1600 houses were constructed in "Puerto Nuevo". This project known as the "Largest Residencial Enterprise of the World" was constructed by the L. D. Long Co. of South Carolina. Each house had between 3-5 rooms and the total cost was about 3,095 dollars to be paid 25 dollars monthly.

3 Jesus T. Piñero or Central Avenue as much as Roosevelt were not completely constructed in 1950, both were already finished in the early 1960s. Although Baldorioty de Castro Avenue existed previous to 1970, it was not to this point that it was converted into an expressway.

5 "90.8 Están Deteriorados", El Mundo, (September 2, 1967), 3.

6 "Evacuación Sector de San Juan Obedeciendo Ordenanza", El Mundo, (December 6, 1969), 168.


9 "Inauguran Projecto de 172 Unidades de la Puntilla", El Mundo, (September 30, 1978), 10D.

10 "Hato Rey Será el Centro del Area Metropolitana", El Mundo, (April 13, 1965), 47.


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CHAPTER VII
Coastal Modification
in the San Juan Bay Area

Introduction

This chapter intends to analyze more closely those geographical aspects that result from considerable intervention of man. First, it includes the coastal changes associated with modifications in coastal morphology, erosion, deposition, sedimentation, and ocean circulation. It also includes the human impact on vegetation and the hydrosphere, and its effect on environmental quality through the pollution of air and water. The historical aspects of these elements were discussed in previous chapters, thus this section only intends to present the total human impact outcome and actual state of each one of these environmental components.

In the San Juan Bay Area all the natural elements seem to be integrated. Thus, any change in the condition of one element would probably raise a chain of changes in the others, in most cases very difficult to determine. However, there are some environmental changes that are relatively simple to recognize because they directly affect society.

This chapter will deal with those environmental disruptions that are of more concern to man. The main goal is to describe the observed modifications, with the help of cartographic analysis, studies of sediment and stratigraphic analysis, as well as coastal measurements taken in the field and statistical interpretation of climatological data. Although this form of analysis is basically qualitative, it is
the most accurate, rapid and inexpensive method of locating coastal changes. Quantitative measurements will be given whenever they have been possible to determine.

**Cartographic Analysis of Coastal Changes**

**Coastal Morphology**

One way to identify coastal changes is through cartographic comparison of historic maps. When Spaniards arrived in San Juan, they prepared the first maps and sketches of the study area. Later, the English, Dutch, and French drew maps of the San Juan Bay area mostly for military purposes. Many of the maps produced during the colonial period have been presented in Chapter IV, but a purely cartographic analysis of them was not attempted there.

Although most of the maps prepared before 1790 expressed well selected geographical conditions of the area, they did not have the geometric or orthomorphic precision necessary to allow exact measurements of distance and area. Nevertheless, these maps are useful, and often the only way to obtain general information about the cultural and physical condition of the region.

Analysis of pre-1790 maps shows that the coastal morphology of the San Juan Bay suffered light modifications throughout the 1518-1795 period. The areas that have undergone more significant changes are those affected by human activities, particularly La Puntilla, Palo Seco, Punta Cataño, Isla de Cabras, and El Condado lagoon. Most of the coastal morphologic changes occurred as a result of land reclamation processes in coastal areas for urban land use and especially the construction of port facilities.
The first chart presenting a relatively accurate coastal configuration of San Juan Bay was the map drawn by Cosme Churrucá in 1794 (Fig. 4-23). A second, more accurate map was prepared in 1912 by the Coast and Geodetic Survey of the United States (Figure 5-9). All of the maps produced later for scientific or navigational purposes show relatively accurate the San Juan Bay configuration. A useful tool is the series of Topographic Quadrangles, prepared since 1930 by the United States Geological Survey. The 1969 quadrangle, revised as of 1980, is used as the base map for this chapter. Other useful sources have been the 1981 aerial photographs, and the 1975 nautic chart of the San Juan Bay.

The technique used in this analysis consisted of the overlaying of the three maps (1794, 1912, 1980) after they were photographically reduced to the same scale, approximately 1:60,000. The result of this comparison is presented in Figure 7-1. As is evident, the most significant shoreline changes occurred between 1912 to 1980. The coastal progradation that characterizes this area before 1912 occurred as a result of the natural expansion of the mangrove, while coastal accretion in some areas and retrogradation in others after 1912 occurred due to human activities induced through landfilling and erosion.

For example, the mangrove islands that today constitute the area of Isla Grande, extended approximately 100 feet (30 meters) toward the sea at the northwestern point between 1794 and 1912, while about another 30 meters were eliminated from its southern section as a result of dredging activities. In the same period, the eastern side of the bay underwent a significant decrease of the mangrove.
Fig. 7.1. Coastal configuration changes, 1794-1980.
Significant coastal accretion (2.44 ft/yr or 0.74 meter/yr) characterized the western and southern bay areas as a result of sand deposits and mangrove expansion, respectively.

Between 1912 and 1980, the coast of the San Juan Bay was drastically modified, thereby interrupting or altering the natural physical processes of the bay. For example, the accretion that was occurring in its southern section was contained due to the construction of sea walls and the destruction of the mangrove.

Shoreline modifications have caused changes in the patterns of current circulation; these have had to adjust to the new shoreline configuration. The size of the bay has diminished, approximately 50 meters in some areas and thus the circulation cells have also diminished especially in the Bay View and Martin Pena areas.

Besides the zone of Puerto Nuevo, Isla Grande, and the southern shoreline of the San Juan Islet, the other three areas that have had their configuration more drastically altered are Isla de Cabras, La Puntilla and Punta Cataño.

The shoreline variations of Isla de Cabras (Fig. 7-1) and La Puntilla (Fig. 7-1) are the results of the landfilling of the southern portions between 1912 and 1980. Both areas are low wave energy zones, and deposition has extended about 170 feet (52 meters) in La Puntilla and about 578 feet (176 meters) in Isla de Cabras.

The morphological alteration of Punta Cataño (Fig. 7-1) is due to the dredging of its northeastern part and the landfilling of the southern point. Its panhandle shape was widened at least 206 feet (63 meters) at its eastern point, while it was dredged about 100 feet (30 meters) in the northern coast.
Erosion

Significant erosion, both man induced and natural has occurred in the San Juan Bay area. Human activities have contributed notably to the disappearance of beaches and sand deposits. Some of the areas today characterized by high erosion, such as the western shore of El Condado Lagoon and the coastline of Sabana, were typical deposition zones in the past, as it is proven by the 1912 map (Fig. 5-9).

All the present day erosional areas of San Juan Bay are represented in Figure 7-2. As can be seen, there are two major areas of erosion. First, those concentrated in high energy wave environments, such as "El Morro", "El Escambron" and Isla de Cabras, and second, those concentrated in a low energy wave environment, such as in El Condado lagoon, "La Puntilla", Isla Grande, Bay View, Punta Cataño and "Sabana". It is in the areas of low wave energy that erosional effects are induced directly (through sand extraction and building of structures) or indirectly (through changes in wave amplitude and refraction) by human activities.

Some of the areas that are losing sand very rapidly are the coastal regions previously filled. Often, when the sand- or soil-fill makes contact with the water, large amounts of earth material are lost, specifically in those areas where the filling material is not well consolidated, as in Isla Grande and El Condado lagoon. Apparently, after the reconstruction of El Condado bridge in 1980, a greater volume of water entered the lagoon, eroding the coastline previously filled.
Fig. 7-2. Erosional and depositional areas in San Juan Bay.
In other areas of the bay erosion has increased because more ships, with greater velocities, are using the facilities. Faster ships produce higher waves, therefore increasing the coastal erosion.

If we add to these factors the effect of hurricanes, with a frequency of one every two years, and the effect of swells, also with a high frequency, we will find the explanation for the high erosion in San Juan Bay Area.

Another important agent of erosion in this area is the wind. Reduction of the coastal vegetation has helped to make it a severe problem on open beaches. This situation is highly perceptible in El Condado and Levittown beaches. In addition, the ocean circulation has contributed to the loss of sediments offshore and to the elimination of beaches formed in the southern section of El Condado lagoon and in the western side of Isla Grande. During high tide, the sediments are carried away from the coast by marine currents. According to our observations, tidal beaches are only exposed during low tide conditions.

Changes in the coastal configuration have been an important factor in new wave refraction patterns. Now, the waves approach the coastline at a higher angle, increasing then longshore current erosional effect. Based on field observations and on the study of aerial photographs, this is an important factor in the erosional problem of the western tip of Isla Grande and Bay View beach, where the angle of wave approach and coastal erosion seem to be correlated (Fig. 7-2).

The intense recreational use of the San Juan beaches seems also to contribute to the loss of sand and earth materials. Some of
these beaches have been used to race jeeps and trucks, an activity that contributes to the destruction of coastal vegetation and the loss of sand. This phenomenon is observable in El Condado and Levittown beaches.

As important as any of the previous factors is the effect of river channelization and diversion. Without the input of sediments, the possibility of beach, shoal and sand bank erosion has increased in the bay. A typical example is the Bay View beach. After the channelization and diversion of Puerto Nuevo and Bayamón rivers in 1962, the total amount of sediment carried by the shore current has diminished considerably. Although this beach began to present erosional problems caused by dredging activities ever since 1951, the problem has increased since 1962. According to our measurements and observations based on aerial photos, in 1981 this beach lost about 170 feet (59 meters) of sand. This represents an annual erosion rate of 9 feet (2.9 meters). Other factors that complicated the problem were the sand extraction and dredging activities.

In the case of "El Morro" the situation is different (Fig. 7-2). The northeastern section of El Morro cliff is receding in a way that will lead to the partial collapse of El Morro and San Cristobál castle. The main erosional force here is high energy waves coming from the Atlantic Ocean and the runoff water that forms weak zones within this consolidated sand.

The Corp of Engineers of Jacksonville District plan to construct an offshore breakwater along the ocean and harbor entrance to protect El Morro castle from the pounding waves, which have been known to reach an amplitude of more than 20 feet above mean sea level.
Deposition

One geomorphological principle states that the amount of material deposited in one area depends on the material eroded in another. This postulate seems to be true for the San Juan Bay area, where depositional environments are common in the southern section of El Condado lagoon, in the mouth of Martín Peña channel, in the Palo Seco spit, and in the east central shore of Isla Grande (Fig. 7-2).

The depositional patterns as well as the erosional ones have been possibly altered by human activities such as river diversion and channelization, dredging and landfilling changes in coastal configuration. The sum of all these activities seems to transform the positive sediment budget of San Juan Bay into a negative one; that is to say, the change from one system where the amount of sediment received exceeds the total amount lost, into a system where the total amount lost is higher than the amount received.

The main sources of sediments for the San Juan Bay are El Condado lagoon, which contributes 36 tons daily through the San Antonio channel, the Martín Peña channel, and Puerto Nuevo river, which contributes with 47 tons daily. This amount of sediment represents less than one third of the original quantity. After the diversion of the Bayamón river and the changes in land surface through the urbanization process, the total amount of sediment carried to the bay should have diminished considerably.9

The contribution of marine erosion to the sedimentary budget within the bay can be considered significant. Most of this sediment moves offshore, transported by the bay currents. This occurred primarily with the sediment carried from El Condado Lagoon through the
San Antonio channel. A fraction of this sediment is not transported offshore and aids the formation of the beach located at the southeastern point of "La Puntilla".

Sedimentary areas of the bay present different seasonal depositional characteristics due to the changes in wave frequency, direction and magnitude. One example is the tidal beaches. They are exposed only during the summer period and when the waves are small and tides are low. As a result, these beaches disappear during the winter season after the current carries its sediment offshore. Field observations show that during the winter the beach profile of most beaches in San Juan Bay moves back to the berm, located backshore.

Three examples of human interference in the depositional pattern of the San Juan Bay are the formation of Palo Seco spit, of the mudflat located at the mouth of Martín Peña channel, and the construction of an artificial beach in El Condado area.

As we mentioned before, the Palo Seco spit (Fig. 7-3) was formed in 1963, when the dredge sediments were deposited at that site. Through time the deposit acquired an elongated shape, perpendicular to the coast, as a result of the impact of waves and currents. However, this configuration has been recently changing to a position more parallel to the coast. At the same time that its two ends have been growing, the central portion shows a tendency to decrease significantly (Fig. 7-3). This damage seems to reflect the direct effect of alterations in the ocean circulation pattern perhaps induced, directly or indirectly, by man.

The actual size of the spit is approximately 1 mile long (1.6 km) and 0.3 miles wide (0.48 km). The northern section includes a beach
Figure 7-3. Morphological Changes of Palo Seco Spit Between 1969-1981

--- 1981 Shoreline
----- 1975 Shoreline
---- 1969 Shoreline
line, while the southern section consists of a small bay surrounded by a beach. The spit does not present erosional characteristics, and according to aerial photos, taken in 1981, it is seen that its amount of loose sediments is equivalent to the amount of sediment gained.

In 1797 the Spaniards set a long line of rocks at the mouth of El Condado Lagoon to defend the San Antonio channel from an English attack. This same line of rock was used as the base for the construction of an artificial beach in 1960 (Fig. 7-2). After the west point of El Condado peninsula was filled, the mean between the rock line and the peninsula was closed forming a depositional zone behind the rocks. The beach was nourished in the 1960s for tourist purposes and remains that way today.

Another physiographic feature formed under human influence was the mudflat mangrove peninsula located at the mouth of Martín Peña channel (Fig. 7-2). After the connection of the Puerto Nuevo river with the Martín Peña channel, the amount of sediments accumulated in the Martín Peña mouth increased. According to 1965 aerial photos, the mudflat located at the northern side of the channel was already formed. By 1973, the southern mudflat mangrove (Fig. 7-2) was also formed. The development of both mudflats has been controlled by dredging in 1978 and 1980. Today these areas constitute the only wild regions of San Juan Bay. More than 5000 birds and more than 70 species are represented. The most common are the Caspian Tern, Fostern's Tern, Cayenne Tern, Ring Billed Gull, Black headed Gull, Herons, Cattle Egrets, Snowy Egrets and Brown Pelicans.¹⁰
Sediment Characteristics

Because of its geographical dimensions, San Juan Bay contains the basic types of existing sediments; sand, clay, and silt. Of these the most important in the area are clay and silt, which combine with varying amounts of sand and organic debris forming the San Juan Bay mud.

The sampling location of the San Juan Bay sediments is represented in Figure 7-4. Table 7-1 presents the nature and condition of the predominant sediments in each station. These samples were taken by the Marine Geology Division of the United States Geological Survey and later analyzed in the laboratory of the Department of Natural Resources in San Juan, Puerto Rico.

According to this data, El Condado lagoon contains a high sedimentary composition characterized by dark silt and clay, with abundant coraline fragments and fine sand. The San Antonio channel is marked by greenish silt and clay. The central part of the bay, as well as in Bay View, includes mainly silt, and clay. In contrast to these areas just mentioned above, the Cataño spit and Isla de Cabras include mainly fine and medium calcareous sand and the section between "El Morro" and "La Funtilla" consists of sand and calcareous fragments coming from old scanty corals.

Some interesting deposits of sediment in the San Juan Bay are: 1) the rock fragments located at the southeastern point of the Hilton Hotel (Station 14); this sediment indicates the probable existence of an old beach rock in this area; 2) The coral shell with terrigenous clay deposited on the shore of Sabana (Station 19); and, 3) The coral sands located east of Palo Seco (Station 24-25) and west of the San
Fig. 7-4. Location of sediment stations in the San Juan Bay area.
<table>
<thead>
<tr>
<th>#</th>
<th>Sediment Type</th>
<th>Additional Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>Silty clay-coarse clay</td>
<td>Very dark greenish color</td>
</tr>
<tr>
<td>1B</td>
<td>Silty sand</td>
<td>Possibly associated with dredging deposits</td>
</tr>
<tr>
<td>2</td>
<td>Clay</td>
<td>Includes pelecypod shells</td>
</tr>
<tr>
<td>3</td>
<td>Silt and mud</td>
<td>Black silt mixed with sand and organic debris</td>
</tr>
<tr>
<td>4</td>
<td>Silty clay</td>
<td>Includes also some calcareous fragments and sand</td>
</tr>
<tr>
<td>5</td>
<td>Green to black mud</td>
<td>----</td>
</tr>
<tr>
<td>6</td>
<td>Silt and mud</td>
<td>Includes some calcareous fragments</td>
</tr>
<tr>
<td>7</td>
<td>Silt and clay</td>
<td>Gray and black color</td>
</tr>
<tr>
<td>8</td>
<td>Clay and silt</td>
<td>Includes also fair amount of very fine white sand</td>
</tr>
<tr>
<td>9</td>
<td>Silt and clay</td>
<td>Also has some shell fragments</td>
</tr>
<tr>
<td>10</td>
<td>Grayish-green clay and silt</td>
<td>Little to none calcareous fragments of sand</td>
</tr>
<tr>
<td>11</td>
<td>Grayish-black silt and clay</td>
<td>Abundant fine sand and some calcareous shell fragments</td>
</tr>
<tr>
<td>12</td>
<td>Brownish-dark gray silt and clay</td>
<td>Abundant fine sand and some calcareous shell fragments</td>
</tr>
<tr>
<td>13</td>
<td>Brownish silt and clay</td>
<td>Abundant shell fragments and some fine sand</td>
</tr>
<tr>
<td>14</td>
<td>Rock fragments</td>
<td>Apparently old beach rock with mega shell fragments</td>
</tr>
<tr>
<td>No.</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>-----</td>
<td>--------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Grayish silt and clay</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Blackish green silt</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Greenish black silt</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Greenish black silt and clay</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Greenish black clay and silt</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Greenish black clay and silt</td>
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<tr>
<td>21</td>
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<tr>
<td>22</td>
<td>------</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Black clay and silt</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Calcareous sand</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Fine-medium calcareous sand</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Silt and clay</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>Grayish black silt</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>Black silt</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>Black silt</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Black silt and clay</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>Blackish green silt and clay</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>Blackish green silt and clay</td>
<td></td>
</tr>
</tbody>
</table>

- Very little clay
- Some shell fragments
- Large pieces of coral with orange ferruginous clay
- Some calcareous shell fragments and sand
- No sample; bottom appeared to be hard
- No sample; bottom appeared to be similar to Station #21
- Abundant sand present
- Shell fragments in abundance
- Abundant shell fragments
- Grayish to green
- ------
- Much organic material
- ------
33 Olive green fine sand and silt Consistency of weak pudding
34 Greenish-black clay and silt -----
35 Greenish-gray silt and clay Abundant sand and some shell fragments and organic material
36 Greenish-gray silt and clay -----
37 Grayish-gray silt and clay Abundant shell fragments and sand
38 Blackish-green clay and silt -----
39 Greenish-gray silt Abundant shell fragments
40 Fine grained grayish sand Abundant shell fragments
41 Fine and medium grained sand Dark color with abundant shell fragments
42 Greenish-black silt and clay -----
43 Fine grained sand Dark greenish color with abundant shell fragments
44 Greenish-black silt and clay -----
45 Fine grained sand and clay Greenish black color with abundant shell fragments
46 Black coarse grained sand Some silt leaves and shell fragments
47 Greenish-black silt Some clay and fine sand
48 Medium to fine grained sand Abundant calcareous shell fragments
49 Greenish-gray shell hash Some pieces of coral, silt and clay

* #* refers to the Station number.
Juan Islet (Station 48-49). 4) The mud deposit located at the mouth of Martín Peña channel (Station 28-29).

The sediments of the San Juan Bay move westerwardly under the influence of the northeast trade winds. The only offshore pass is the mean between "El Morro" and Isla de Cabras. The movement of this sediment forms a turbid plume observed in aerial photographs.

Man could have modified the nature and distribution of the San Juan Bay sediments through river diversion and channelization, dredging, landfilling and recreational sports. These activities should have reduced the total amount of sediment coming to the bay by 85% and the offshore loss of more than 90% of the arrived sediments.

Ocean Circulation

The general circulation pattern in San Juan Bay is controlled by the trade winds coming from the northeast, and by the coastal configuration of the bay. The bay's present current system is a result of wind, waves and tides. The general circulation pattern is presented in Figure 7-5. This represents the 1982 surface pattern and was constructed from an aircraft aerial photo and from multispectral remote sensing analysis. As is expected, this general circulation pattern is different from the previous ones due to recent changes in coastal configuration.

The mean tidal range is 1.1 feet (0.3 meters) and the spring tide range is 1.3 feet (0.4 meters). Tides in San Juan Harbor are semidiurnal. There is no observed data on hurricane tides along the north coast of Puerto Rico; however, the U.S. Weather Bureau has established a hurricane tide level for the region of 6 feet (1.8 meters) above mean sea level.  

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Fig. 7-5. San Juan Bay ocean circulation.

- Predominant current
- Longshore current

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The mean wind speed for San Juan is about 10 knots, which generates ocean waves between 1-4 feet in an area where the average depth is 20 feet (6 meters). However, during hurricanes, heavy northerly winds form heavy seas and breakers in the harbor mouth. When these winds set into the harbor entrance, a surge may be felt as far as San Antonio channel. The ocean floor rises steeply from a 100 fathom-depth contour which is only 7000 feet (2134 meters) offshore. That steep slope causes a marked increase in height of incoming waves outside the harbor; however, large waves diminish rapidly as they pass through the entrance channel.\footnote{12}

One of the circulation systems in which the effects of man have been more noticeable is in the longshore current. In 1912 this current flowed from El Condado lagoon through the San Antonio channel. Then, it moved to the south through the Isla Grande tidal channel and Miraflores Bay (Fig. 4-16). Finally, the current moved towards the east in Puerto Nuevo shoreline and to the northwest in the western side of the bay. The filling of Isla Grande tidal channel plus the formation of new physiographic features, (such as the Palo Seco spit), and the construction of coastal structures, have modified the 1912 longshore current, creating a new circulation pattern (shown in Figure 7-5).

A structure that has significantly modified the circulation on San Juan Bay is the Palo Seco causeway. Before its construction the ocean currents moved from the San Juan Bay to Ensenada de Boca Vieja, through "El Cañuelo" mean. After the causeway construction, this circulation was interrupted causing the current to move in a direction.
toward the northeast, and forming a new circulatory cell at the southern side of Isla de Cabras.

Our observations in the field indicate that sea wall constructions have diminished the effect of tidal currents. This is observable in Martín Peña channel, where the tidal current flows in the San Juan Bay direction at high tide and in the San Jose lagoon direction during the low tide period. The mitigation of the tidal current effect in Martín Peña channel apparently contributed to its sedimentation through sediment deposition.

Recent changes in the coastal configuration of "Ensenada de Boca Vieja" have altered its longshore circulation. Most of these changes seem to be the result of the coastal structure construction discussed in the following section.

Coastal Structures

Perhaps one of the most conspicuous ways in which man has affected the erosion, deposition, circulation and sedimentary pattern of San Juan Bay has been through the construction of coastal structures. These include the construction of sea walls, piers, wave breakers, groins, jettys, bridges, causeways, and sheds.

Two long coastal sea walls have been constructed in San Juan Bay. The first extends 1 mile (1.6 km) along the northern shore of Isla Grande, and the second extends 1.5 miles (2.4 km) along the southern shore of San Juan Bay (Fig. 7-5). Both have been constructed for protecting the shore from the wave attack, besides being used as a pier platform or shed. In the particular case of Isla Grande, the western extreme of the sea wall is severely eroded. Apparently, the construction of this wall has contributed to the acceleration of the
longshore current culminating in the erosion of the area not covered by the wall.

Piers also play an important role in deflecting longshore currents and dispersing of sediments. These phenomena can be observed in any aerial photo of the area of Isla Grande, where the dispersion of the longshore current, by effect of the southern pier, formed a turbid plume.

The rock revetment placed in Cataño, Bay View and Isla de Cabras have caused the same effect as the Isla Grande southeastern piers. In particular, they serve as sediment traps and probably enhance the formation of new refraction and reflection patterns. The rock line set up in El Condado lagoon entrance has modified the effect of current circulation transforming a typical high wave energy environment into a low wave energy area.

Although none of the early wave breakers remain today in San Juan Bay, their effects are still noticeable in some areas. Two of the best known are "La Puntilla" and "San Cristóbal". The first, constructed in the 1940s, had some effect on the eroded beach of "La Puntilla", which finally disappeared in 1960.

Of more importance because of their abundance and impact are the groins and jetties. By 1912 two jetties were already constructed in San Juan Bay, one in Puerto Viejo, and the other in the southern section of "La Puntilla". These two jetties disrupted the natural movement of the longshore current. However, no further effects were determined.

Several groins have been recently constructed in El Condado beach, modifying the coastal morphology and beach profile of this
area. The coast seems to be more irregular after the construction of these groins, and the slope of the beach has increased about 5%.

Another groin constructed in "El Escambrón" has been a major factor in beach erosion on the western side. In this case, the groin has obstructed the natural movement of the longshore current, enhancing the loss of sediment offshore and preventing beach deposition on the lee side of the groin (Fig. 7-6).

"Ensenada de Boca Vieja" represents a typical example of coastal changes due to the combined effect of man and nature. Between 1776, when Thomas O'Daly constructed the first accurate map of this area, and 1941, this half moon bay has shown a marked tendency toward beach erosion (Fig. 7-7). During this period, approximately 660 feet (201 meters) of coast has been lost on its eastern side, and 190 feet (46 meters) along the western coast.

Nearly all this beach erosion is explained in terms of the effects of swells and storm surges, as well as by the human effects after the construction of Palo Seco and Punta Salina causeway. This retrogradational process has continued during the last 40 years, transforming areas that were originally depositional into erosional ones and vice versa (Fig. 7-8).

The most important factor in the modern coastal changes of "Ensenada de Boca Vieja" appeared to be the construction of 5 groins. The natural movement of the longshore current in this bay seems to be towards the center, where, according to aerial photographs, it forms a rip current. After the construction of the groins, the erosional and depositional systems of this rip current have been altered. For example, the west groin (Fig. 7-9) has contributed to beach accretion.
Fig. 7-6. Source: Clifford A. Kaye, Shoreline Features and Quaternary Shoreline Changes, Puerto Rico.
Fig. 7-8. Ensenada de Boca Vieja shoreline changes, 1962-1981.
on its western side and to beach erosion on the eastern one. On the other hand, the eastern groin (Fig. 7-10) has contributed to the accretion of the eastern side and erosion of the western.

Due to these human induced changes, the Levittown beach (Fig. 7-8), has registered severe erosional problems. This beach retreated more than 30 feet (9 meters) between 1962-1981 period, with an erosion rate of 1.6 feet/yr (0.5 meters/yr). Heavy erosion has also been observed in the Punta Salinas Tombolo and the western coast of Palo Seco peninsula.14

**Dredging and Landfilling**

More than one third of the bay shoreline has been filled or dredged, creating clearly significant changes, including destruction of submarine and subaerial geomorphological features. Most of the dredging and filling occurred after 1940. The areas filled by 1980 included Puerto Nuevo, Martín Peña, the southern and eastern portion of San Juan Islet, La Puntilla, Isla Grande, Sabana y Amelia, Isla de Cabras, Puente Blanco, Juana Matos, El Condado, and Palo Seco spit. The dredged areas primarily include the main channel within the bay; the San Fernando, Martín Peña, and San Antonio channels; El Condado lagoon; and the Bayamón river mouth at Palo Seco (Fig. 7-11).

Dredging activities have contributed directly and indirectly to the increased marine erosion. By dredging man has increased the amplitude of the waves that strongly attack the San Juan Bay shoreline.

Most of the historical bathymetrical changes of San Juan Bay have been caused by dredging activities. By 1888, the average depth of the bay was 10 feet (3.0 meters) increasing to 14 feet (4.3 meters) by
Fig. 7-11. Dredges and landfilling of the San Juan Bay area throughout its geographical history.
In 1912, the shallow water depth ranged from 1 to 3 feet, whereas now, as is the case of Puerto Viejo Bay, areas are present near the shoreline of more than 25 feet in depth.

Figure 7-12 summarizes the bathymetric changes that occurred between 1912 and 1980. Dredging activities have eliminated the Capitaneja, Largo, Anegado, and Punta Larga shoals, and also have destroyed portions of Yaboa and Tablazo shoals. Simultaneously, there has been dredging activity at the Grande and Mojiganga banks, and in the sand deposit located north of "Punta Cataño" and west of "Palo Seco".

According to a 1981 description provided by the United Coast Pilot, only San Agustín, Santa Elena and Isla de Cabras shoals remained in the bay. The maximum depth reached by the Bar and Anegado channels were 46 feet (14 meters) and 35 feet (10.6 meters), respectively. The terminal channel had 36 feet (10.9 meters) at maximum depth; the Graving Dock, 36; Puerto Nuevo channel, 32; and the San Antonio, 35. The depth of the areas outside the main channel ranges from 4 feet (1.2 meters) to 18 feet (5.5 meters).\(^\text{15}\)

**Geomorphological Changes**

The present geomorphology of the San Juan Bay area is the result of the effects of natural processes alone, (such as tectonic activity, erosion, and deposition) and natural processes that have been modified by (such as changes in winds and runoff). Figure 7-13 shows the 1980 geographical distribution of the main geomorphological features, such as reefs, beaches, beachrock, swamps, old meanders, limestone hillstacks, marine terraces, spits, and lagoons.
Fig. 7-12. Bathymetric changes in San Juan Bay, 1912-1980.
Man could be considered an important factor in the creation, elimination, and modification of many of these geomorphological features. Man has destroyed a small island called "Isla de Chivo" located at the southern edge of Punta Cataño. The 1962 landfills eliminated the tidal channels of Puerto Nuevo. In the field, we observed that the erosion registered by the cliffs below the San Cristóbal Fort and the Escambrón and Levittown beachrock was mainly caused by extraction of earth materials.

Inland, deliberately or inadvertently, man has eliminated or modified the geomorphic nature of the limestone hillstacks of Caparra (Fig. 7-14). Half of the San Patricio "mogote" has been removed and "El Seboruco del Rey" was completely eliminated. The limestone extracted from both "mogotes" was used for the earthfilling of Isla Grande and Puerto Nuevo, as well as the construction of a coastal rock line wall.

The largest limestone hillstack in that area is Monte Canejas. This "mogote" has also been partially destroyed in order to obtain the raw materials needed by the Puerto Rican Cement Company and the Puerto Rico Bottle Co. The first disruption of the "mogote" occurred in 1940 when the construction of road No. 40 divided this hillstack into two parts. The construction of the De Diego expressway in 1980 then divided it into three sections. Monte Canejas has thus been reduced two thirds of its original size. Further, deforestation has caused large amounts of material to be lost by weathering and mass wasting effects.

When the new Bayamón river channel was dug in 1962, artificial levees were constructed. The old levee system was at that time
Fig. 7-14. Limestone hillstack reduction in the Caparra area, 1912-1981.

--- Original area
---- Eliminated by 1981
------------- Eliminated by 1962
---------------- De Diego expressway
partially destroyed; however, the system did not persist for a long
time, because during the 1970s, the old levees were destroyed for
urban purposes.

Other features destroyed include the reef and sand dunes
described in the colonial period, and located at that time in Puerto
Nuevo shore. Although some meanders remain in Puerto Nuevo and in the
Bayamón river floodplain, indicating old river beds, most of them were
eliminated by the channelization of both rivers.

**Vegetational Changes**

The geologic and hydrologic changes induced by man have produced
alterations in the nature and distribution of vegetation. The more
obvious effects are those associated with cutting and reforestation.
In order to determine possible changes in plant distribution, we
identified samples from 22 different field stations, each selected in
order to represent a particular environmental condition (Fig. 7-15).
The species collected were classified in Table 7-2 according to the
present coverage.

Our field observations indicate that the predominant type of
vegetation in the southeastern point of the Condado Lagoon (Station 1)
was black mangrove (*Avicennia germinans*) and cork tree (*Thespesia
populnea*). The original vegetation of this area was mangrove, as
indicated on the 1912 map (Figure 5-9).

The vegetation cover of the south coast of the Condado lagoon
(Station 2) was cork tree, Australian pine (*Casuarina equisetifolia*)
and the coconut palm tree (*Cocos nucifera*). All these species were
Fig. 7-15. Location of the field work and vegetational stations.
Table 7-2  Vegetation Distribution and Coverage Percentage in San Juan Bay Area

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<td>Pelticourea sp.</td>
<td>5</td>
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</tr>
<tr>
<td>54</td>
<td>Psidium guajava</td>
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<td>Lantana camara</td>
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<td>Ricinus communis</td>
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<tr>
<td>58</td>
<td>Trichilia hirta</td>
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### Herbaceous:

<table>
<thead>
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<tbody>
<tr>
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<td>Euphorbia triplata</td>
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<td>62</td>
<td>Sansevia minervaria</td>
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</tr>
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<td>63</td>
<td>Bidens pilosa</td>
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<tr>
<td>64</td>
<td>Chamaesyce spp.</td>
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</tr>
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<td>65</td>
<td>Serjania portulacaria</td>
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<td>Lippia nodifera</td>
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<td>Setaria sp.</td>
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<td>Zea mays</td>
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<td>71</td>
<td>Sesbania sp.</td>
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<td>72</td>
<td>Urena lobata</td>
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<td>Sida carpinifolia</td>
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<td>Acrosticum aurum</td>
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<tr>
<td>80</td>
<td>Pentamedium sp.</td>
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<td>1</td>
</tr>
</tbody>
</table>

### Dodders:

<table>
<thead>
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<tbody>
<tr>
<td>81</td>
<td>Ipomea per-capra</td>
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<tr>
<td>82</td>
<td>Canavalia maritima</td>
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</tr>
<tr>
<td>83</td>
<td>Ipomea sp.</td>
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<td>1</td>
</tr>
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<td>84</td>
<td>Banegalia sectensia</td>
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<td>1</td>
</tr>
<tr>
<td>85</td>
<td>Pilosea guadalupensis</td>
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<td>1</td>
</tr>
<tr>
<td>86</td>
<td>Chococa alba</td>
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<td>1</td>
</tr>
<tr>
<td>87</td>
<td>Dioscorea sp.</td>
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<td>1</td>
</tr>
<tr>
<td>88</td>
<td>Calyptracia echastophyllum</td>
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<td>89</td>
<td>Capulapina bondoc</td>
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<tr>
<td>90</td>
<td>Vitis melifera</td>
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### Aquatics:

<table>
<thead>
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<th>No.</th>
<th>Species</th>
<th>Height</th>
<th>Width</th>
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</thead>
<tbody>
<tr>
<td>91</td>
<td>Eichornia crassipes</td>
<td>60</td>
<td>1</td>
</tr>
</tbody>
</table>
introduced and planted in the area; they remain there because they are
adapted to higher levels of salinity.

As is the case with Station No. 2, most of the vegetation in the
Escambrón area has been planted by man. The predominant plants are
the Australian pine, Tropical almond (*Terminalia catappa*) and some
herbaceous species. These plants tolerate strong winds and saltpeter
conditions which have characterized the region. According to the 1912
map and to the analysis performed on the samples taken, the original
vegetation of El Escambrón was marsh (Fig. 7-16).

The vegetation complex that predominates in the San Juan Islet
Cliff area (Station 4-5) is composed of compact plants of camomile
(*Wedelia trilobata*), seaside bean (*Canavalia maritima*), African
bowstring (*Sangiveria guineensis*), sea grapes (*Coccolova uvifera*), and
Arbol de María (*Calophyllum calaba*). Man has also introduced large
amounts of grass which, according to our measurements cover 80% of the
coastal side between El Morro and La Perla.

With the landfilling of La Puntilla, the original mangrove
vegetation (Station 6) was substituted by ornamental plants. Among
them prevail the Botree (*Ficus retusa*), Queen of flowers
(*Lagerstruemia speciosa*), black olive (*Bucida buceras*), rubber plant
(*Ficus elastica*), fig (*Ficus sp.*), Thibet tree (*Albizia lebbeck*), cork
tree, tropical almond, and grasses.

The landfilled area of Puerta Tierra and Parque Central (Station
8-9) exhibits a similar type of vegetation, dominated by herbaceous
plants and shrubs. All these types represent a successional forest of
which some of the species, such as Guava (*Psidium guajava*) and the
Royal Palm (*Roystonea borinquena*), were artificially introduced.
Stations 9 and 10 represent mangrove areas that were filled by slums. After their elimination, a secondary succession of mangrove has grown. This new predominant mangrove forest includes white mangrove (*Laguncularia racemosa*) and black mangrove. Red mangrove (*Rhizophora mangle*) is absent. In the area of Buenos Aires (Station 11), the mangrove vegetation has been substituted by ornamental plants consisting of cork tree, tropical almond, fig, white cedar (*Tabebuia heterophylla*), and African tulip tree (*Spathodea campanulata*). The dominant shrubs include the guava tree and papagayo (*Sesbania cericea*); also, grass comprised 10% of the total vegetation cover.

Another mangrove area that has been destroyed by slums is "El Fanguito" (Station 12). However, this area is different in the sense that no large trees, with the exception of Thibet tree, has been introduced into this region. Most of the vegetation today is composed of herbaceous plants such as Guaco (*Mikonia* sp.), sensitive plant (*Mimosa pudica*), bur (*Urena lobata*), camomile, and dodders, mainly El Zarza (*Senegalia westiana*).

Hato Rey Centro (Station 13) represents one of the few areas where the original mangrove forest remains untouched. The predominant mangrove types are white and black. However the presence of leather ferns (*Acrusticum aureum*) seems to be an indicator of the reduction of soil salinity conditions.

The dump surrounding the Puerto Nuevo river (Station 14) contains a thicket 2 to 3 meters high, with an abundance of dodders, grass, and some dispersed trees. All these species represent a secondary forest, probably introduced there through the waste disposal process. No detailed vegetation study of that area has been made.
Our observations indicate that the vegetation cover of the San Patricio hillstack (Station 15-16) was destroyed several times, finally recovering in a new secondary forest. Most of the present species have invaded the area, except for the soot-soot tree (*Piper amalago*) and broomstick (*Trichilia hirta*).

The actual rubbish dump of San Juan (Station 17-18) shows a very compact vegetation that has developed recently, which includes shrubs, mainly papagayo, and herbaceous plants. Most of these species are thought to have arrived by wind action. Many species such as the mango tree were probably introduced with domestic garbage.

The Palo Seco spit (Station 19) presents the most heterogeneous vegetation in the bay area. Patches of black mangrove, Australian pine, coconut palm, cork tree, tropical almond, seaside bean, camomile, and grass are the dominant species, and all these species are present in different stages of development due to the different sequences of landfilling. One of the few places where the red mangrove still predominates is in the old Bayamón river bed (Station 20). Although this mangrove developed under very high water pollution conditions, it has not been possible to determine any kind of effect in its development. Here the mangrove vegetation reaches a height of 12 to 14 feet (3.6 to 4.3 meters).

In the marshland of "Ciénaga Las Cucharillas" (Station 21), we found that the main cause for the disappearance of vegetation was the urbanization process. However, there still remains some patches of vegetation composed by cat-tail (*Typha angustifolia*) and water hyacinth (*Eichornia crassipes*). We can also find some grass patches covered by scattered trees, such as the immortelle (*Erythrina* sp.).
Today the Isla de Cabra's vegetation (Station 22) is covered both by plants that were introduced by man and those that have invaded the area naturally. The first group includes coconut palm, Australian pine, tropical almond, and cork tree; whereas, the principal invader (sea grape) diffused through land and water.

The 1912 vegetation of the San Juan Bay area has been reduced by about 80% since 1508 (Fig. 7-16 and Fig. 7-17). Between 1508-1912 the hardwood forests of the San Juan Islet and Santurce were destroyed. Some coconut and palm trees were planted in land claimed to the mangrove as in Palo Seco, El Condado, and Hato Rey. Between 1912 and 1980 the mangrove areas were reduced by 90%. The Escambron marshes have been completely eliminated and substituted by ornamental vegetation, and the marshland swamp of "Las Cucharillas" has also been reduced to half of its original size. Today, the only remaining areas of hardwood forest are on the limestone hillstack and in recreational parks with their recently introduced trees. Regarding coconut palm areas, with the exception of Isla de Cabras, not a single one remains. In some places where the mangrove has been cut, new aquatic plants have successfully proliferated.

**Hydrological Changes**

Of all the original rivers, creeks and channels, only the Puerto Nuevo river and the Martín Peña and San Fernando channels flow into San Juan Bay today. The others have been diverted or channelized in different directions. These hydrological constraints have reduced significantly the flood plain area of the Bayamón and Rio Piedras rivers. (Fig. 7-18).
These two rivers display characteristics similar to the rivers that flow toward the northern coast. The Rio Piedras basin is relatively small, being less than 10 miles long with a drainage area of about 25 square miles. This river enters the San Juan Bay through the Puerto Nuevo dredge channel, which enters the bay at the same point as the Martín Peña channel.

The Bayamón river drains an area of about 100 square miles. It has its source in the Central Mountain Range (Cordillera Central), and its length is about 21 miles. Of all the channelization projects, the one that perhaps had the greatest impact on the Bay was the Bayamón river diversion and channelization. Historically, the river floodplain was used for agriculture and pastures, but the urbanization changed the area greatly. When its predominant use was agriculture, flooding did not represent a difficult problem, but during the 1960s, when the area was converted into a residential zone, surface runoff and flooding became far more widespread. In order to reduce the problem, the river was channelized.

Before its channelization, the Bayamón river was a fluvial system characterized by two watersheds (Rio Bayamón and Caño de Aguas Frías), an alluvial valley, (dissected by river meanders), and a multiple river mouth system, one flowing to the Ensenada de Boca Vieja and the other to the San Juan Bay.

When the diversion-channelization project began in 1962, the first stage involved the channelization of Caño de Aguas Frías. It was not until 1978 that a second channel was dug channelizing the Bayamón and Rio Hondo river watersheds (Fig. 7-19). By 1980, the
Bayamón river project was finished, and the river was diverted, so its flow to the San Juan Bay was completely closed.

The alteration of the Bayamón river channel through the deepening, widening, straightening, concreting, and diverting of its river bed could have further effects on its hydrologic characteristics. It can prevent the water exchange between the river and its bank, changing the soil's hydrologic nature. With the construction of Cidra's Lake in the Cordillera Central, the river's flow was controlled, probably diminishing the transportation of sediments; these also modified the coastal erosion, deposition and circulation patterns. Similar effects to those of the Bayamón river could have occurred after the diversion and dredging of the Rio Piedras river.

**Ground Water**

The ground water formations of San Juan include the beach and dune deposits, marshes, swamps, and Tertiary limestone deposits. Wells drilled close to the northern coastal areas reach fresh water within a few feet of the surface, whereas wells drilled in the extreme southern portion of the San Juan metropolitan area reach ground water within 50 feet of land surface. Many of the wells in the unconsolidated sediments and swampy areas in the San Juan area are saline. Deeper wells drilled to reach tertiary age limestone formations produce low to moderate yield of fresh water. In 1970, the yield of 36 wells in limestone, in the vicinity of Bayamón and San Juan, averaged 350 g.p.m. (gallons per minute). Records for industrial pumpage during that period are not available, but were
estimated to be approximately 6 m.g.d. (million gallons per day) of fresh and 2 m.g.d. of saline water.

According to the U.S. Geological Survey, the total volume of water in the San Juan aquifer is diminishing. This aquifer includes the upper part of the Cibao, Aguada and Aymamón limestone formations, and it extends from Bayamón to Carolina, through San Juan. It is reasonable to conclude that the apparent recharge area for the unconfined aquifer does not appear to be extensive enough to supply the required volume of water.17

From the studies mentioned before we cannot determine the magnitude of man's effect upon San Juan area's ground water system. However, based on our knowledge of the area there are some indications of possible modifications. For example, chemical waste coming from industries could have changed the chemical composition of waters. The diversion and channelization of part of the superficial circulation as well as the modification of river flow could be expected to have some effect in the underground circulation of water.

Hydrologic Cycle

The possible changes discussed in the previous section present an idea of how human activities can interfere in the hydrologic cycle of the Bay of San Juan. The major runoff impact has involved infiltration, channel store, and stream flow. Further, interception, surface storage, soil moisture, ground water, surface runoff, and groundwater flow, are moderately affected, while a slight impact appears to result from precipitation, throughflow, and evapotranspiration.18

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One of the effects that man has had on the hydrological cycle is in the control of its water storage and transfer stages (infiltration, runoff, etc.). For example, a change in the vegetation cover affects the amount of water lost to evaporation and infiltration; deforestation increases the total volume of water that flows to a river, while the aforestation diminishes the total amount of rainfall available for the next hydrological stage.\(^1\)

Based on my experience in this area and on the information available from other regions of the world, we can say that the urban development of San Juan seems to be the reason for the changes in hydrologic cycle. The substitution of the natural soil by cement increases the surface runoff and decreases infiltration; thus, while the amount of water stored in the surface increases, the amount of water stored in the soil has decreased. As is the case in other large cities, the cutting of vegetation seems to reduce evapotranspiration while it increases surface runoff.\(^2\)

**Water Quality**

It might be argued that water is the most polluted element of the San Juan Bay area system. Our highest public environmental agency, the "Junta de Calidad Ambiental" (Environmental Quality Board), described the environmental conditions of the bay in 1978. The Board stated it as being the recipient of more than 90 million gallons of water per day coming from the Puerto Nuevo Treatment plant, the Martín Peña channel, and many other heavily polluted sources (such as the hot waters coming from Palo Seco and Puerto Nuevo thermoelectric plants, San Juan Distilling Co., and the petrochemical industries).\(^3\)
San Juan Bay has a low content of dissolved oxygen (D.O.) and a high index of suspended material and coliform bacteria. Under current water quality standards, the bay, including the Martín Peña channel, is today classified "SC...Coastal waters intended for uses where the human body may come in indirect contact with the water, and for use in propagation and maintenance of desirable species." Criteria include a minimum D.O. concentration of 4 mg/l (milligrams per liter), "except where natural conditions cause this value to be depressed," and no more than 10,000/100 ml total coliforms or 2000/100 ml (milliliters) fecal coliforms. The acceptable range of pH is normally 7.3-8.5. The Condado Lagoon is classified "SP...Coastal waters intended for use where the human body may contact with the water. These waters shall contain no less than 5 mg/l D.O.," the fecal coliform shall not exceed 200/100 ml, and the acceptable pH should range between 7.3 and 8.5.22

Evidence of the degree of water pollution in the San Juan Bay area is the abundance of dead fish, and their total absence in areas such as El Condado Lagoon.23

Human Influence on San Juan Coastal Climate

Introduction

Although the effect of man on the climate of San Juan is not precisely known at this time, this section intends to present some possible coastal climatic modifications based on such data as are available, and to add a few personal speculations.

Up to now no attempts have been made to explain man's influence on the climate of the San Juan Bay area, and we may present this brief section as a good starting point that at least will present some basic arguments and questions which may be answered in future research.
Based on studies of other regions, it can be said that man has modified local climatic systems through changes in land use, artificial heat production, construction of many and often high urban buildings, and changes in air quality. The effects of these activities caused alterations in the albedo, as well as in temperatures, winds, humidity, cloudiness, and precipitation at the microlevel. Many of these studies focus on coastal cities such as Houston, Los Angeles, and San Francisco.\textsuperscript{24}

According to these studies human climatic modifications include an increase in mean annual temperature of about 1°C, an increase in annual precipitation of as much as 5%, a reduction in annual mean relative humidity of up to 6%, a 20% reduction in wind speed and an increase in cloud frequency of up to more than 5%.\textsuperscript{25}

Unfortunately the number of weather stations in the San Juan Area are not as many as would be desirable, so the data presented here are limited in terms of the geographical area covered. The San Juan area includes four climatic stations: Isla Verde, Rio Piedras, San Juan City, and Cataño. The distribution of these stations is presented in figure 7-20. All the stations, except Rio Piedras, are located no further than a mile from the coast.

Although natural conditions are considered an important factor, probably the most significant human variable in climatic variation is local land use. For example Isla Verde station is surrounded by natural mangrove, grass, and coconut palms, while San Juan City is a built up area; Catano represents a heavy industrialized zone, and Rio Piedras a built up area further inland. However, it should be
stressed that in this area it is extremely difficult to separate human
from natural factors.

Our observations of the San Juan Area indicates that this region
could be considered a distinct "climatic dome", in contrast to its
surrounding areas. The primary reason for considering San Juan to be
climatically different is because of the overwhelming development of
the local area.

**Temperature Changes**

San Juan's annual mean temperature at Isla Verde station is about
79.2°F (26.2°C). Annually the highest temperatures of the San Juan
stations are registered during July and August and the lower ones are
in February and March.

Figure 7-21, prepared using the data obtained from the National
Weather Service station at Isla Verde, show the variation of San Juan
annual temperatures between 1952-1981. From the analysis of this
Figure, I can conclude that the annual temperature average of this
station has increased about 3°F (1.7°C) during this period of time.
Temperature shows a tendency to increase after 1964, reaching a
maximum in 1981.

Throughout the period of 1971-1981, temperature data of the four
stations show a slight tendency to increase (Table 7-3). The
increments during these intervals, 1952-1981 and 1971-1981, can be the
consequence of many natural and human factors. My opinion is that
temperature started to increase by the effect of urbanization. These
changes could be the outcome of land use changes, where the
substitution of the natural surface by a cemented one and the addition

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Figure 7-21 Temperature variations between 1952-1981 at Isla Verde weather station, San Juan, Puerto Rico

Source: Weather Bureau, ESSA, NOAA, San Juan, Puerto Rico
<table>
<thead>
<tr>
<th>Year</th>
<th>Rio Piedras</th>
<th>San Juan City</th>
<th>Isla Verde</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971</td>
<td>77.8°F(25.7°C)</td>
<td>78.8°F(25.7°C)</td>
<td>80.8°F(26.8°C)</td>
</tr>
<tr>
<td>1972</td>
<td>78.2°F(25.4°C)</td>
<td>79.0°F(25.8°C)</td>
<td>81.1°F(27.0°C)</td>
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<tr>
<td>1973</td>
<td>-</td>
<td>81.1°F(27.0°C)</td>
<td>78.9°F(25.8°C)</td>
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<td>1974</td>
<td>77.5°F(25.3°C)</td>
<td>-</td>
<td>80.7°F(26.7°C)</td>
</tr>
<tr>
<td>1975</td>
<td>76.8°F(24.6°C)</td>
<td>-</td>
<td>80.2°F(26.5°C)</td>
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<tr>
<td>1976</td>
<td>77.1°F(24.5°C)</td>
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<td>1978</td>
<td>78.1°F(25.3°C)</td>
<td>-</td>
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<tr>
<td>1979</td>
<td>77.9°F(25.3°C)</td>
<td>-</td>
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<td>1980</td>
<td>79.1°F(25.9°C)</td>
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<td>82.3°F(27.6°C)</td>
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<tr>
<td>1981</td>
<td>79.0°F(25.8°C)</td>
<td>-</td>
<td>82.1°F(27.5°C)</td>
</tr>
</tbody>
</table>

of heat to the atmosphere, due to domestic, industrial and transportation activities, augments temperature.

**Precipitation Changes**

San Juan's changes in precipitation are more difficult to determine and explain than those alterations associated with temperature. Conforming to the data presented by the pluviometric station of Cataño (Fig. 7-22), the average precipitation for this station between 1940 and 1975 was 63.0 inches (1600mm). The natural agents that produce this precipitation are the trade winds, tropical storms, and a few fronts.

The year with minimum precipitation for Cataño (1955), showed 47 inches (1195.5mm). The year of maximum precipitation was 1970 with 84 inches (2133mm). After 1965 precipitation began to increase, reaching the highest point in 1970, but since then precipitation decreased again to 52 inches (1330mm) in 1975.

Based on Figure 7-22, it can be pointed out that for this period, the seasonal precipitation pattern of Cataño is very irregular. The dry period is usually during winter, although is sometimes occurs in spring. The rainy season is in the summer time, however, sometimes it is delayed until fall. No major cause has been presented explaining this inconsistent precipitation pattern. Based on my knowledge of this area, I would say that because this is one of the most polluted area in terms of particulate emission, probably the amount of precipitation could be associated with the amount of particles emitted to the atmosphere; but evidently, this does not seem to be the only factor.
Figure 7-22  Precipitation in Cataño Between 1945 and 1975
(Data in millimeters)

Cataño - 1945

Cataño - 1950

Cataño - 1955

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CATANO - 1960

CATANO - 1965

CATANO - 1970

CATANO - 1975

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Precipitation variation within the San Juan Area between 1971-1981 can be observed in Table 7-4. This data shows that there is some areal variation of precipitation when we statistically correlate the four stations that comprise the San Juan region. Precipitation is relatively low in Isla Verde compared with the stations of Cataño, San Juan City, and Rio Piedras. Although the data for the period under study is incomplete, we can say that the station of Isla Verde and Rio Piedras represents the most inconsistent pattern of precipitation, while Cataño tends to stabilize at 62 inches of annual precipitation. The stabilization may come as a result of the more strict control of particle emission applied to industry during the 1970s decade.

Wind Changes

The San Juan Bay area is under the influence of the Trade Winds and the sea-land breezes, causing the winds to blow from a NE to SSE direction.

Although there is no study in relation to the effect of urban structure in the wind speed and movement in San Juan, based on the experience of other cities, we can produce some speculations.

The three main high-rise nuclei in the study area are El Condado, Santurce, and Hato Rey. Some of these buildings represent north-south elongated structures, positioned nearly perpendicular to the trade winds and more or less parallel to sea-land breezes. One would thus anticipate that the San Juan buildings are expected to affect the natural tropospheric winds, deflecting their natural direction and forming a system of eddys currents at the lee side of the building. We have observed this condition in El Condado where the structural modification of natural wind flow creates atmospheric turbulence.
TABLE 7-4

Annual Precipitation Variation in the San Juan Area Climatic Stations

1971-1981

<table>
<thead>
<tr>
<th></th>
<th>Rio Piedras</th>
<th>San Juan City</th>
<th>Isla Verde</th>
<th>Cataño</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971</td>
<td>* 58.36(1482mm)</td>
<td>60.06(1525mm)</td>
<td>35.28(896mm)</td>
<td>64.59(1640mm)</td>
</tr>
<tr>
<td>1972</td>
<td>59.89(1521mm)</td>
<td>62.12(1578mm)</td>
<td>37.72(958mm)</td>
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</tr>
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<td>1973</td>
<td>64.27(1632mm)</td>
<td>59.68(1516mm)</td>
<td>44.55(1132mm)</td>
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<td>1974</td>
<td>79.94(2030mm)</td>
<td>52.60(1336mm)</td>
<td>41.68(1059mm)</td>
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<td>1975</td>
<td>71.48(1815mm)</td>
<td>63.22(1606mm)</td>
<td>51.26(1302mm)</td>
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<td>1976</td>
<td>58.79(1493mm)</td>
<td>56.68(1440mm)</td>
<td>47.20(1199mm)</td>
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</tr>
<tr>
<td>1977</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1978</td>
<td>75.07(1907mm)</td>
<td>-</td>
<td>49.86(1266mm)</td>
<td>-</td>
</tr>
<tr>
<td>1979</td>
<td>43.35(1101mm)</td>
<td>-</td>
<td>15.40(391mm)</td>
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</tr>
<tr>
<td>1980</td>
<td>25.36(644mm)</td>
<td>-</td>
<td>23.20(589mm)</td>
<td>-</td>
</tr>
<tr>
<td>1981</td>
<td>75.07(1906mm)</td>
<td>-</td>
<td>49.86(1266mm)</td>
<td>-</td>
</tr>
</tbody>
</table>

* Data in inches

CHAPTER VII

FOOTNOTES

1 Churraca, Cosme, *Plano Geométrico del Puerto de la Capital de la Isla de Puerto Rico*, (1794), Historical Archive of Puerto Rico (H.A.P.R.), No. 1161-1162, Scale: 1 inch = 3 nautical miles (map).

2 Coastal and Geodetic Survey, *San Juan Harbor, Porto Rico*, (March 1912), Scale: 1:10,000 (map).


5 National Oceanic Atmospheric Administration (NOAA), *San Juan Bay Nautical Chart*, Map no. 25670 (October 1975), Scale: 1:10,000.


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21 Junta de Calidad Ambiental, Mejoras Temporeras a la Calidad del Agua del Canal de Martín Peña, (San Juan, 1978), 3-6.

22 Chief of Engineers, op. cit., 130.
23 Gelabert, Pedro A. and Rafael Cruz, "Calidad del Ambiente en el San Juan 2000", San Juan 2000, (San Juan, Ed. Ralph Ortiz and Municipio de San Juan, 1976), 251-252; "La J.C.A. Descubre Aguas Contaminadas playa del Condado, El Mundo, (October 6, 1978), 9A.


25 Ibid., 122; Andrew Goudie, op cit., 255.
SUMMARY AND CONCLUSIONS

Throughout this work, it has been possible to appreciate that the natural history of San Juan Bay has not been detached from its cultural counterpart. Both have evolved together affecting themselves in such a way that if one becomes more complex, that same one transmits its complexity to the other.

The natural history of the San Juan Bay area begins with its development as a physiographic feature through the Cretaceous, Tertiary, and Quaternary periods. This development was basically caused by fluctuations in eustatic sea level, tectonic movements or both. The fact that the original characteristics of the bay were different from the ones we observe today is explained in terms of the actions that nature and man have, together, exerted on the region. This dissertation emphasizes the human impact on this region without ignoring the influence of the milieu.

Human impact has been perceptible since the arrival of the first indigenous groups. Archaeological evidence shows the presence of Indians before 350 A.D. The climax of the indigenous activity was reached with the arrival of the Tainos after 1200 A.D. Just when this cultural group was succeeding in attaining a greater control over the bay's confines, the Spaniards appeared.

In 1508 began a new chapter of the bay area's geographical history, which led to the process of four hundred years of land transformation in this region.

The Spanish colonial period left traces contained in the military, civil, and religious structures that impart the colonial
architectural character predominant today in San Juan. Landfilling, vegetation cutting and other environmental changes also occurred during this period, playing a vital role in the modifications registered by the bay.

Under the political vision of the 20th century, the port of San Juan was reinforced as the main economical center of the city, and the city itself became the most significant developing nucleus of Puerto Rico. Once the city became an important pole of attraction, the rural population began to migrate to this urban area, forming the slums that have characterized the city throughout this century.

The last forty years of geographical transformation have evolved under the idea that industrialization is the main choice to economic development. This phenomenon materialized with the conversion of the bay's shore and its surrounding area into one of the main heavy industry cores of Puerto Rico.

The intensive urban growth expanded the city outside limits ever before imagined. After the 1960s, the San Juan urbanized area was considered to include Carolina, Guaynabo and Bayamón. By the 1980s, the area extends as far as Toa Baja, Trujillo Alto and Canóvanas.

As a result of the deterioration of the old urban sectors, and better services offered by the new ones, a population shift to the periphery of the city began. This process included some conversion of residential-oriented land use into industrial and commercial purposes. This trend was further reinforced by the government as it proceeded to relocate the slum population living around the bay into new residential complexes, located outside the San Juan periphery. In this
way they reserved the land around the bay for portuary and industrial purposes only.

It is the residential, industrial and commercial development of the last forty years which has been the main factor in the geographical modifications registered by the San Juan Bay area.

Up to now, man has had some effect, either profound or light, on almost all of the natural components of the San Juan Bay area and historically, this impact is recognized to be greater and more sophisticated as time goes on.

Apparently, the most important modifications are those associated with coastal changes. Our cartographic analysis of maps shows that the coastal morphology of the San Juan Bay registered slight modifications through 1518-1790 period. The areas that have undergone more significant changes were those affected by human activities, particularly La Puntilla, Palo Seco, Punta Cataño, Isla de Cabras, and El Condado lagoon. Most of the coastal morphologic changes occurred as a result of the land reclamation process of coastal areas.

Between 1912 and 1980, the coastal configuration of the bay was drastically modified thereby interrupting or altering its physical and natural process. Some possible consequences of these shoreline modifications are changes of wave refraction, reflection, erosion, deposition, and circulation patterns within the Bay. During this time the area of La Puntilla was filled 28,900 square feet (2685 square meters), and Isla de Cabras was filled about 94,792 square feet (8800 square meters); while the Southeastern point of Punta Cataño was
extended about 67,980 square feet (6338 square meters) and its northern coast dredged about 14,600 square feet (1335 square meters).

The annual rate of erosion changes within the bay, according to the local condition of each point. In Bay View this rate is about 9 feet/yr (2.9 meters/yr). At Levittown beach this erosion rate is about 2 feet per year (0.6 meters/yr). Natural factors, such as hurricanes and winds, together with human induced changes through dredging, landfilling and river diversion, and channelization have been the main agents causing erosion in the Bay.

These same agents have caused changes in the deposition patterns of San Juan Bay. Today, the amount of sediments lost are considered to exceed the total amount received. Three examples of human interference in the depositional pattern of the San Juan Bay are the formation of Palo Seco Spit, of the mangrove peninsula, located at the mouth of Martin Pena channel, and the construction of an artificial beach at the mouth of the Condado Lagoon.

The human effect is also noticeable in the circulation system of the Bay. The filling of Isla Grande tidal channel plus the formation of new physiographic features and the construction of new coastal structures have modified the 1912 longshore and general circulation system. In particular coastal structures have contributed to the coastal erosion to the western point of Isla Grande. They have also deflected longshore current and modified the effect of ocean circulation, transforming a typical high wave energy coast into low wave energy areas. This seems to be the case of areas such as Levittown coast, the entrance of El Condado lagoon and La Puntilla.
The areas filled in San Juan Bay by 1980 includes Puerto Nuevo, Martín Peña, the Southern and eastern portion of Jan Juan Islet, La Puntilla, Isla Grande, Sabana, Amelia, Isla de Cabras, La Puntilla de Cataño, Puente Blanco, Juana Matos, El Condado and Palo Seco Spit. All this area represents one third of the total size of the bay's area.

By 1888, the average depth of the bay was about 10 feet, increasing to 14 feet by 1912; today it is about 25 feet. Dredging activities have eliminated the Capitanejo, Largo, Anegado and Punta Largo shoals, destroying portions of Yaboa and Tablazo shoals.

Man can be considered an important agent in the creation and elimination of some of San Juan Bay geomorphological features. He has eliminated the Puerto Nuevo beaches and created an artificial beach in El Condado, while inland he has modified the geomorphic nature of the limestone hillstacks of Caparra.

The original vegetation of San Juan Bay Area has been reduced by about 80% since 1508. The Santurce and San Juan Islet hardwood forest, as well as the Escambrón marsh were the first in being eliminated. By 1980 Cienaga Las Cucharillas have been reduced 50% of its 1508 size and 90% of the mangrove forest has been cut since that time.

Hydrological urban constraints reduced by 95% the extension of the Bayamón and Río Piedras rivers floodplains. Although further studies are needed, man possibly affected the ground water system of San Juan area through changes in the underground circulation and chemical composition of the water. The urban development of San Juan can be considered a reason for changes in the hydrologic cycle. The
substitution of soil by cement has probably increased the runoff and decreased infiltration.

Although the effect of man on the San Juan climate is at this time not precisely known, some personal speculations of possible coastal climatic modifications have been constructed using the data available. The station of Isla Verde shows an increase of 3.06°F (1.70°C) in temperature between 1952-1981. For the 1971-1981 period, the data shows a very slight increase in temperature of 1°F for all four weather stations at San Juan Area. We interpret two of the possible causes for this change as being the substitution of natural surface by cement and the addition of heat to the atmosphere.

Precipitation presents an inconsistent pattern at the Cataño's Station, between 1945-1970. Based on a speculation, we propose that this inconsistency is produced by differences in the amount of particles emitted to the atmosphere. The post 1970 precipitation stabilization of Cataño is perhaps the result of the important control of particle emission applied to this industrial area.

In conclusion, the San Juan Bay represents one of the most modified areas of Puerto Rico, this being the result of human impact. As it was possible to observe throughout this dissertation, human impact in transforming the natural landscape of San Juan Bay Area has extended to practically all the components of the Bay's system.

If the effect of the human impact on the San Juan Bay area continues with the trend it has been following up to the present, it can be asserted that future environmental changes will be irreversible, and that a stage will be reached when the reversion of
the bay to its original conditions will not be feasible due mostly to
the exhorbitant costs that would have to be incurred.

Achievement of a healthy condition for the bay should be of
primordial importance, and in order to get as close as possible to
this goal, remedial, for the actual damage, and preventive action, for
what will come in the future, should be adopted now. Let it happen
otherwise and the responsibility will be ours.
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"Han Terminado 1600 Casas en Puerto Nuevo", (October 14, 1948), 4.
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"Gobernador Asigna 3 Millones para Construcción de Muelles", (July 1, 1958), 4.
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"Progresa Labor de Relleno en Laguna del Condado", (May 13, 1959), 12.
"AP Amplía la Zona de Muelles Isla Grande", (November 2, 1959), 5.
"Inician Labor Restauración Arsenal de San Juan", (July 14, 1960), 28.
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   - Subseries San Juan – Santurce, Box 251
   - Subseries San Juan – Santurce, Box 252
   - Subseries San Juan – Santurce, Box 253
   - Subseries San Juan – Puerta de Tierra, Box 247
   - Subseries San Juan – Puerta de Tierra, Box 248
   - Subseries San Juan – Puerta de Tierra, Box 251
   - Subseries San Juan – La Marina, Box 234

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   a. File 6, Record 3
   b. File 8, Record 4
   c. File 9, Record 5
   d. File 140, Record 81
   e. File 19, Record 216
   f. File 23, Record 122
   g. File 142, Record
   h. File 113, Record 37
   i. File 138, Record 5
   j. File 83, Record 5

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APPENDIX I

List of Plants, Fishes, Birds, Amphibians and Reptiles Known to the Indians of Puerto Rico


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293
<table>
<thead>
<tr>
<th>Common Spanish or Native Name</th>
<th>Scientific Name</th>
<th>English Name</th>
</tr>
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<tbody>
<tr>
<td>Cohitre</td>
<td>(Varieties)</td>
<td>Tradescantia</td>
</tr>
<tr>
<td></td>
<td>(Monandra, Vepens, Zanonia, Diffusa, Elegans, Ganiculata, Persicari, Fulia)</td>
<td></td>
</tr>
<tr>
<td>Yuca</td>
<td>Manihot esculenta</td>
<td>Cassava</td>
</tr>
<tr>
<td>Piña</td>
<td>Anarás Comosus</td>
<td>Pineapple</td>
</tr>
<tr>
<td>Lerenes</td>
<td>Culathea allouio</td>
<td>Sweetcorn root</td>
</tr>
<tr>
<td>Yuquilla (amaranta)</td>
<td>Maranta arundinacea</td>
<td>Arrowroot</td>
</tr>
<tr>
<td>Dunguey</td>
<td>Dioscorea altissima</td>
<td></td>
</tr>
<tr>
<td>Guanda, Hícamo</td>
<td>Dioscorea polygonoides</td>
<td>Wild yam</td>
</tr>
<tr>
<td>Mapuey</td>
<td>Dioscorea trifida</td>
<td>Cush-cush yam</td>
</tr>
<tr>
<td>Calabazón</td>
<td>Angustatum</td>
<td></td>
</tr>
<tr>
<td>Palma real (Palma de yagua)</td>
<td>Roystonea borinquena</td>
<td>Puerto Rico royal palm</td>
</tr>
<tr>
<td>Henequén</td>
<td>Agave americana</td>
<td>Century plant</td>
</tr>
<tr>
<td>Maguey</td>
<td>Furcraea tuberosa</td>
<td>Porto Rican century plant</td>
</tr>
<tr>
<td>Gorgojo</td>
<td>Scorzonerifolia</td>
<td></td>
</tr>
<tr>
<td>Coquí</td>
<td>Cucumbens</td>
<td></td>
</tr>
<tr>
<td>Llanten</td>
<td>Plantago major</td>
<td>Greater plantain</td>
</tr>
<tr>
<td>Maíz</td>
<td>Zea mays</td>
<td>Indian corn</td>
</tr>
<tr>
<td>Cañamo</td>
<td>Cannabis sativa</td>
<td>Hemp</td>
</tr>
<tr>
<td>Uvas de playa (Güíbara)</td>
<td>Cocolovis uvifera</td>
<td>Sea grapes</td>
</tr>
<tr>
<td>Guanábana</td>
<td>Annona muricata</td>
<td>Soursop</td>
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**Fish**

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VITA

José Seguinot-Barbosa was born on February 17, 1954, in Mayagüez, Puerto Rico. He spent most of his early life in Añasco, a town located approximately 10 miles from Mayagüez. He graduated with honors from Añasco High School in May, 1971. The following fall he entered the University of Puerto Rico at Rio Piedras. From this university he received in May 1975, the Bachelor of Arts degree in Geography (Cum laude). In the same year he moved to Mexico City to obtain his Master's degree in geography, finishing this goal in May, 1978. He enrolled at Louisiana State University in June, 1979 for further graduate work in geography and anthropology.

Mr. Seguinot has been a geography professor at the Interamerican University, San German and at the University of Puerto Rico, Rio Piedras. He also worked as a cartographer and aerial photograph technician at the Electoral Board and the Department of Natural Resources in San Juan. Actually, he is a member of the following professional organizations: Association of American Geographers, American Society of Photogrammetry, Conference of Latin American Geographers and Panamerican Institute of Geography and History.

During his career he has been the recipient of the Innovative Technician Awards in 1976 from the Interamerican University, the Latin American Studies Fellowship from the Center of Latin American Studies at Louisiana State University and the University of Puerto Rico fellowship in 1983.
EXAMINATION AND THESIS REPORT

Candidate: José Seguinot-Barbosa

Major Field: Geography

Title of Thesis: COASTAL MODIFICATION AND LAND TRANSFORMATION IN THE SAN JUAN BAY AREA: PUERTO RICO

Approved:

[Signatures]

Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

[Signatures]

Date of Examination:

October 27, 1983