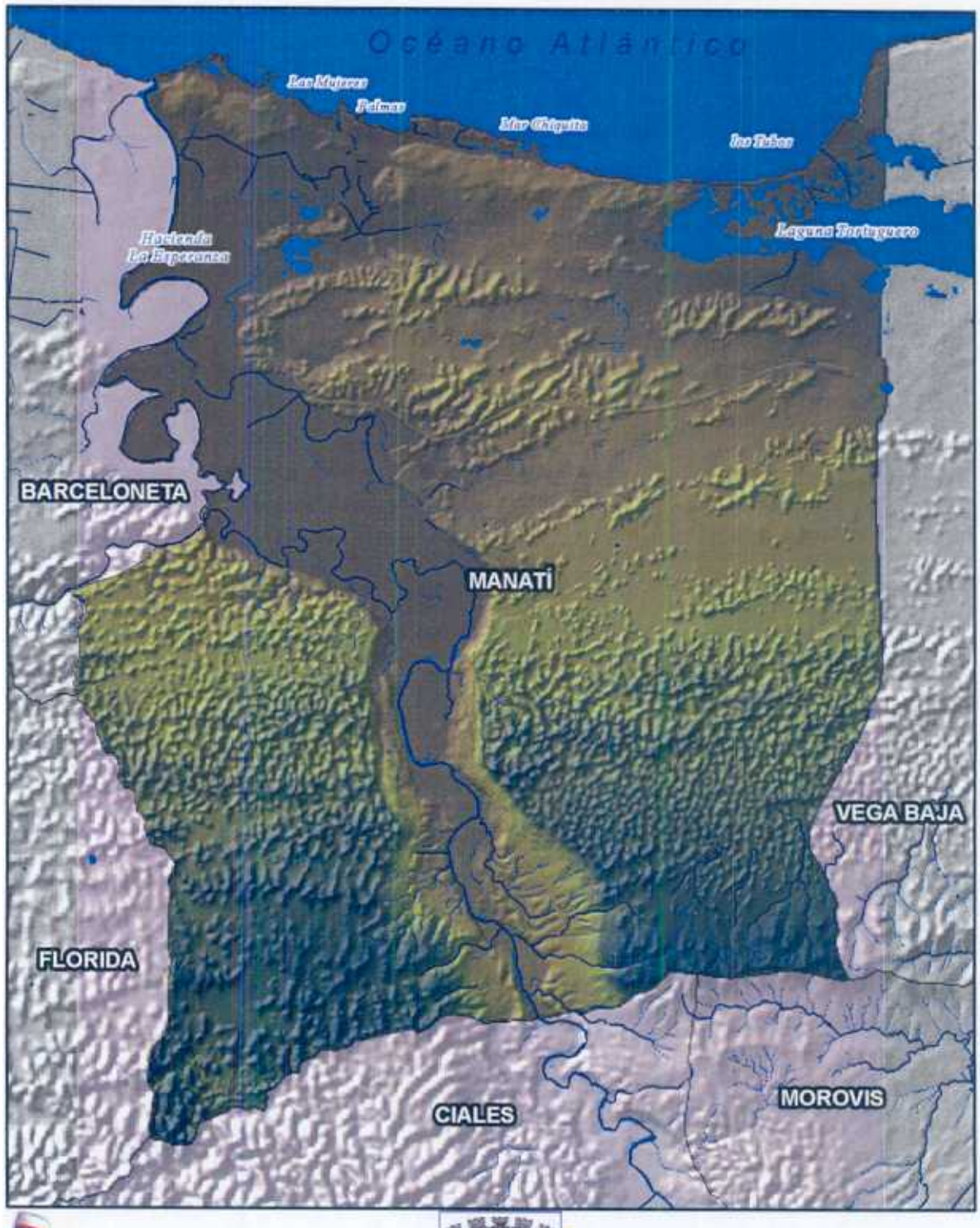
Estado Libre Asociado de Puerto Rico
Municipio Autónomo de Manatí
Plan de Escorrentías Pluvial



Hon. Juan Aubín Cruz Manzano, Alcalde
Municipio Autónomo de Manatí

Oficina de Planificación Estratégica
y Ordenación Territorial
Plan. Leslie Rosado Sánchez, Directora

ESTADO LIBRE ASOCIADO DE PUERTO RICO
MUNICIPIO AUTÓNOMO DE MANATÍ
OFICINA DEL ALCALDE
Calle Quiñones Núm. 10
Manatí, Puerto Rico 00674
Tel. (787) 854-2024

Notice of Intent (NOI) of the Autonomus Municipality of Manati

Required by the Environmental Protection Agency (EPA) under the NPDES Program of Discharges of Water Runoff Associated to the Municipal of the Separate Water Sewer System (MS4, acronym in English) In urbanized areas subject to Phase II, Resource 64 FR 68722 December 8, 1999.

Realizad by:
Plan. Leslie Rosado, Director of the Department of Strategic and Land Use Planning of the Autonomous Municipality of Manatí

Revised by:
Hon. Juan Aubín Cruz Manzano, Mayor of the Autonomous Municipality of Manatí

October 10, 2008

ESTADO LIBRE ASOCIADO DE PUERTO RICO
MUNICIPIO AUTÓNOMO DE MANATÍ
OFICINA DEL ALCALDE
Calle Quiñones Núm. 10
Manatí, Puerto Rico 00674
Tel. (787) 854-2024

I certify under oath, exposing myself to the penalty of perjury, that this document made by the Plan. Leslie Rosado Sánchez, Director of the Department of Strategic and land Use Planning of the Municipality of Manati, has been examined by me, and that to the best of my knowledge and belief all the information provided in the Water Runoff Plan for the Autonomous Municipality of Manati, created in compliance with Administrative Order CWA-02-2008-3109 under the Permits Program of National Pollutant Discharge Elimination System (NPDES) "NPDES Storm Water Municipal Separate Storm Sewer Systems General Permit (GP MS4-PRR040000)", which is required by the Environmental Protection Agency (EPA). In their interest to improve bodies of water through the sound management of stormwater runoff into the stormwater discharges municipal systems (MS4) Phase II in urbanized areas, that is true, correct and complete.

know the criminal penalties to which I'm exposed to in the Penal Code of Puerto Rico, as amended, for the crime of perjury, for providing false information in the above document mentioned, such as: penalty for a fourth-degree felony. Without prejudice to any administrative action that might be taken.

October 10, 2008, Manatí, Puerto Rico

Hon. Juan Aubin Cruz Manzano
Mayor

Description of Activities Required for the NOI

a) Type of activity: The type of activity responding municipalities.

b) Name, local and postal address of the permit applicate.
Hon. Juan Aubín Cruz Manzano
Mayor of the Municipality of Manati
City Hall 10 calle Quiñones
Manati, PR. 00674
Tel. (787) 854-2024

c) Type of activity by the Standard Industrial Classification: The code is 9199 corresponding to administrative activities of the government.

d) Name (s) of the operator (s), address, telephone numbers and position:
Plan. Leslie Sánchez Rosado
Department Director of Strategic Planning
and Land Use Planning
10 calle Quiñones
Manati, PR 00674
(787) 884-0742 or (787) 854-3475
Fax. (787) 884-5415

e) List of Permits or Construction Approvals received or applied of the Municipality of Manati

a. Resource Conservation and Recovery Act.

b. Underground Injection Control under the Safe Drinking Water Act.

c. NPDES Program under the Clean Water Act.

d. Nonattainment Program under the Clean Air Act.

e. National Emission Standards for Hazardous Air Pollutants Preconstruction Approvals under the Clean Air Act.

f. Ocean Dumping Permits under the Marine Protection Research and Sanctuaries Act.

g. Dredge or Fill Permits under Section 404 of the Clean Water Act.

h. Puerto Rico EQB (DS-1)

Department of Natural Resources.

Listing of any Permits or Construction Approvals received or applied of the Municipality of Manati

Agency	Permit Number	Description	Facility
JCA 21/09/07 al 21/09/12	PGC-07-47-0218-RC PERMISO GENERAL CONSOLIDADO	PERMISO CES, DS-3, PFE, GENERALES	Techo del Coliseo Municipal
ARPE	08EA8-00000-02656 R-03-30-8 14/10/03	Exclusión Categórica	Ampliación de Casa Alcaldía
ARPE	06EA8-00000-05649 R-03-30-8 14/10/03	Exclusión Categórica	Monumento a las Volibolistas
			Remodelación de la Plaza del Mercado

f) Topographic map or in GIS that extends 1 mile beyond the borders of the source indicated in each structure registered discharge and runoff, TDS hazardous materials facilities, etc. (See Attachment 1).

To obtain more scientific data we incorporated Appendix 3, a study conducted in June 2008, signed by Perez Blair Consulting Engineers, PSC to conduct a Hydrologic Evaluation of the urban area of Manati, since the municipality is in the process of implementing an urban drainage system on the northern side of town. Although the Model of Hydraulic Flow made for this study covers an area of 1.48 square miles, is the only scientific study that allows us to better understand our area of study selected. This way we can conclude the following:

- The area covers 3.95 square miles and is located in the northern central part of town of Manati, towards the south of the PR-22 and the urban center of Manati. The area consists mostly of urban soil. The topography of the study area is relatively flat, with the presence of some karst hills and elevations in areas of development may vary between 5 to 60 meters. The most of vegetation caver consists of grass and some trees.

- The main system runs along the PR-2 through a reinforced concrete tube of 60 ¨ in diameter, where the waters drain into the west side of town. The waters drain into a sewer on Rd. 604 and discharges into the Caño Nacho. From there the discharge goes through a concrete channel that drains beneath some houses located on State Highway PR-685. Finally the rainwater, discharges in the valley of the Rio Grande de Manati, or Paseo Real (west of the town).

- According to the Flood Insurance Rate Map, the area studied is not in the f100d zone (Zone X), Appendix 4.

- The existing drainage system does not have the sufficient capacity to channel water discharges caused by floods in parts of the urban area.

- The infiltration of types of soil varies widely and is affected by the permeability of the subsoil and the intake of the types of surface. The hydraulic soil, according to groups defined by the ¨ Soil Conservation Service ¨, are the following: A, low potential runoff, high infiltration rate; B, moderate infiltration rate; C, low infiltration rate, and D, high-potential runoff. The Soil Map (Appendix 4) shows the types of soil in the area studied.

- The soils that make up the hydrological group of soil fall into the categories of Group B (moderate rates of infiltration) and D (high potential runoff). The vegetation cover of these basins is composed of concrete and asphalt in urban areas.

g) Brief description of the nature or operator's business: The municipal government concern is for its public interest or community service.

h) Estimated miles ² service by the MS4 (s). It was estimated that it measured 3.95 m2

i) Define the Best Management Practices (BMP) that will meet at least 6 minimum control measures, these are:

1 **Program to Educate the General Public.** Create and develop an educational campaign within the community. The purpose for this is intended: to reproduce informative material, create local newsletters produced by the EPA, planning and implementing communal workshops, meetings and seminars.

2. **Participation and community involvement.** It aims to create committees in communities to carry out cleanup activities at specific locations and develop an assessment of necessities to involve the community.

3. **Detection and elimination of illicit discharges.** Develop, implement and maintain a comprehensive program to identify and eliminate illicit connections to the stormwater system and discharges that are not run-off (sewer overflows, disposal of used oils to stormwater system, etc.).

In addition a **Stormwater Infrastructure Map** will be reproduced and digitized in GIS the infrastructure of existing stormwater sewer system, supported by a database in an Access Format, containing descriptive information of the system. It requires intense research for any active and inactive document in the municipality, state agencies and nonprofit agencies in order to collect any descriptive information or blueprint of stormwater infrastructures to be scanned into a in digital format and georeference them to the coordinate system in GIS system. It requires further review of existing electronic files that may contain relevant information. We need to prepare an inventory of documents reproduced for the benefit of the municipality. This will require further fieldwork to create a database of the stormwater system with its descriptive information of all the elements of the system, such as: in what state the infrastructure was found in, their discharges, where stormwater the piping system runs, locating grills, structure regulations, discharges, among others; and documentation through the use of photographs and then integrate them to the updated map in GIS. Every new construction project should provide us information on CD-ROM in ARC View 9.1, format to incorporate it into our database.

4. **Control of water runoff in projects under construction.** In Puerto Rico, the Environmental Quality Board requires a plan to control erosion and sedimentation (Plan CES), with the purpose of preventing and controlling the contamination of Puerto Rico water and other resources caused by the erosion and sedimentation resulting from such erosion. Activities that require a CES plan include: clearing, filling, leveling, digging, removing vegetative cover from the soil, building or demolishing structures, removing, storing stacking, creating mounds or disposing of land, including products of dredging, the injection of land by mechanical means, the operation of landfills or any other activity that involves the alteration of soil conditions and all

construction activities that disturb more than 5,000 feet ^{2} of land or 100 cubic yards of excavation. The regulation contains procedures for the approval of construction plans and proposed Plan ESC, before starting construction. It requires that the Municipality of Manati monitor the compliance of the requirements of the ESC plan and carry out a survey of needs to make any additional regulations. It will require that any new construction project has to possess sufficient capacity to connect to the system. In addition, any project that requires more than 1 acre, must comply with a special permit issued by EPA. A procedure will be developed to inspect the project in order to detect: type of clearance, impact to the sanitary sewer and stormwater systems, runoff control measures (Control of sediments, fugitive dust, mud, truck transport, problems consequent of sedimentation, erosion, accumulation of waste because of limited use of containers, land spills drainage system not working at its full capacity, etc.).

5. **Managing water runoff on projects in post construction, construction and re developments.** Implement measures to manage water runoff for any project that alters more than 5,000 square feet of land. The municipality will be responsible for reviewing, approving and ensuring the implementation of plans to control water runoff, required for each project. It will also study the need to consider applying municipal ordinances.

6. **Prevent Contamination in Municipal Operations** - Requires establishing good practices of order and cleanliness (good housekeeping) in municipal operations, to reduce pollutants that can be generated in municipal operations. It requires training for municipal employees. It must include a preventive maintenance of streets and sewers. It should also require establishing an emergency response plan for spills. Some examples of good practice that should be

introduced, are: good management of paint storage, maintenance of heavy equipment, oil disposal, oil containers, chemicals that are used in green areas, identify areas suitable for management, install filters in rain registers such as grease traps for absorbent material, ways to retain material that will not be washed away by stormwater runoff, etc.

7. **Improvement Program in Stormwater and Health Infrastructure** - Develop, implement and maintain a program aimed at improving the sanitary and stormwater infrastructure to prevent pollution of bodies of water.

8. **Evaluation process and reports to quantify effort**. Periodic reports should be made to the EPA based on the activities carried out in compliance with the NPDES permit, as established in the program. It shall be instituted that any permitted limited discharge or illicit discharge must be reported to EPA within 24 hours of it not being in compliance.

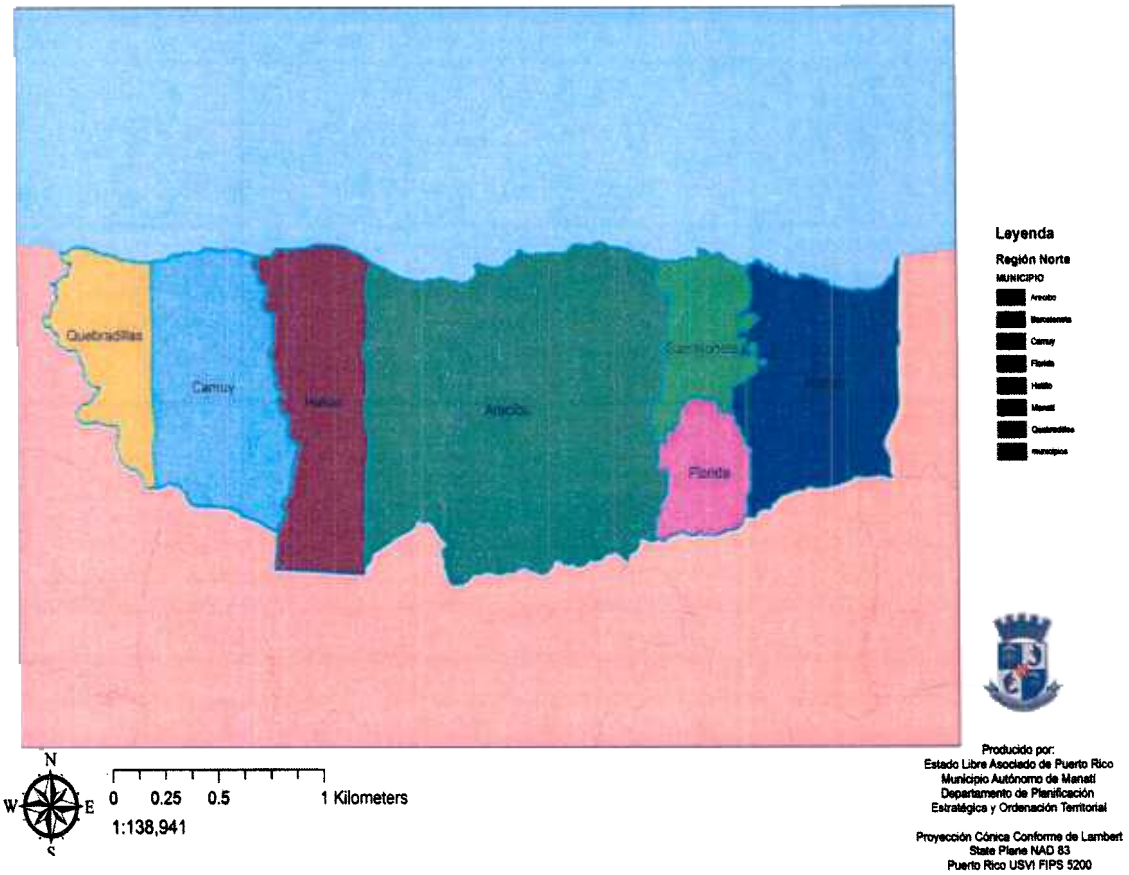
9 **Inspections Process**. The municipality will inspect monthly, areas identified as a potential source of pollution to ensure that they are operating properly.

10. **Program for Register Maintenance**. The recording and archiving of documents relating to the Program Management of Water Runoff, such as inspections, monitoring activities, laboratory tests, reports, trap maintenance or other; must be kept for a period of retention of a minimum of 3 years. An annual report must be done summarizing the progress of implementation of MS4 Program.

General Overview of the Municipality of Manati

The Municipality of Manati, located on the northern coast of the island of Puerto Rico, covers an area of 119,059,544.2725m^2 (30,292 curds). Bordering to the north with the Atlanta Ocean, on the west borders with Barceloneta and Florida and to the south, borders with Ciales and Morovis. Towards the east it borders with the Municipality of Vega Baja.

Región Norte de Puerto Rico
Municipio Autónomo de Manatí



Regional Access

The most important regional accesses run in an east-west direction (Diego Freeway and State Highway PR-2), as well as north-south direction (PR-149). Both systems cross near the central part of the city of Manati.

Carreteras Municipio de Manati

Sectors

Manati has 9 sectors these are: Manati Pueblo, Bajura Adentro, Bajura Afuera, Coto Norte, Coto Sur, Rio Arriba Saliente, Rio Arriba Poniente, Tierras Nuevas Saliente and Tierras Nuevas Poniente.

Population

According to the 2000 Census the populatio of the municipality amounted to 45 409 habitants. This makes Manati the highest populated city in this region after Arecibo which is head of the district.

is projected that every years, the Manati population will increase to 4 thousand habitants.

PROYECCIÓN DE POBLACIÓN MANATÍ 2005-2025

Años	2000	2005	2010	2015	2020	2025
Manatí	45,409	49,193	53,292	57,733	62,544	67,765

Cada 5 años se proyecta un aumento de 3 a 4 mil habitantes. El Municipio con mayor crecimiento poblacional en la Región Norte es Florida.

NECESIDAD DE VIVIENDA PUERTO RICO, ARECIBO Y MANATÍ 1995-2005

	Viviendas	Necesidad	Necesidad
Lugar	1990	1995	2005
Manatí	13,337	1,406	2,888
Arecibo	32,458	3,811	3,491
Puerto Rico	1,097,066	129,503	190,113

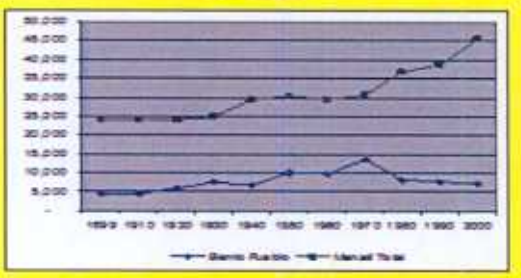
Fuente: Proyecto Puerto Rico, 2005

[illegible] un aumento de necesidad de vivienda en Manatí de 21.7%, mientras Puerto Rico reflejó 17.3%.

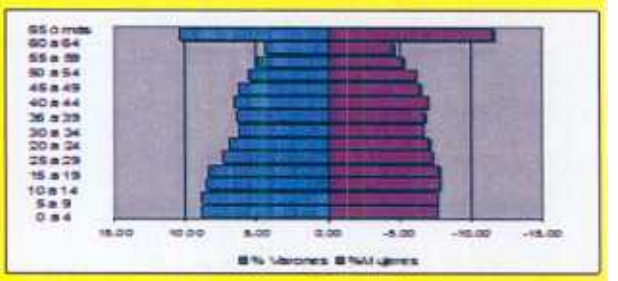
In addition, we see an increased in population of residents 65 years of age or more, hence the provision of geriatric services should be addressed.

CARACTERÍSTICAS DE LA POBLACIÓN

EVOLUCIÓN DE LA POBLACIÓN MUNICIPIO DE MANATÍ 1930-2000



PIRÁMIDE DE POBLACIÓN MUNICIPIO DE MANATÍ, AÑO 2000

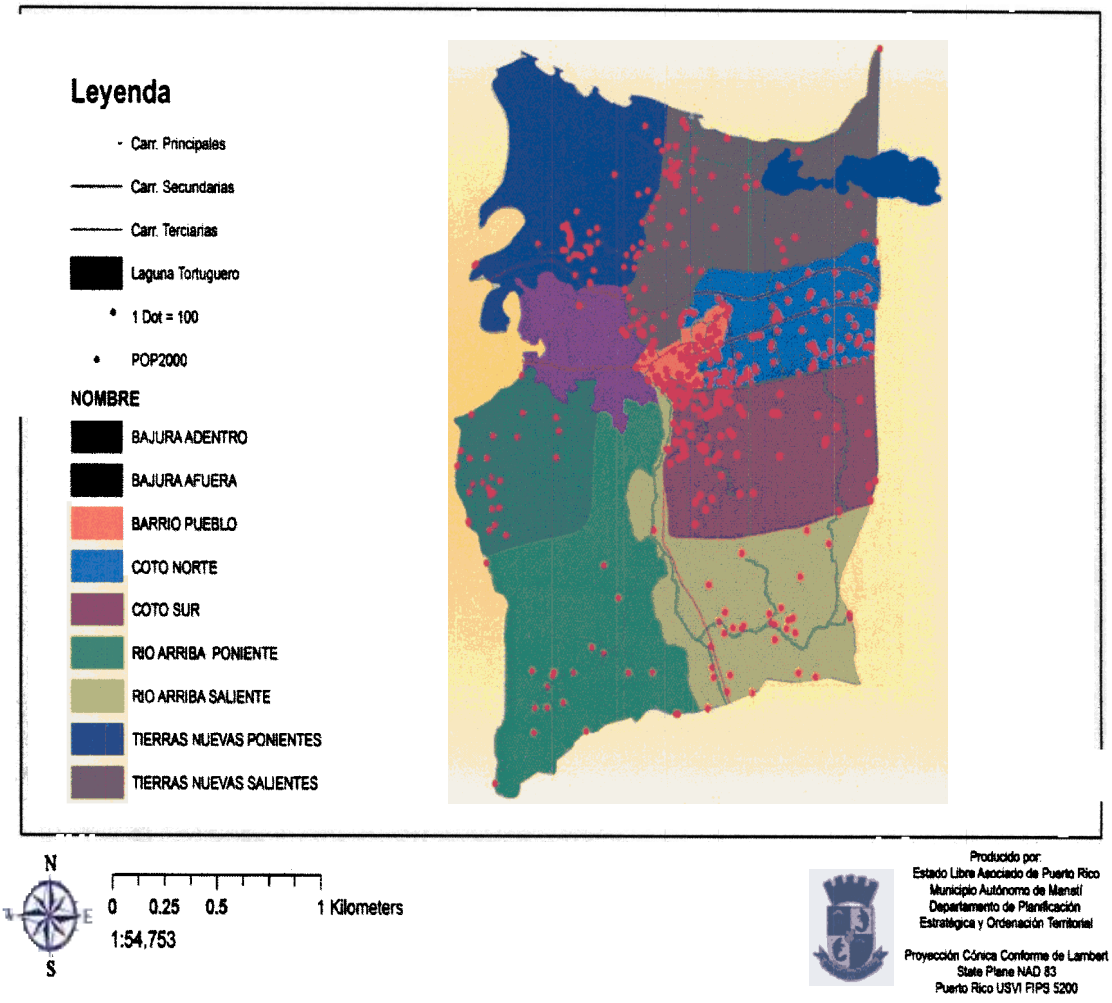


45,409 habitantes en 45.20 millas2 con 1,005 personas por milla2.

Aumento en la población +65 y en los nacimientos, por tanto la provisión de servicios debe dirigirse a servicios geriátricos y servicios a niños y jóvenes de 0-14 años.

In 2000 most of Manat's population, 92.49% or 41,997 lived in an urban area.

Municipio Autónomo de Manatí
Distribución Poblacional Por Barrios, Censo 2000



The distribution of the population in urban and rural districts in 2000 is shown in the following table:

Comparative of Urban and Rural Population by Sector, in Manati

1990 and 2000 Census

Sector	Urban 1990	Rural 1990	Urban 2000	Rural 2000	Total 1990	Total 2000
Bajura Adentro	0	2,395	2,064	248	2,395	2,312
Bajura Afuera	364	77	491	158	423	649
Coto Norte	8,738	127	11,374	0	8,865	11,374
Coto Sur	6,512	1,111	8,215	741	7,623	8,956
Manatí Pueblo	7,750	0	7,131	0	7,750	7,131
Río Arriba Poniente	0	1,681	841	913	1,681	1,754
Río Arriba Saliente	0	2,394	2,477	691	2,394	3,168
Tierras Nuevas Poniente	2,619	795	3,698	661	3,414	4,359
Tierras Nuevas Saliente	1,302	2,845	5,706	-	4,147	5,706
Total	***27,285***	***11,425***	***41,997***	***3,412***	***38,692***	***45,409***

Source: Census Population 1990 and 2000.

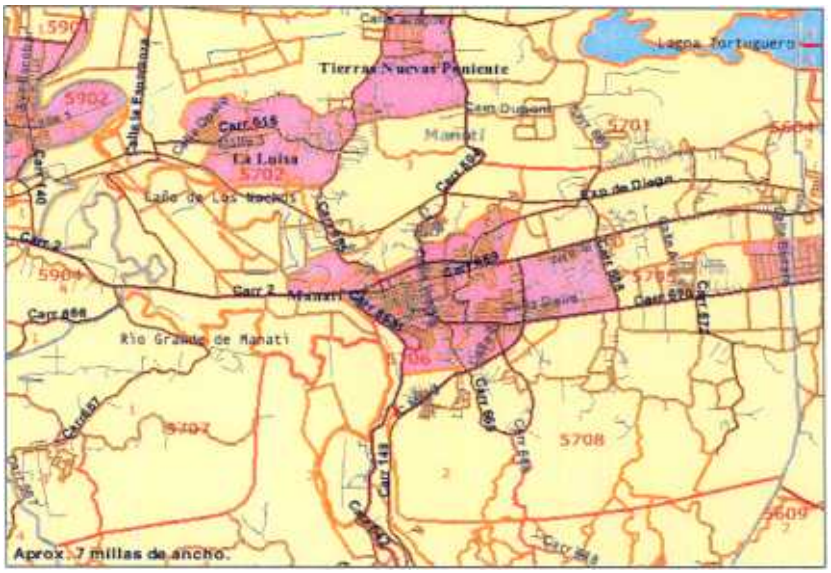
Percentage of Urban and Rural Population – Municipality of Manatí,

Census 2000

Census	Urban	%	Rural	%	Total	% Urban
Bajura Adentro	2,064	4.91	248	7.27	2,312	89.27
Bajura Afuera	491	1.17	158	4.63	649	75.65
Coto Norte	11,374	27.08	-	0.00	1,374	827.80
Coto Sur	8,215	19.56	741	21.72	8,956	91.73
Manatí Pueblo	7,131	16.98	-	0.00	7,131	100.00
Río Arriba Poniente	841	2.00	913	26.76	1,754	47.95
Río Arriba Saliente	2,477	5.90	691	20.25	3,168	78.19
Tierras Nuevas Poniente	3,698	8.81	661	19.37	4,359	84.84
Tierras Nuevas Saliente	5,706	13.59	-	0.00	5,706	100.00
Total	***41,997***	***100.00***	***3,412***	***100.00***	***45,409***	***92.49***

Source: Census Population 2000.

Map Manati's Urban Areas, Census 2000



Source: American Factfinder.census.gov2000

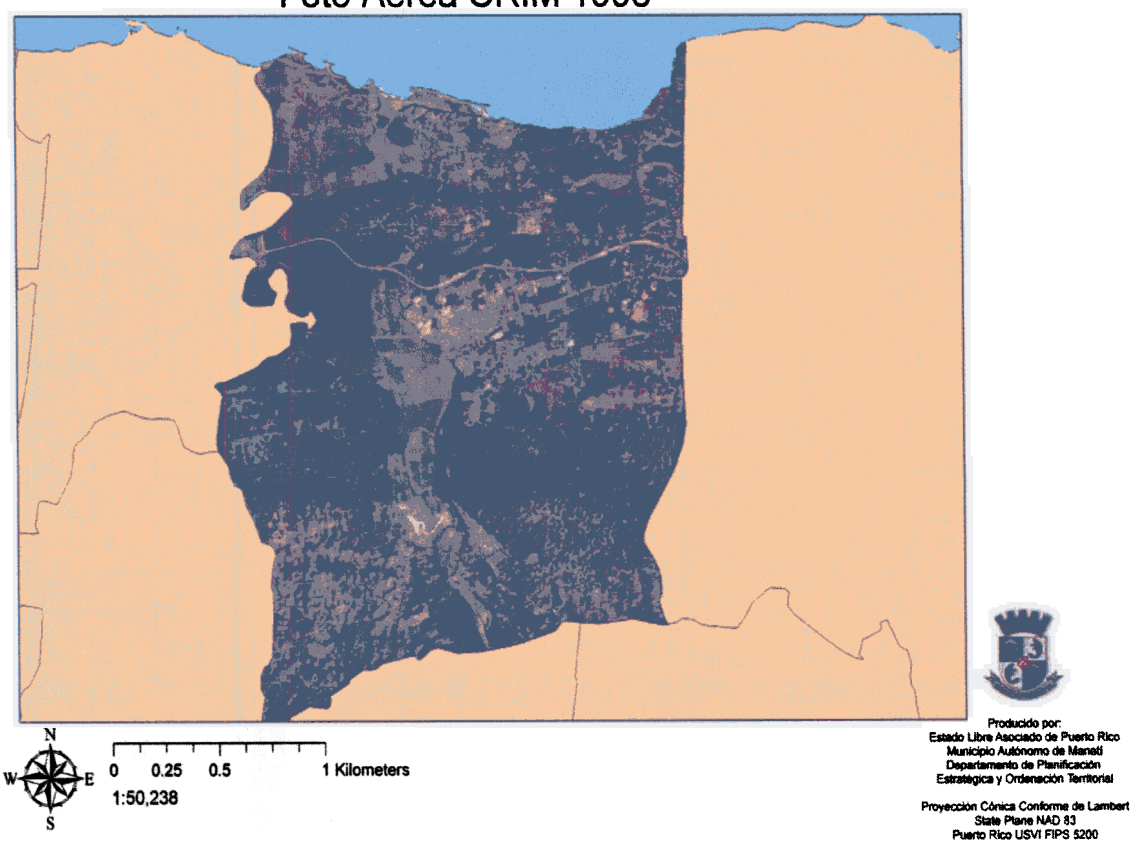
In addition, the Land Use Plan of Manati, approved in 2002, distributed land classifications, as follows:

Extension of the Classification of Land Municipality of Manati		
Type Of Classification	**Area m^2 (Curds)**	**Distribution Percentage**
Urban Land	9,093,161.79821875m^2 (2,313.55 curds)	7.63%
Common Rustic Land	8,342,500.5378m^2 (2,122.56 curds)	7.0%
Specially Protected Rustic Land	99,697,983.08023125m^2 (25,365.89 curds)	83.73%
Programmed Urban Land	1,100,510.775m^2 (280 curds)	.09%
Non Programmed Urban Land	825,383.08125m^2 (210 curds)	0.7%
Total	119,059,544.2725m^2 (30,292 curds)	100%

Importance of Manati in the Region:

Manati is important in the Northern Region for several reasons, some are: employment opportunities located within the municipal boundary, its natural resources and its historical area.

Municipio Autónomo de Manatí
Foto Aérea CRIM 1998



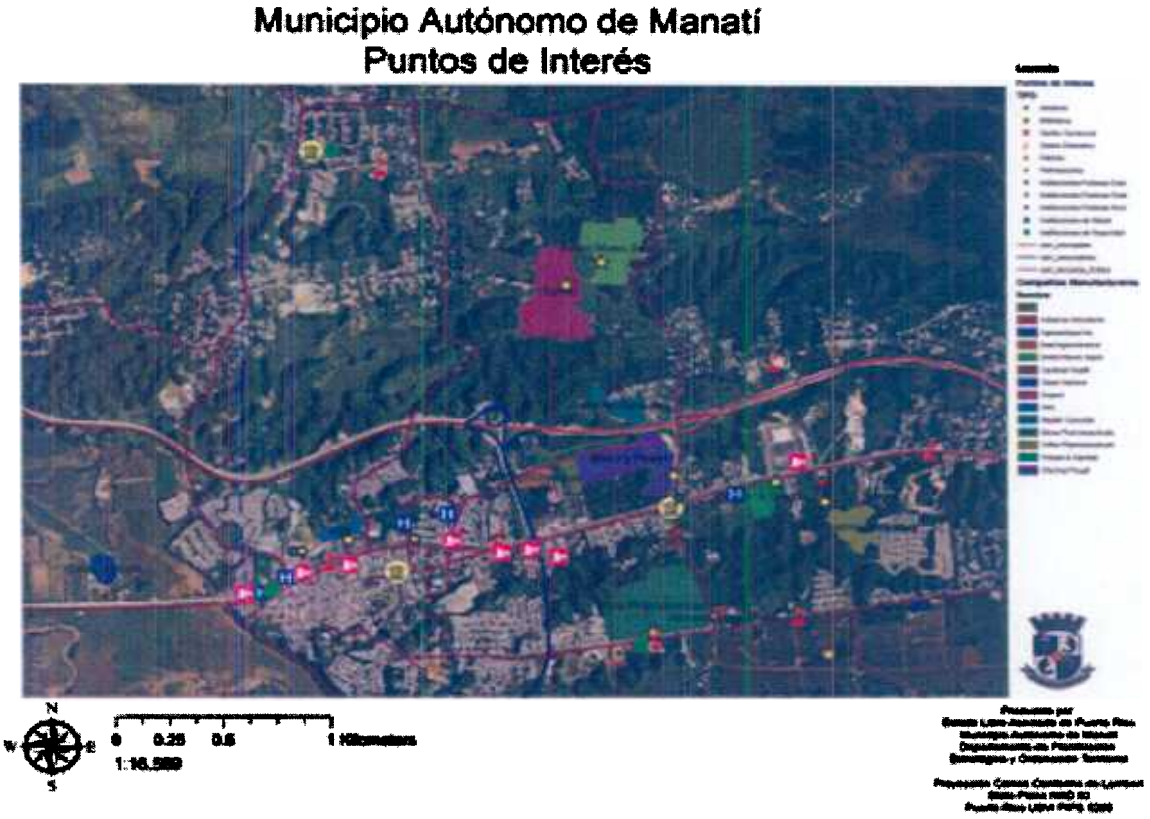
The Municipality of Manati is a regional center of great importance. According to the Department of Labor and Human Resources, 47% of total employment in the service sector of the Northern Region is located in Municipality of Manati, even though only 15% of the total population in the Northern Region resides in Manati.

Man lso mportant to the northern regio ince out the atura rea d signated this region re located in the Municipa ity of Manati. One of the most importa tural resource that we ca mentio the Tortugu ro Lagoo This resource of regio nd su ig ificance located between th city limits of he Municipa iti of Vega Baja and M nati and ea the co stal area It consists of of he most mportant sweet wate systems of Puerto Ri th area th are many endem nd end ngered speci

Another atural re identified al historic site W re referri ig to The speranza Plantati ed by the Co tion Trust.

rh ps the most important tural reso rce fo thi region and fo Puerto Rico, would he Aym món iqu ife This system of groundwater an lement of vital importance to m atural coasta system the most mportant of which is th Tortuguero Lagoo The aq ife lso vita for ndustri nce he mai of d king water

Among the most important resources constructed by m ound in Mana its historica rea industrie particularly pharmaceutical hos itals nd th High y osé Diego Most of he nd stries are located close to tate Road PR-2 toward the north south it.

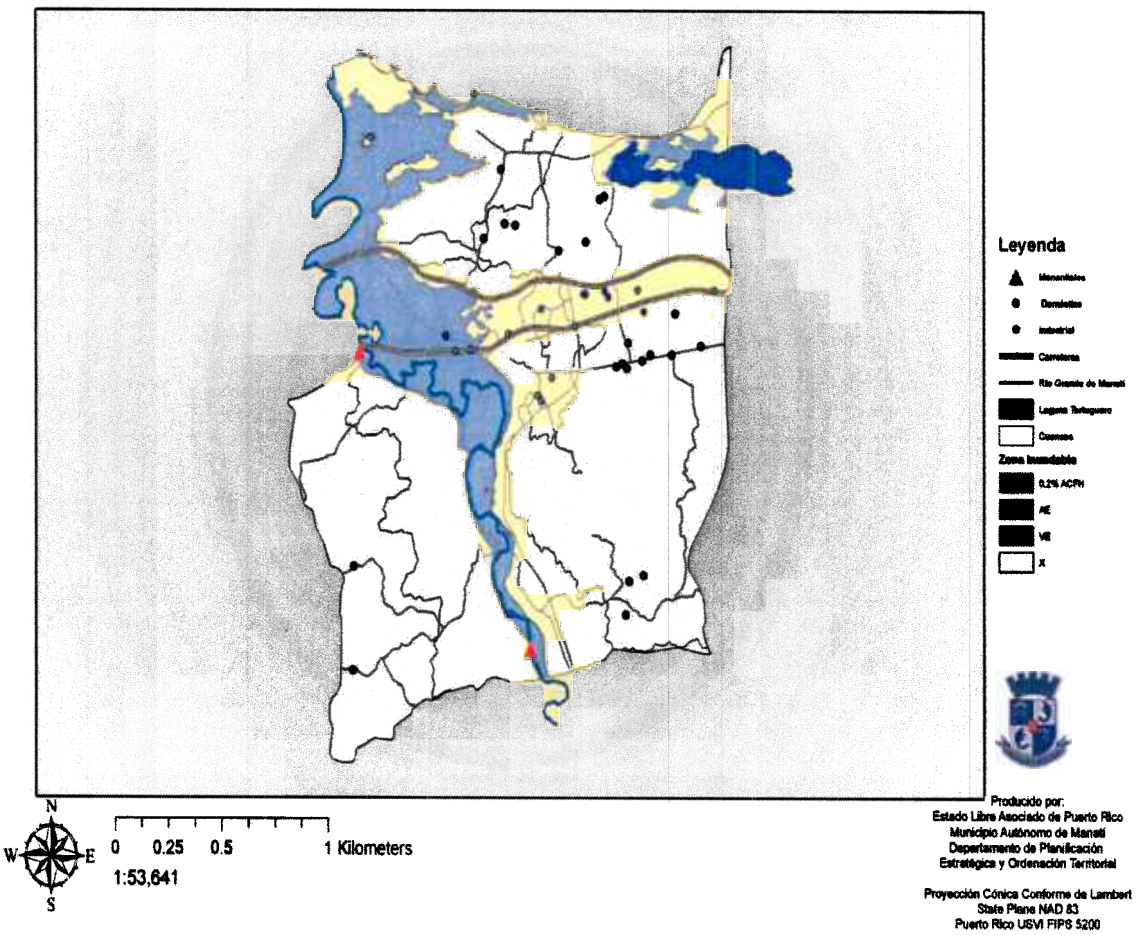


Hydrology

To understand the situation of the Municipality of Manati, it is important to know the surface and groundwater hydrology that sustains the natural resources and human uses of the land.

The Rio Grande of Manati is the second longest river in Puerto Rico, it measures 56.8 miles, and starts in the mountainous interior of the Island. With a flow rate of 275,820 and has two reservoirs: El Guineo located in Ciales and Morovis, and Matrullas in Orocovis. The Rio Grande of Manati is the only major river that runs though the municipality. It feeds from other sources such as: Quebrada, Pugnado, Canas y Terrenes which are located in the valleys of the interior.

Municipio Autónomo de Manatí
Mapa Hidrológico



In the coastal valley, the hydraulic capacity of the riverbed of the Rio Grande of Manati is poor, because it discharges the same or greater than the discharges of two years in frequency causing the overflow of waters. The main flooded areas occur on both sides of the River. There are no large communities affected by these floods in the Municipality of Manati.

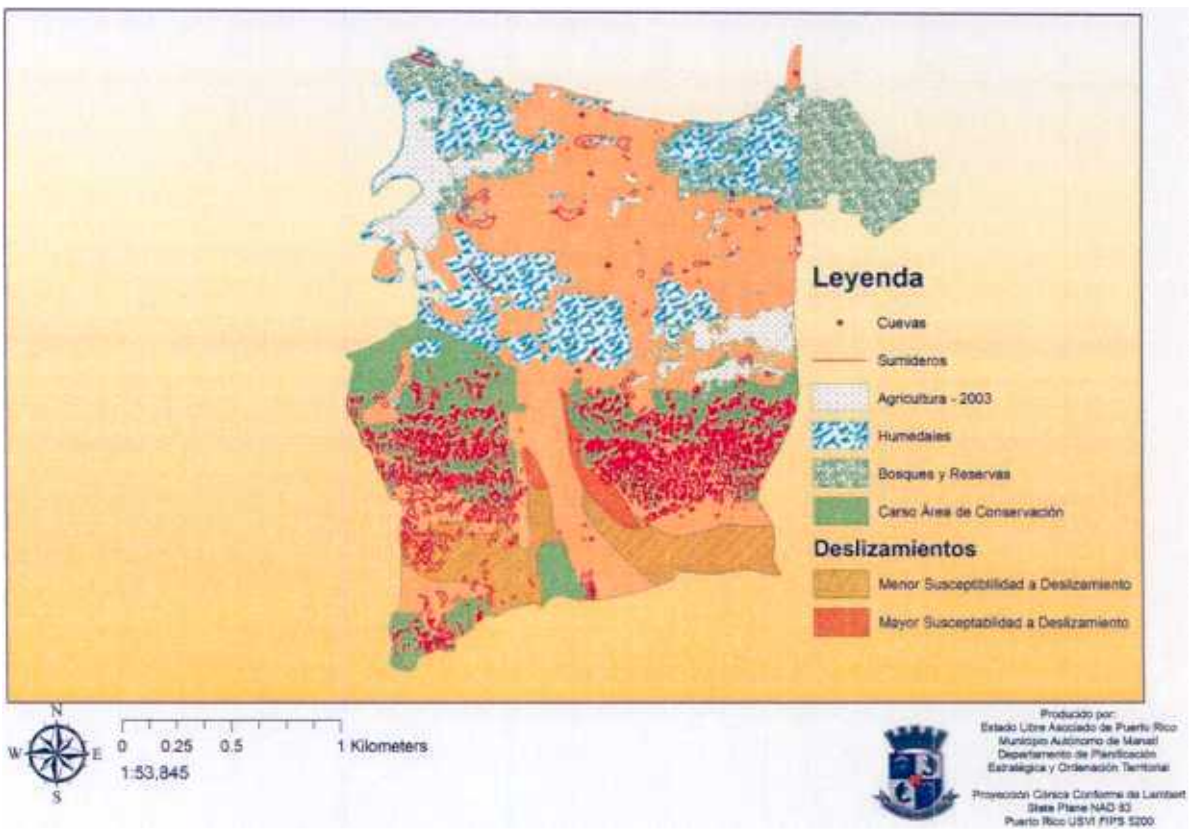
The underground water system is the most important for the municipality, because it supplies drinking water for human consumption and industrial use, as to the wildlife in the Tortuguero Lagoon. Tortuguero Lagoon and Cartagena Lagoon are the only freshwater lagoons in Puerto Rico.

Aquifers

The aquifers of the northern area stretch from Luquillo to Aguadilla. The most important ones of Puerto Rico are the limestone of the North, with a secondary permeability caused by the dissolution of the rock caused by the action of the water. This formation is mainly found to the west of San Juan, concentrated in the area from Dorado to Arecibo. (Appendix 5)

The karst region of the northern coast is an aquifer, complex in its structure and operation. Its overall structure consists of two Limestones, one above the other, separated by a formation of lower permeability: The Cibao Limestone. The two aquifers are known as the Superior Aquifer and the Inferior Aquifer, also known as aquifer Llano or Freático (Superior) and Profundo or Artesiano (Inferior). Appendix 6.

Municipio Autónomo de Manatí
Mapa Recursos Naturales



Sub terrain Water

According to the report "Puerto Rico Water-Use Program: Public-Supply Water Use and Wastewater Disposal During 1990" of the U.S. Geological Survey, the Municipality of Manati did not obtain water from surface sources yet obtained 7 million gallons of water a day from underground sources. For this reason Water wells are an important element in our infrastructure.

Aquifers in the North Coast

The aquifer of the Northern Coast stretches from Luquillo to Aguadilla, occupying an area of approximately 905 MI2 (Appendix 5).

The most important ones of Puerto Rico are the limestone of the North, with a secondary permeability caused by the dissolution of the rock caused by the action of the water. This formation is mainly found to the west of San Juan, concentrated in the area from Dorado to Arecibo.

The karst region of the northern coast is an aquifer, complex in its structure and operation. Its overall structure consists of two limestone aquifer, one above the other, separated by a formation of lower permeability: the Cibao Limestone. The two aquifers are known as the Superior Aquifer and the Inferior Aquifer, also known as aquifer Llano or Freático (Superior) and Profundo or Artesiano (Inferior). Appendix 6 provides a cross section of the area of the Caño Tiburones showing the basic configuration of the formations that make up the aquifers.

The Superior Aquifer consists of limestone rocks with moderate to high levels of permeability over a floodplain, formed by sediments that deposit in river valleys that run through the limestone. This aquifer includes layers of alluvial deposits and marine limestone formations that overlays, primarily the ones named Aymamón, Cibao, Camuy and Aguada (Monroe, 1980). This extends from the Luquillo area towards the west. Its maximum thickness varies depending of the location from east to west, as well as alluvial deposits formed in the immediate valley of the river in that region. The permeability in the limestone is due to winding channels. The Superior Aquifer is a major supply source of water for consumption, industrial and agricultural activities, with a collection of 52 MGD in 2002 (DNRE, 2004). The lower limit of this aquifer is the permeable rock of the Cibao formation.

The inferior aquifer (deep or artesian) includes layers of formations of San Sebastian, Lares and Montebello, confined by layers of mud and silt from the Cibao Formation. The aquifer extends from the metropolitan area of San Juan to Aguadilla, even though the areas with higher capacity of production of water are between Manati and Arecibo. In this area where artesian conditions occur prior to the development of the aquifer, the level of metric power water allows the wells in the area flow without the need for pumping. However, the exploitation of this has led to a dramatic reduction in the level metric power in this aquifer. The inferior aquifer is the main source of water for industrial uses in the area of Manati to Barceloneta, in addition to supplement supplies for moderate consumption. The extraction of water in this aquifer was 7 MGD in 2002 (DNRA, 2004).

The limestone aquifers are recharged through the percolation of rainwater through the ground, by the discharge of surface runoff into sinkholes and by the infiltration through the bottom of the rivers. They can also receive recharge from the discharge of septic tanks and leaks from broken pipes. Both aquifers discharged into the sea, although the upper aquifer discharges towards springs, the bottom of rivers, wetlands and coastal lagoons including the Caño Tiburones and Laguna Tortuguero. The wells in operation also represent points of discharge for both aquifers.

Al uvia Aquifer

The lu aquifers re th f'ood pla ns m: ily th South Co st and som te al ys There are al uvia ife he North Co st described above combi ati with th imeston Th se aquifers -consolidated fo ations perm le sand and vel posited by ancient rivers now find themselves below the iround surface Th areas of reatest permeability rrespond to areas of sand nd ıra of th cestra ch nels Th most important iif rs the outhern Coa tration Appendix nd som nterior leys Cayey and Cag A iq ifers re less prod ctive the Northern Co st beca se in thi th re are lo mo cl the sedim nts nd it very permea le

Estuaries

stu re ıre: whe fresh wate m with seawater ce fresh water less se tha lty sea wate estuaries tend to be stratified hich means laye of fre hwater floats above the sea wate rivers salt te th enters land known sea wedge y terin below th ye of freshwate resh wate mixes with sea ter fo ing sa ne ater Thi mixture roduced by the com ined action of the es waves nd he force of rface runoff. sides stratified estuaries there stuaries tha re rti lly lended nd others tha re completely lended Due to that the tid waves nd ru off vary m space the estuary is very dynami system regard: to the salinity of its wate Within th estu ıry, the sal ity ca be eq to that of sea water and ch nge to have termediate salinity or become fresh water As he inity of the wate changes lso ch nge: its ity When the flow fresh water ecli es th wedge of sea te penetrate the river severa kilometers land Thi happen eral of the m: jo rivers of th northern coast, includ ng th jata Ri rande d Arecibo Rio rand de M La Plata Rio Grand íza nd sp ritu Santo H vy rai cause ncrease th flow of fresh water nto rive which rn back nto th wed of brackish water nto th sea

In Puerto Rico, there are five classes of estuaries. One is formed at the mouth of rivers and lakes systems. The estuary of the river mouth can be separated from the sea by a verge of sand except during short periods in which the rise removes the verge from the mouth. This verge will be re-established by the action of waves from the beach. The pattern of mixing in this kind of estuary shows the normal condition of vertical stratification with saline water on the bottom and a layer of fresh water flowing over the top. When there is little flow of fresh water, for example downstream from reservoirs, movement in this kind of estuary can be essentially paralyzed; saline water is trapped at the bottom with very little input of oxygen which can create anaerobic conditions at the bottom of the estuary for prolonged periods of time.

Another feature of river estuaries is the presence of mangroves, which grow in areas where there is enough salinity (about 5 mg / l) as to prevent the growth of freshwater plants. The mangroves tolerate a wide range of salinity and also grow where there is no fresh water, such as keys and dry shores. The mangrove areas receive input of fresh water, but during most of the year are fed mainly by saline water.