WATER RESOURCES ASSESSMENT OF NICARAGUA

US Army Corps of Engineers
Mobile District &
Topographic Engineering Center

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Executive Summary

Nicaragua is rich in hydrologic resources, although much of the surface water is contaminated and not developed for water supply. The major source of surface water contamination is from untreated domestic and industrial waste disposal, as most effluent is released into the rivers and coastal areas without any treatment. Little regulation exists that addresses waste discharge and disposal.

Nicaragua is one of the poorest countries in the Western Hemisphere, with one of the highest annual growth rates in Latin America. Access to water and sanitation facilities is inadequate, particularly in the east where the population is sparse. This inadequacy of water services contributes to poor living conditions, disease, and a high mortality rate.

Given the rainfall and abundant water resources, there is adequate water to meet the water demands, but proper management to develop and maintain the water supply requirements is lacking. Major problems in water management are the lack of a national water sector and the lack of a national water law. A national water law is before Congress now, but has not been passed.

Deforestation, with its devastating environmental consequences, is a serious problem. Deforestation accelerates soil erosion, decreases the amount of recharge to aquifers by increasing surface runoff, damages barrier reefs and ecosystems, increases turbidity which affects mangroves, decreases agricultural production, and causes problems and increased maintenance of water systems and impoundments. Decades of land abuse and environmental neglect exacerbated the devastation of Hurricane Mitch (1998), in which deforestation played a major role.

As a result of the polluted surface water, ground water is heavily relied upon for water supply. Sufficient supplies of fresh ground water are available throughout most of the country. The most abundant supplies are in Quaternary age alluvial aquifers interbedded with pyroclastic materials and Tertiary to Quaternary age volcanic deposits consisting of basalt and andesite lava flows with pyroclastic flows and fall deposits in the Nicaraguan Depression and Caribbean and Pacific lowlands. Many shallow aquifers are, however, becoming contaminated from surface pollution, and deeper springs and wells are depended upon to provide potable water.

Many agencies share responsibility for overseeing the water resources of the country. A national water sector could enhance the coordination between the individual agencies working to provide water and sanitation. The passage of a national water law would also help preserve and protect the nation's future water resources and supplies. Long-term national construction programs of wastewater treatment plants to eliminate the continued discharge of waste into the nation's waters would help reduce the amount of chemical and biological wastes contaminating the rivers, lakes, and ground water. A large-scale ground water exploration program, starting in the areas having the best aquifers, would increase the amount of potable water available for water supply.

Preface

The U.S. Southern Command Engineer's Office commissioned the U.S. Army Corps of Engineers District in Mobile, Alabama, and the U.S. Army Corps of Engineers, Engineer Research and Development Center, Topographic Engineering Center in Alexandria, Virginia, to conduct a water resources assessment of Nicaragua. This assessment has two objectives. One objective is to provide an analysis of the existing water resources and identify some opportunities available to the Government of Nicaragua to maximize the use of these resources. The other objective is to provide Nicaragua and U.S. military planners with accurate information for planning various joint military training exercises and humanitarian civic assistance engineer exercises.

A team consisting of the undersigned water resources specialists from the U.S. Army Corps of Engineers Mobile District and the Topographic Engineering Center conducted the water resources investigations for this report from 1998 through 2000.

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List of Acronyms and Abbreviations

Acronyms

ADRA	Adventist Development and Relief Agency
BID (IDB)	Banco Interamericano de Desarrollo (Inter-American Development Bank)
CARE	Cooperative for American Relief to Everywhere
CEPREDENAC	Center for Coordination of Prevention of Natural Disasters in Central America
EHP	Environmental Health Project
ENACAL	Empresa Nicaragüense de Acueductos y Alcantarillados (Nicaraguan Management of Aqueducts and Sewerage)
ENAP	Empresa Nacional de Puertas (National Port Authority)
ENEL	Empresa Nicaragüense de Electricidad (Nicaraguan Management of Electricity)
FISE	Nicaraguan Social Investment Fund
GDP	Gross domestic product
GNP	Gross national product
IDB (BID)	Inter-American Development Bank (Banco Interamericano de Desarrollo)
INAA	Instituto Nicaragüense de Acueductos y Alcantarillados (Nicaraguan Institute of Aqueducts and Sewerage)
INETER	Instituto Nicaragüense de Estudios Territoriales (Nicaraguan Institute of Territorial Research)
IRENA	Instituto de Recursos Naturales (Institute of Natural Resources)
MAGFOR	Ministerio Agropecuario y Forestal (Ministry of Agriculture and Forestry)
MARENA	Ministerio del Ambiente y Recursos Naturales (Ministry of the Environment and Natural Resources)
MIFIC	Ministerio de Fomento, Industria y Comercio (Ministry of Promotion, Industry and Commerce)
NGO	Non-government organization
NOAA	National Oceanic and Atmospheric Administration
UNICEF	United Nations International Children's Fund
USACE	U.S. Army Corps of Engineers
USAID	U.S. Agency for International Development (Agencia para el Desarrollo Internacional)
USGS	U.S. Geological Survey
USSOUTHCOM	United States Southern Command
WHO	World Health Organization

Abbreviations

Ca	calcium
$CaCO_3$	calcium carbonate
Cl	chloride
CO_3	carbonate
Fe	iron
ft^3/s	cubic feet per second
gal/min	gallons per minute
HCO_3	bicarbonate
H_2S	hydrogen sulfide
K	potassium
km^2	square kilometers
L/min	liters per minute
L/s	liters per second
L/s/m	liters per second per meter
Mg	magnesium
mL	milliliters
mm	millimeters
Mm^3	million cubic meters
MPN	most probable numbers
m^2/d	square meters per day
m^3/s	cubic meters per second
m_{eq}/L	milliequivalents per liter
mg/L	milligrams per liter
MW	megawatts
Na	sodium
NaCl	sodium-chloride
NO_3	nitrate
pH	hydrogen-ion concentration
P	phosphate
SO_4	sulfate
SiO_2	silica
TDS	total dissolved solids
TSS	total suspended solids

List of Place Names

Place Name	Geographic Coordinates
Asturias	1315N08554W
Bocana de Paiwas	1248N08508W
Caribbean coast	1254N08332W
Caribbean Coast drainage region	1300N08400W
Caribbean Coastal Plain	1400N08400W
Ceilan	1235N08714W
Chococente	1131N08610W
Ciudad Dario	1243N08608W
Copalar	1254N08454W
Corriente Lira	1333N08550W
Departamento de Boaco	1230N08530W
Departamento de Carazo	1145N08615W
Departamento de Chinandega	1250N08705W
Departamento de Chontales	1205N08510W
Departamento de Esteli	1310N08620W
Departamento de Granada	1150N08555W
Departamento de Jinotega	1345N08535W
Departamento de Leon	1235N08635W
Departamento de Madriz	1330N08625W
Departamento de Managua	1200N08625W
Departamento de Masaya	1200N08610W
Departamento de Matagalpa	1255N08540W
Departamento de Nueva Segovia	1342N08610W
Departamento de Rio San Juan	1120N08435W
Departamento de Rivas	1118N08545W
El Castillo de la Concepcion	1101N08424W
El Contrabando	1204N08640W
El Dorado	1315N08552W
El Jicaral (on Rio Mayales)	1203N08521W
El Jicaral (on Rio Sinecapa)	1244N08623W
El Tamarindo	1214N08643W
Esquipulas	1240N08549W
Estero Real	1255N08723W
Guana	1331N08557W
Interior Highlands	1255N08540W
Islas del Maiz	1215N08300W

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Place Name	Geographic Coordinates
La Canoa	1304N08659W
La Flor	1108N08547W
La Gallina	1238N08658W
Lago de Managua (Lago Xolotlan)	1220N08620W
Lago de Nicaragua (Lago Cocibolca)	1130N08530W
Lago de Wani (Bismuna)	1445N08320W
Lago Xolotlan (Lago de Managua)	1220N08620W
Laguna Bismuna (Lago Wani)	1445N08320W
Laguna de Apanas	1311N08559W
Laguna de Apoyeque	1215N08621W
Laguna de Apoyo	1155N08602W
Laguna de Asososca	1208N08619W
Laguna de Jiloa	1213N08619W
Laguna de Perlas	1233N08340W
Laguna de Wounta	1338N08334W
Laguna Karata	1356N08330W
Laguna Pahara	1418N08315W
Las Banderas	1220N08557W
Las Brisas	1253N08608W
Las Enramadas	1140N08559W
Managua	1209N08617W
Masapa	1306N08531W
Masaya	1158N08607W
Miramar	1122N08557W
Muelle de Los Bueyes	1204N08432W
Namasli	1328N08614W
Nicaraguan Depression	1220N08620W
Pacific coast	1200N08641W
Pacific Coast drainage region	1230N08700W
Pacific Hills	1145N08615W
Pacific Lowlands	1235N08635W
Pacora	1228N08612W
Palmira	1336N08636W
Pochomil	1146N08630W
Rama	1209N08413W

List of Place Names (Continued)

Place Name	Geographic Coordinates
Region Autonomista Atlantico Sur	1200N08400W
Region Autonomista Atlantico Norte	1400N08400W
Rio Acoyapa	1148N08516W
Rio Amaka	1414N08509W
Rio Atoya	1235N08715W
Rio Bambana	1327N08350W
Rio Bocay	1418N08510W
Rio Brito	1120N08559W
Rio Coco	1500N08310W
Rio Escalante	1131N08610W
Rio Escondido	1204N08345W
Rio Esteli	1330N08616W
Rio Grande	1138N08621W
Rio Grande (Rio Viejo)	1228N08621W
Rio Grande de Matagalpa	1254N08332W
Rio Indio	1057N08344W
Rio Kukalaya	1339N08337W
Rio Kurinwas	1249N08341W
Rio Malacatoya	1207N08547W
Rio Mancotal	1314N08555W
Rio Mayales	1152N08527W
Rio Mico	1211N08416W
Rio Negro	1302N08708W
Rio Ochomogo	1141N08554W
Rio Oyate	1138N08507W
Rio Pacora	1225N08617W
Rio Paiwas	1247N08507W
Rio Prinzapolka	1324N08334W
Rio Punta Gorda	1130N08347W
Rio Rama	1209N08413W
Rio San Cristobal	1220N08658W
Rio San Diego	1155N08637W
Rio San Juan	1056N08342W
Rio San Juan drainage region	1200N08600W
Rio Sinecapa	1228N08625W
Rio Siquia	1209N08413W

List of Place Names (Continued)

Geographic coordinates for place names and primary features are in degrees and minutes of latitude and longitude. Latitude extends from 0 degrees at the Equator to 90 degrees north or south at the poles. Longitude extends from 0 degrees at the meridian established at Greenwich, England, to 180 degrees east or west established in the Pacific Ocean near the International Date Line. Geographic coordinates list latitude first for Northern (N) or Southern (S) Hemisphere and longitude second for Eastern (E) or Western (W) Hemisphere. For example:

Asturias......1315N08554W

Geographic coordinates for Asturias that are given as 1315N08554W equal 13°15' N 85°54' W and can be written as a latitude of 13 degrees and 15 minutes north and a longitude of 85 degrees and 54 minutes west. Coordinates are approximate. Geographic coordinates are sufficiently accurate for location features on the country-scale map. Geographic coordinates for rivers are generally at the mouth of the river.

Figure 1. Country Map

Water Resources Assessment of Nicaragua

I. Introduction

Water, possibly the world's most indispensable resource, nourishes and sustains all living things. At least 400 million people in the world live in regions with severe water shortages. By the year 2050, it is expected to be 4 billion people. At least 5 million people die every year from water-related illnesses. The projected short supply of usable potable water could result in the most devastating natural disaster since history has been accurately recorded, unless something is done to stop it. It is believed that water resources will be among the principal global environmental challenges of the 21st Century.

There is a direct relationship between the abundance of water, population density, and quality of life. As the world's population grows, pressure on the limited water resources grows. Unless water resources are properly managed, scarcity can be a roadblock to economic and social progress. A plentiful supply of water is one of the most important factors in the development of modern societies. The two major issues in the development of water resources are quantity and quality. Availability of water for cleansing is directly related to the control and elimination of disease. The convenience of water improves the quality of life.[1] In developing countries, water use drops from 40 liters per day per person when water is supplied to the residence to 15 liters per day per person if the source is 200 meters away. If the water source is more than 1,000 meters away, water use drops to less than 7 liters per day per person.[2] As well as being in abundant supply, the available water must have specific quality characteristics, such as the low concentration of total dissolved solids (TDS). The TDS concentration of water affects the domestic, industrial, commercial, and agricultural uses of water. The natural nontoxic constituents of water are not a major deterrent to domestic use until the TDS concentration exceeds 1,000 milligrams per liter. As TDS values increase over 1,000 milligrams per liter, the usefulness of water for commercial, industrial, and agricultural uses decreases. In addition to TDS concentrations, other quality factors affect water. These factors include the amount of disease-causing organisms, the presence of manufactured chemical compounds and trace metals, and certain types of natural ions that can be harmful at higher concentrations.

The purpose of this assessment is to document the general overall water resources situation in Nicaragua. This work involves describing the existing major water resources in the country, identifying special water resources needs and opportunities, documenting ongoing and planned water resources development activities, and suggesting practicable approaches to short- and long-term water resources development. This assessment is the result of an in-country information-gathering trip and from information obtained in the United States on the part of three water resources professionals. The scope is confined to a “professional opinion,” given the size of the country and the host of technical reports available on the various water resources aspects of Nicaragua.

This information can be used to support current and potential future investments in managing the water resources of the country and to assist military planners during troop engineering exercise. The surface water and ground water graphics, complemented by the tables in Appendix C, should be useful to water planners as overviews of available water resources on a country scale. The surface water graphic divides the country into surface water regions, based on water quantities available. The ground water graphic divides the country into regions with similar ground water characteristics.

In addition to assisting the military planner, this assessment can aid the host nation by highlighting its critical need areas, which in turn serves to support potential water resources development, preservation, and enhancement funding programs. Highlighted problems are the lack of access to water supply by much of the population, the low density of the population in most of the country, the lack of wastewater treatment, the devastating effects of deforestation on the water resources, and the lack of hydrologic data. Watershed management plans should be enacted to control deforestation and to manage water resources.

Responsibility for overseeing the water resources of Nicaragua is shared by several government agencies and institutions. The U.S. Army Corps of Engineers assessment team met and consulted with the organizations most influential in deciding priorities and setting goals for the water resources (see Appendix A). Most of these agencies conduct their missions with little or no coordination with other agencies, which creates duplication of work and inefficient use of resources.

II. Country Profile

A. Geography

Nicaragua, with 129,494 square kilometers of territory, is the largest country in Central America. In land area comparison, it is about the size of the U.S. state of New York. Nicaragua borders Costa Rica to the south and Honduras to the north, with the Caribbean Sea to the east and the Pacific Ocean to the west.

Figure 2. Vicinity Map

The physical geography of the country is divided into three major zones: the Pacific lowlands, the central highlands, and the Caribbean lowlands. The Pacific lowlands extend about 75 kilometers inland from the Pacific coast. Most of the area is flat, except for a line of young volcanoes between the Golfo de Fonseca and Lago de Nicaragua. These peaks lie just west of a highly conspicuous feature in the landscape, which is a long low-lying rift valley, extending from the Golfo de Fonseca to the boundary region with Costa Rica along the Caribbean shoreline. Two of the largest freshwater lakes in Central America, Lago de Nicaragua (Lago Cocibolca) and Lago de Managua (Lago Xolotlan), are in this rift valley. Western Nicaragua is situated at the juncture between colliding tectonic plates, resulting in high incidence of earthquakes and volcanic activity. The Caribbean lowlands region, which is largely uninhabited, covers about half of the national territory, and consists of tropical rain forest and pine savannas crossed by numerous rivers flowing to the Caribbean. The eastern Caribbean lowlands, swampy and indented, are aptly called the "Mosquito Coast."

Since western Nicaragua is located where two major tectonic plates collide, it is subject to earthquakes and volcanic eruptions. Sixty percent of the population lives in this geologically unstable Pacific area. Although periodic volcanic eruptions have caused agricultural damage from fumes and ash, earthquakes have been far more destructive to life and property. Most volcanism occurs in a narrow zone that extends through Managua. In 1972 an earthquake destroyed the center of the capital city and killed more than 5,000 persons. Flooding caused by hurricanes sometimes occurs along the sparsely populated Caribbean shoreline, and western Nicaragua occasionally suffers from extended periods of drought. Hurricane Mitch caused extensive damage to Nicaragua in 1998. See figures 1 and 2 for general geographic information.[3,4,5,6]

B. Population and Social Impacts

Nicaragua is the largest but one of the most sparsely populated of the Central American countries. In the early 1990's, the country population was estimated at over 4 million people. The estimated population for 2001 is 4,812,569. The growth rate estimates range from 2.3 to 3.4 percent, which is among the highest in Latin America. Since the 1950's, Nicaragua has had a persistently high rate of population increase and rapid urban growth, both of which are expected to continue into the 21st Century. Much of the urban growth is concentrated in the capital city of Managua. See table 1 for the 1995 population figures by department and region.

Table 1. Population Distribution

Department or Autonomous Region*	Population	Approximate Area (km^2)
Boaco	136,949	4,244
Carazo	149,407	1,050
Chinandega	350,212	4,926
Chontales	144,635	6,378
Esteli	174,894	2,335
Granada	155,683	929
Jinotega	257,933	9,755
Leon	336,894	5,107
Madriz	107,567	1,602
Managua	1,093,760	3,672
Masaya	241,354	590
Matagalpa	383,776	8,523
Nueva Segovia	148,492	3,123
Rio San Juan	70,143	7,473
Rivas	140,432	2,155
Atlantico Norte*	192,716	32,159
Atlantico Sur*	272,252	27,407
Total	**4,357,099**	**121,428**

Source: National Census, 1995.

The population has historically been unevenly distributed across the country. Most of the population is concentrated in the Pacific lowlands, with the Caribbean lowlands sparsely populated. Nearly 60 percent of the population resides within the narrow confines of the Pacific lowlands, which constitutes only 15 percent of the country's land area. About 25 percent of the total population of the country is in Managua. The Caribbean lowlands, covering more than half of the national territory, holds less than 10 percent of the population. Overall, about 45 percent of Nicaragua's total population is rural.

Explosive population growth and rapid urbanization magnify many of Nicaragua's development problems. High birth rates strain the country's inadequate health and education systems, and the expanding population takes a heavy toll on the environment. Rapid urbanization requires expensive investment in transportation and sanitation infrastructures.[7,8,9,10]

C. Economy

The Nicaraguan economy, devastated during the 1980's by economic mismanagement and civil war, is beginning to rebound. Nicaragua began free market reforms in 1991 after 12 years of economic free-fall under the Sandinista regime. The economy began expanding in 1994, and economic growth rose sharply in 1995-97, due to surges in exports and efforts to enhance trade liberalization. Despite this growing economy, Nicaragua remains the second-poorest nation in the hemisphere with a per capita gross domestic product (GDP) of $438. Unemployment remains a pressing problem, with roughly half the country's work force unemployed or underemployed.

Nicaragua is primarily an agricultural country, and much of the potential for investment and growth is in this area. Agriculture employs about 45 percent of the work force. Production is heavily oriented toward export of coffee and cotton, which generate about half of total export revenues. Bananas, sugar, tobacco, sesame, rice, corn, and beef are also important export commodities. Agricultural production accounts for 26 percent of Nicaragua's GDP. The sector grew 15.4 percent in 1996, making agriculture one of the nation's most dynamic sectors. The government is placing great emphasis on agricultural reactivation. However, much of this emphasis for economic recovery is dependent on exploiting the abundant forest reserves, which in turn can cause irreparable environmental damage.

Rapid expansion of tourism has become the nation's third-largest source of foreign exchange.[11,12,13,14]

D. Flood Control and Flooding

Instituto Nicaragüense de Estudios Territoriales (INETER) is the agency that assumes responsibility for flood control. Currently, INETER is working with U.S. Geological Survey (USGS) and National Oceanic and Atmospheric Administration (NOAA) on an early warning system.[15]

Center for Coordination of Prevention of Natural Disasters in Central America (CEPREDENAC) was established in 1988 to initiate and promote regional cooperation in Central America for the prevention and alleviation of natural disasters encompassing earthquakes, volcanic eruptions, flooding, and landslides. Mathematical Modeling for Real-time Flood Forecasting and Flood Control in Central America is a project for forecasting and flood control. As part of the project, national flood centers are being established in each country in Central America. Computers and mathematical flood forecasting and river modeling package MIKE 11 are being installed at the flood centers. Flood modeling and forecasting systems are being established and tested on river basins in each country.[16]

Hurricane Mitch (1998) flooding costs to Nicaragua are estimated at $1.5 billion. As much as 40 inches of rain in a 3-day period fell on Nicaragua during that hurricane. Where there were no trees and minimal plant life to slow the rain runoff, sharp surges of water rushed off mountains and fields into rivers causing flooding and mudslides of unprecedented proportions. Deforestation plays several roles in the flooding equation, because trees prevent sediment runoff and forests hold and use more water than farms or grasslands. Deforestation has a second impact on flooding, which is the release of sediment. Vast amounts of eroded soil are washed into riverbeds, shrinking channels and the river's ability to carry water without flooding.[17,18]

E. Legislative Framework

Nicaragua does not have a comprehensive water policy. Numerous agencies and organizations share the responsibility for overseeing the water resources and supply. Fundamental problems with water resources and supply are a lack of water laws and regulations, and the lack of a sole encompassing water sector. A few environmental laws exist, but no water law. Congress has a water law under consideration that has not been passed yet. The General Environmental Law 217 states that the regulating entity is also the enforcing entity. Also, a decree, 3395, outlines the maximum concentration limits in materials for sewage disposal and prohibits certain materials altogether. However, no laws exist to control improper sewage disposal. Many of the agencies and organizations address specific areas relating to water. Ministerio del Ambiente y Recursos Naturales (MARENA) controls the water quality, and is in charge of ground water protection. The Ministerio de Fomento, Industria y Comercia (MIFIC) allows exploitation of water resources, and issues permits for water use. Instituto Nicaragüense de Acueductos y Alcantarillados (INAA) regulates Empresa Nicaragüense de Acueductos y Alcantarillados (ENACAL), which is the national government agency for water supply and sanitation services. ENACAL, created in 1998, established water well protection, and regulates the relief organizations and agencies that work throughout the country to provide water. The water resources division of INETER collects, processes, and publishes hydrological data, and assumes responsibility for flood control. The Nicaraguan Social Investment Fund (FISE) is a government organization that primarily provides funding for water projects. Law 290 is being developed which will define the water and other responsibilities for each of the institutions.

Cooperative for American Relief to Everywhere (CARE), U.S. Agency for International Development (USAID), Save the Children, Environmental Health Project (EHP), The Adventist Development and Relief Agency (ADRA) (a missionary group), Project Concern International, and Plan International Nicaragua are the major relief agencies working to provide water supply and sanitation services. CARE is the main relief organization working in water and sanitation, predominantly in the departments of Leon, Chinandego, Matagalpa, and Jinotega, in rural areas of 150 to 3,000 people. EHP is the new $12 million USAID water and sanitation project. USAID's new work in water and sanitation in Nicaragua is due to Hurricane Mitch. World Bank and Inter-American Development Bank (IDB) fund most of the water projects.

III. Current Uses of Water Resources

A. Water Supply and Distribution

Lack of water supply is a serious problem, although the country has an average annual rainfall of over 2,000 millimeters. The uneven distribution of rainfall and population, along with poor overall management of the available water resources, are the major causes of the water supply problem.

INAA regulates ENACAL, which is the national government agency for water supply and sanitation services. ENACAL also regulates the relief organizations and agencies that work throughout the country to provide water. The national coverage of water supply services provided by ENACAL is estimated to be 55 percent; urban coverage is about 77 percent and rural coverage is 31 percent.[19] However, according to the ENACAL 1997/1998 annual report, the total population with water service was estimated to be 63 percent, with 88 percent, coverage in urban areas and 33 percent in rural areas. The urban population with sewage service was estimated to be 32 percent.[20] About 42 percent of the water supply sources have insufficient quantity, principally during the dry season from November to April. During the dry season, supply is sometimes suspended for several days.[21]

About 73 percent of the water supply is from ground water sources.[22] Other sources estimate as much as 90 percent is from ground water. Due to the overall shortage of water, a small lagoon in Managua and Lake Nicaragua are being considered as additional sources of water for Managua.[23]

One critical water supply problem is the short life of many water wells. Many dry up within a few years of installation due to falling water levels. Hand pumps can pull water from a maximum of about 67 meters. This is a serious problem in areas of no power where water depths are great.[24]

The sources of water and number of systems are broken out by region in table 2 below.

Table 2. Water Sources and Systems by Region

Region	No. of Systems	Systems by Resource Type		
		Ground Water	Surface	Mixed
Pacific	82	74	4	4
Central	62	29	29	4
Atlantic	4	3	1	--
Total	**148**	**106**	**34**	**8**

Source: Instituto Nicaragüense de Estudios Territoriales, *Situacion de los Recursos Hidricos de Nicaragua Informe del Pais,* Managua, December 1991.

Dash indicates information is not available.

1. Domestic Uses and Needs

a. Urban Areas

Neglect and poor maintenance of water distribution systems create many problems, such as a fire that put 14 city wells out of service in June 2000 in Managua. More than an estimated 200,000 illegal connections exist in Managua, which consume about 40 percent of the city's water.

Managua depends on a mixed system composed of 83 drilled wells and the Laguna de Asososca, a crater lake.[25] However, Laguna de Asososca is used primarily as an emergency reservoir. Managua has a very sophistocated water distribution and storage system, as opposed to the very simple systems in the rural areas. Chlorination is the only method of water treatment. About 97 percent of the water supply in urban areas is chlorinated.[26]

There are 155 water distribution systems serving about 180 communities throughout the country, installed by ENACAL. This service is provided to about 2.5 million people. During 1997 and 1998, ENACAL constructed potable water services to 40 urban communities, 3 of which had no prior service. Also during this period, over 512 kilometers of distribution lines were installed, 24 new drilled water wells were constructed, 55 pumping stations were constructed or rehabilitated, and 39 water storage tanks were constructed.[27,28]

b. Rural Areas

ENACAL-DAR is the agency responsible for water supply to the rural areas. Water supply for rural areas is a big problem. Most wells are hand dug, up to 15 meters deep. Some are as large as 60 meters deep and 1.5 meters wide.[29] The distribution and storage systems in the rural areas are very simple. ENACAL donates water wells, but the communities are responsible for the maintenance, operation, and treatment of these wells. The rural systems are designed for each particular rural population center. About 60 percent of the funding for rural water systems comes from donors such as United Nations International Children's Fund (UNICEF) and other countries, with the remaining 40 percent coming from the Nicaraguan Government.

A large problem with supplying the rural population is the low-density population of about 8 people per square kilometer, making water supply very expensive per person. According to the 1995 census, 46 percent of the population of Nicaragua is rural.[30] ENACAL does not provide water and sanitation coverage in the country's eastern autonomous areas, known as Region Autonomista Atlantico Norte (R.A.A.N.) and Region Autonomista Atlantico Sur (R.A.A.S.).[31] These autonomous areas are very sparsely populated (see table 1).

2. Industrial, Commercial, and Agricultural Uses and Needs

Industrial and agricultural uses of ground water compared to ENACAL'S extraction for drinking water is very small, as depicted in table 3 below.

Table 3. Ground Water Use by Sector, 1991

Sector	Extraction (Mm^3)
INAA/ENACAL	98.01
Municipal	6.65
Industry	5.88
Agriculture	1.24
Total	**111.82**

Source: Japan International Cooperation Agency, *The Study on Water Supply Project in Managua, Summary*, Tokyo, Japan: Kokusai Kogyo Company, Ltd., September 1993.

The availability of water for irrigation in the foreseeable future is unlimited. Surface water can be used for irrigation on a large scale in the Pacific Region, having an approximate potential of 16,233 million cubic meters per year. This includes Lago de Nicaragua with a value on the order of 15,800 million cubic meters per year, the direct diversion of Rio Viejo of 100 million cubic meters per year, and three possible reservoirs for irrigation of 100 million cubic meters per year. A countrywide total of 17,196 million cubic meters per year is estimated to be available from ground water for irrigation.

In the Pacific Region, about 30 percent of the ground water potential and 15 percent of the exploitable surface water is used. The major part of the captured water (ground water and surface water) is used for irrigating 75,000 hectares, with the domestic and industrial use being very minor in comparison.[32]

The following are estimates of irrigation efficiency:

- Pivot or sprinkling irrigation systems = 70 percent;
- Gravity-fed irrigation systems = 57 percent; and
- Rice irrigation = 70 percent.

The following are estimates of distribution efficiency:

- Ground water irrigation = 90 percent; and
- Surface water irrigation = 60 percent.

Table 4 displays the global efficiency by irrigation method and water source.

Table 4. Estimated Irrigation Efficiencies by Type and Water Source		
System	**Water Source**	**Efficiency**
Sprinkler/Pivot	Ground water	63%
Gravity-fed	Ground water	51%
Rice	Ground water	63%
Sprinkler/Pivot	Surface water	42%
Gravity-fed	Surface water	34%
Rice	Surface water	42%

Source: Ministerio del Ambiente y Recursos Naturales, *Plan de Accion de los Recursos Hidricos en Nicaragua*, "Evaluacion Rapida de los Recursos Hidricos, Anexo B, Calidad de Agua Informacion Adicional," Managua, No date.

The efficiencies listed above are for systems in good working order. Actual efficiencies may be reduced due to the deterioration of many sprinkler and pivot systems, a lack of leveling in gravity-fed systems, and lack of technical assistance and training in maintaining the systems. The efficiency of rice irrigation is high due to the permeability of the soils. The overall global efficiency of irrigation systems in the country is estimated at less than 20 percent.

B. Hydropower

Empresa Nicaragüense de Electricidad (ENEL) is responsible for the generation, transmission, and distribution of energy to Nicaragua. ENEL is in the process of being privatized. In 1998 hydroelectric power provided 35 percent of the country's electricity. There are two large hydropower plants and several smaller plants in the country. A large hydroelectric plant was completed at Asturias in 1989, and another large hydroelectric plant was completed in 1994. These two dams suffered extensive damage due to Hurricane Mitch (1998). Geothermal sources have the greatest potential for producing the country's energy needs. Currently, most power is from fossil-fueled thermal plants. According to the 1999 International Journal on Hydropower and Dams, Nicaragua is planning two new hydro projects, with capacities of 20 and 25 megawatts. [33,34,35,36,37,38,39]

C. Stream Gage Network

INETER is the agency responsible for the collection of water data. However, NOAA and USGS are the only entities currently installing stream gages. The World Bank is working with NOAA and USGS on site selection for additional sites. The hydrological network includes hydrographic monitoring, real time monitoring, and flood forecasting in selected watersheds via a satellite-based system. In 1992,15 stations were monitored; in 1997, 54 stations were monitored; and in 1998, 37 stations were monitored, with 27 stations destroyed in 1998 during Hurricane Mitch. In 1999, 42 stations were monitored, and in 2000, 49 stations were monitored. Of the 49 stations being monitored to date, 5 are satellite based.[40,41,42]

D. Waterway Transportation

The country has 2,220 kilometers of inland waterways. Included are two large lakes--Lago de Managua and Lago de Nicaragua--and six seaports with three on the Pacific coast and three on the Atlantic coast. The seaports are operated by the government-run port authority, Empresa Nacional de Puertas (ENAP). The most suitable for commercial shipping is the Port of Corinto on the Pacific coast, 177 kilometers northwest of Managua. Two other seaports are on the

Pacific coast, and three are on the Atlantic coast. Due to poor infrastructure and high operating expenses, most containerized sea cargo and fresh fruit are shipped by highway to and from Puerto Limon in Costa Rica and Puerto Cortes in Honduras.[43,44]

Since the late 19th century, Nicaragua has been noted as suitable for construction of an interoceanic canal. For various political and other reasons, the Panama Canal route was chosen over the Nicaragua Canal route. Because of the numerous potential problems with the Panama Canal, the Nicaragua Canal is again under consideration. A substantial part would utilize the San Juan River and the huge inland Lake Nicaragua and require only 19 kilometers of new canal. This would realize a drastic change in shipping. The routes between east and west coast ports would be shortened by 845 kilometers, a full day or more in sailing time. Much larger ships could be accommodated in the Nicaragua Canal as opposed to the Panama Canal. The largest barrier to the Nicaragua Canal plan is the cost.[45]

Rivers are the main avenue for transportation in the Caribbean region. The journey from Managua to Bluefields involves a 5-hour boat trip down the Rio Escondido. The San Juan River in the south, near and along the border with Costa Rica, is navigable from Lago de Nicaragua at San Carlos to the Caribbean, at San Juan del Norte.[46] Rio Prinzapolka is also navigable, and natives use Rio Coco for minor transportation of crops, etc.[47]

E. Recreation

Tourism was the country's third most important source of foreign exchange in 1996. The industry offers good opportunities for foreign investment, especially in ecotourism and beach-related projects.[48] Due to the diversity of its resources, much of which is related to water, Nicaragua has great tourism potential. There are beaches on the Atlantic and Pacific coasts, lakes and lagoons, and islands in the Caribbean. Lago de Nicaragua, with 8,157 square kilometers of area, is the largest lake in Central America. It shelters a total of 500 small tropical islets, which are not only natural shelters to orchids and tropical birds but rich in archeological heritage. The lake supports unusual fish, including the world's only freshwater sharks. Many other areas in the country, such as Isla de Ometepe, Rio San Juan, and Isla del Maiz Pequeña, have great potential for ecotouristic development.

In the Caribbean, Isla del Maiz offers one of the best rest retreats and has the potential for sailing, sports fishing, scuba diving, and resort living. Assets include clear turquoise water, white sandy beaches fringed with coconut palms, and coral reefs. On the Caribbean coast, Bluefields is the only part usually visited by travelers. Boats are the only way to get to some places, notably on the Caribbean coast and on Lago de Nicaragua.[49,50] The Caribbean coast has 450 kilometers of beaches. Rivers are the main method of transportation in this region.[51]

The Pacific beaches extend 305 kilometers from the Golfo de Fonseca at the border with Honduras to the border with Costa Rica in the south. Pochomil, an hour from Managua, is a popular vacation area on a beautiful bay. San Juan del Sur, near Costa Rica, also has a beautiful bay, and serves as a cruise port. The waters in this bay abound in blue marlins, swordfish, and many other species. La Flor and Chacocente beaches, near San Juan del Sur, are protected wildlife refuges where sea turtles arrive to lay their eggs.[52]

IV. Existing Water Resources

A. Surface Water Resources

Nicaragua has abundant surface water resources. However, these resources are highly seasonal and unequally distributed. The eastern half of the country is composed primarily of the two autonomous regions, R.A.A.N. and R.A.A.S. This half of the country has an overabundance of surface water. The major streams are the main sources of surface water. Along the Caribbean coast, brackish to saline water exists in coastal lagoons and estuaries. Tidal effects extend several kilometers inland. However, in the western half of Nicaragua, where about 90 percent of the country's population lives, the availability of surface water is highly seasonal. Most of the streams in this half of the country become dry during the low flow season from December through April. Recent droughts have further impacted the availability of surface water. Only Lago de Nicaragua and Lago de Managua are reliable year-round. Sources of brackish to saline water exist in the Estero Real estuary and in marshes along the Pacific coast.

Environmental problems associated with the rivers include the following:

- Contamination by pesticides and agrochemicals in areas of intensive farming (where the main crops are coffee, bananas, vegetables, and other crops);
- Discharge of wastewater from cities and populated areas;
- Discharge of wastes, including mercury and cyanide, from mining areas; and
- Accelerated erosion caused by deforestation.

Access to surface water resources is generally difficult in much of the country because of rough mountainous terrain and dense vegetation.

Surface water flows into both the Caribbean Sea (Atlantic Ocean) and the Pacific Ocean. About 90 percent of Nicaragua's surface area drains into the Caribbean Sea, and the rest drains into the Pacific Ocean. About 96 percent of the annual surface water discharge enters the Caribbean Sea, and the rest discharges into the Pacific Ocean.[53] For the purposes of this study, Nicaragua has been divided into three drainage regions--the Caribbean Coast drainage region, the Rio San Juan drainage region, and the Pacific Coast drainage region. Each region contains several drainage basins.

Throughout the Caribbean Coast drainage region, perennial surface water is generally available from streams, lakes, marshes, and swamps. These sources are numerous and closely spaced. The large amount of rain, associated with the wet tropical climate, provides an overabundance of surface water. In the Rio San Juan drainage region, surface water from streams is generally seasonally available. Most of the streams are intermittent and become dry during the low flow season, generally from December through April. The major exception is the Rio San Juan, which is perennial. The prominent sources of available perennial surface water are the great lakes, Lago de Nicaragua and Lago de Managua. These lakes cover almost 10 percent of Nicaragua's total land area and dominate the central part of the country. In the Pacific Coast drainage region, surface water is generally only seasonally available. In the northern part of this drainage region, most of the larger streams are perennial; in the southern part, most streams are intermittent and stop flowing during the low flow season from December through April.

1. Precipitation and climate

Rainfall in Nicaragua is unequally distributed and fluctuates seasonally, regionally, and annually (see figure 3). The northeastern part of the country, primarily the Region Autonomista Atlantico Norte, receives between 2,000 and 3,000 millimeters of rainfall per year. The southeastern part of the country, primarily the Region Autonomista Atlantico Sur, receives between 3,000 and 6,000 millimeters of rainfall per year. The wet season for these regions lasts from mid-May through February, with only a short dry season that lasts from early March to early May. The extreme southeastern part of the country generally has a dry season that lasts only about a month. In the central part of Nicaragua, precipitation averages less than 1,500 millimeters per year. Managua, the capital city, averages about 1,200 millimeters of rain a year. The wet season is generally from May through October, and the dry season is generally from December to April. In most years, little to no rain occurs during March and April. This almost total lack of rain can last several months. Along the Pacific Coast region, average annual rainfall is between 1,250 and 2,500 millimeters. The northern part of the coast averages about 2,000 millimeters of rainfall a year, while the southern part of the coast averages about 1,500 millimeters of rain. Along the Pacific Coast region, the wet season generally lasts from May through November, and the dry season generally lasts from December to April. In some years, this region has little to no rain for several months. The central and western parts of Nicaragua are also subject to severe droughts, even during the normal wet season.[54]

Nicaragua's climate is tropical in the lowlands and cooler in the highlands. Temperature differential is minimal from season to season. The annual mean temperature in the coastal areas is 26 °C with minimal temperature variations. In the higher elevations of the interior, temperatures average 25 °C for a mean daily high and 16 °C for a mean daily low. Humidity is high year-round, usually from 70 to 90 percent. Winds blow from the northeast. These winds are cool on the high plateau and warm and humid in the lowlands.

Nicaragua is subject to occasional destructive earthquakes, hurricanes, volcanic eruptions, and flooding with mudslides. Tropical storms and hurricanes strike along the Caribbean coast annually from July through November, producing strong winds, rain, and flooding.

2. Drainage Regions

a. Caribbean Coast

The Caribbean Coast drainage region is the largest drainage region in Nicaragua. It includes an area of about 85,600 square kilometers or about 65 percent of the country. The drainage region includes all of the Departments of Jinotega, Madriz, and Nueva Segovia, and the Regions of Autonomista Atlantico Norte and Autonomista Atlantico Sur. It also includes most of the Departments of Esteli and Matagalpa and parts of the Departments of Boaco and Chontales.

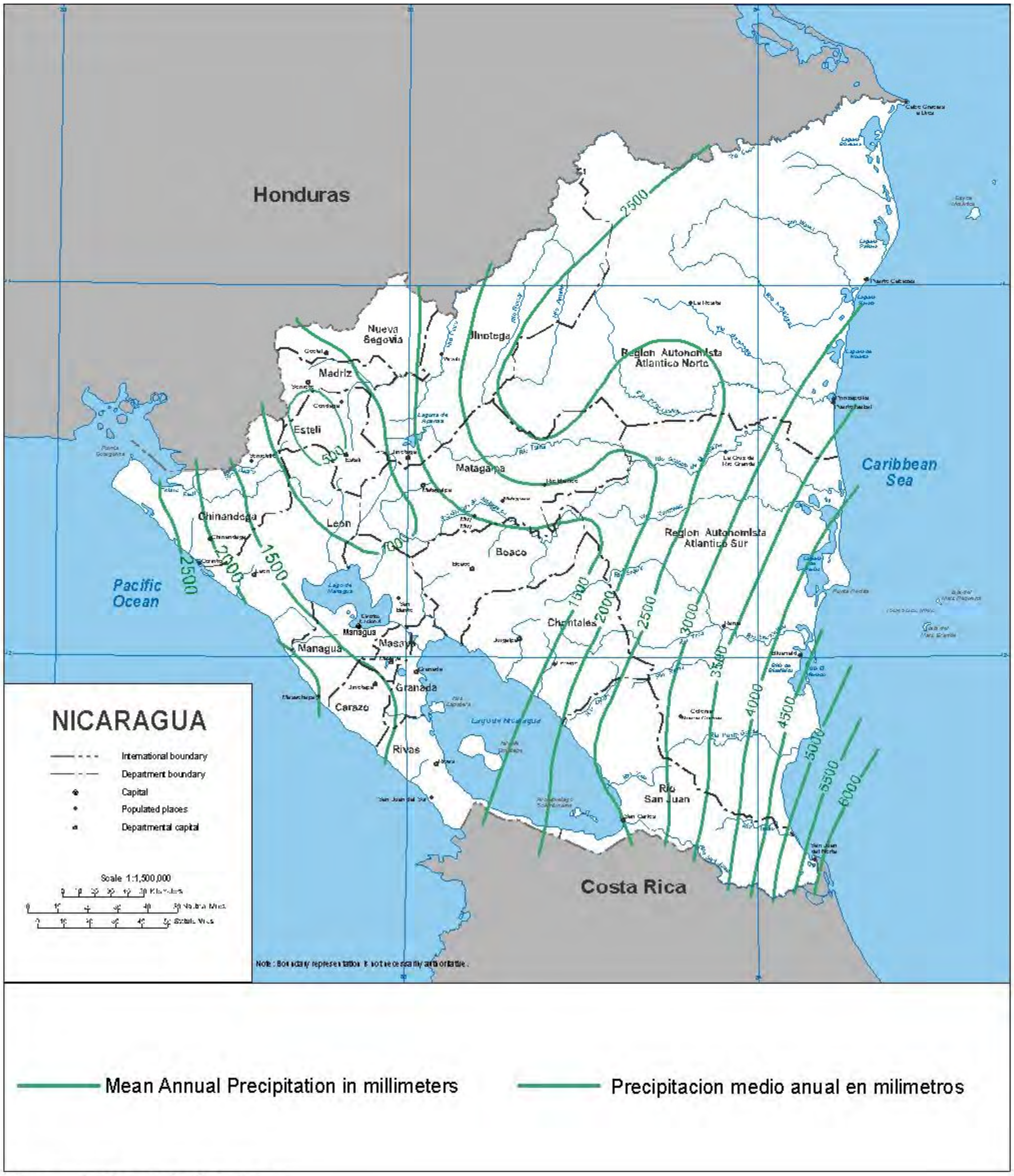

Figure 3. Precipitation Map

Source: Agency for International Development, Regional Office for Central America and Panama. *Nicaragua, National Inventory of Physical Resources*. AID/EIC GIPR No. 6, Section T-7, Washington, DC, November 1966, Section T-7, p. 5.

The major streams of the Caribbean Coast drainage region from north to south are as follows:

- Rio Coco and its tributaries, which are Rio Bocay, Rio Esteli, and Rio Amaka;
- Rio Wawa;
- Rio Kukalaya;
- Rio Bambana;
- Rio Prinzapolka;
- Rio Grande de Matagalpa and its main tributary, Rio Tuma;
- Rio Kurinwas;
- Rio Escondido and its system, which includes Rio Siquia, Rio Mico, and Rio Rama;
- Rio Punta Gorda; and
- Rio Indio.

Most of these streams originate in the mountains of north-central or central Nicaragua. In their upper and middle reaches, these steams primarily flow across volcanic rocks in steep, rocky, incised valleys with numerous rapids and falls.

Records from various periods between 1971 to 1979 are available for the gaging stations on the upper reaches of the major streams. During that period, the gaging station on the Rio Coco at Guana had a minimum flow of 3.75 cubic meters per second, a maximum flow of 798 cubic meters per second, and an average flow of 48.4 cubic meters per second. The gaging station on the Rio Tuma at Yasica had a minimum flow of 1.42 cubic meters per second, a maximum flow of 1,305 cubic meters per second, and an average flow of 19.3 cubic meters per second. The gaging station on the Rio Grande de Matagalpa at Ciudad Dario had a minimum of no recordable flow, a maximum flow of 310 cubic meters per second, and an average flow of 3.78 cubic meters per second.[55] In their lower reaches, these streams meander across the broad, low-lying, densely forested, alluvial coastal plain. Near their mouths, many streams flow through vast wetland areas in braided channels before emptying into one of the coastal lagoons. Only a couple of gaging stations exist on the middle and lower reaches of these streams. Maximum flows are 2,730 cubic meters per second for the Rio Coco at Correinte Lira; 1,030 cubic meters per second for the Rio Bocay at Uruskirna; 7,850 cubic meters per second for the Rio Grande de Matagalpa at San Pedro del Norte; 439 cubic meters per second for the Rio Siquia at Salto Grande; and 1,490 cubic meters per second or the Rio Mico at Muelle de Los Bueyes.[56]

Flood peaks for the Rio Coco produce depths between 12 and 15 meters. (Normal stream depths are about 2 meters).[57] The low flow season for the Caribbean Coast drainage region is typically from early March to early May. In the extreme southeast, the low flow season lasts only about a month. The high flow season is typically from mid-May through February. Peak flows are generally during July through October. The region is subject to severe flooding.

Access is generally very limited. In the mountains of north-central Nicaragua, access is very difficult due to rugged terrain, steep gradients, deep gorges, and the lack of all-weather roads. In the coastal lowlands, the thick dense tropical forest, the vast wetlands, and the extremely sparse road network make access very difficult. Most roads become almost impassable during the wet season. Even during dry weather, access to potential water points is generally only feasible along the few roads.

b. Rio San Juan

The Rio San Juan drainage region includes an area of about 36,100 kilometers or about 27 percent of the country. This drainage region includes essentially all of the Departments of Granada, Masaya, and Rio San Juan, and parts of the Departments of Boaco, Carazo, Chontales, Esteli, Leon, Managua, and Matagalpa. From north to south, the major streams of this drainage region include the following:

- Rio Sincecapa;
- Rio Grande (Rio Viejo);
- Rio Pacora;
- Rio Tipitapa;
- Rio Malacatoya;
- Rio Mayales;
- Rio Ochomogo;
- Rio Acoyapa;
- Rio Oyate;
- Rio Tule; and
- Rio San Juan.

The region also includes the great lakes, Lago de Nicaragua (Lago Cocibolca) and Lago de Managua (Lago Xolotlan). Also included are several smaller lakes in the caldera of volcanoes, such as Laguna de Asososca and Laguna de Masaya.

Most streams flow from the north-central or central mountains into either Lago de Managua or Lago de Nicaragua. The Rio Ochomogo is the only major stream to enter the lakes from the western mountains. The streams flow across volcanic rocks in rough, rocky, incised valleys before a short run across the flat alluvial valley to the lakes.

Records from various periods between 1971 and 1979 are available for the gaging stations on some of the streams within this drainage region. During that period, the gaging station on the River Grande (Rio Viejo) at Santa Barbara had a minimum of no recordable flow, a maximum flow of 535 cubic meters per second, and an average flow of 6.24 cubic meters per second. The gaging station on the Rio Malacatoya at Las Banderas had a minimum of no recordable flow, a maximum flow of 782 cubic meters per second, and an average flow of 4.44 cubic meters per second.[58] Maximum flows are 501 cubic meters per second for the Rio Sinecapa at El Jicaral; 389 cubic meters per second for the Rio Grande (Rio Viejo) at Las Brisas; 111 cubic meters per second for the Rio Pacora at Pacora; 114 cubic meters per second for the Rio Mayales at El Jicaral; 54.6 cubic meters per second for the Rio Ochomogo at Las Enramadas; and is 39.2 cubic meters per second for the Rio Acoyapa at Santa Rosa.[59,60]

The Rio Tipitapa meanders across the valley floor between the great lakes, allowing water to flow from Lago de Managua to Lago de Nicaragua. For most of the year, the Rio Tipitapa is stagnate with little flow, because it only receives inflow from Lago de Managua when the lake level is above 40.73 meters above mean sea level. A brackish water marsh has developed near the mouth of the stream. The source for the Rio San Juan is the Lago de Nicaragua. The Rio San Juan meanders in a narrow valley through a variety of igneous and sedimentary rocks. Below El Castillo de la Concepcion is a series of rapids and falls. A gaging station on the Rio San Juan at El Castillo de la Concepcion has had a minimum flow of 21.5 cubic meters per second, a maximum flow of 1,950 cubic meters per second, and an average flow of 76 cubic meters per second. No gaging station data are available near the mouth of the Rio San Juan. However, an 1898 study estimated the maximum flow at the mouth of the Rio San Juan to be about 8,700 cubic meters per second.[61] A recent study indicates the maximum flow at the mouth of the Rio San Juan could reach as high as 11,000 cubic meters per second during heavy tropical storms.[62] The high flow season for most of the Rio San Juan drainage region is from May through November. Because of the increased rainfall in the southeastern part of the drainage region, the high flow season for the Rio San Juan is from May through January with peak flow occurring from June through October. The Rio San Juan is subject to severe flooding. The low water season for the Rio San Juan drainage region is typically from December through

April with streams reaching their minimum flow during April. Most streams are completely dry for many days during the low flow season.

Access is generally limited. In the mountains of north-central and central Nicaragua, access is very difficult due to rugged terrain, steep gradients, deep gorges, and lack of all-weather roads. Most roads become almost impassable during the wet season. In the lower elevations and near the great lakes, access is generally manageable. However, locally, access may be difficult because of rugged terrain, wet marshy ground, and lack of roads. Access along Rio San Juan is very difficult because of rugged terrain, steep gradients, dense forests, and lack of roads.

c. Pacific Coast

The Pacific Coast drainage region, the smallest drainage region in Nicaragua, includes an area of about 10,900 square kilometers or about 8 percent of the country. The drainage region includes all of the Department of Chinadega and parts of the Departments of Carazo, Leon, Managua, and Rivas. From north to south, the major streams of the drainage region include the following:

- Rio Negro;
- Estero Real;
- Rio Villa Nueva;
- Rio Viejo;
- Rio Atoya;
- Rio Telica;
- Rio San Cristobal;
- Rio Tamarindo;
- Rio Soledad;
- Rio San Diego;
- Rio Escalante;
- Rio Grande;
- Rio Tular;
- Rio Tecolapa; and
- Rio Brito.

Rio Negro, Rio Villa Nueva, and Estero Real originate in the north-central mountains and the central rift valley and empty into the Golfo de Fonseca. In their upper reaches, these streams flow through volcanic rocks in rough, rocky valleys before meandering across the alluvial sediments of the rift valley floor. A large saltwater estuary with extensive mudbanks has developed at the mouths of these streams. The other streams flow from the western mountains directly into the Pacific Ocean. In their very short upper reaches, these streams flow through a variety of volcanic and sedimentary rocks. They then quickly descend onto the narrow coastal plain before emptying into the Pacific Ocean through small branching estuaries.

Records from various periods from 1971 to 1979 are available for the few gaging stations that exist in this drainage region. The gaging station on Rio Tamarindo at El Tamarindo had minimum of 0.13 cubic meters per second, a maximum flow of 767 cubic meters per second, and an average flow of 3.34 cubic meters per second.[63] Maximum flows are 3,220 cubic meters per second for Rio Negro at La Canoa; 1,620 cubic meters per second for Rio Villa Nueva at a bridge; 38.8 cubic meters per second for Rio Atoya at Ceilan; 37.5 cubic meters per second for Rio San Cristobal at La Gallina; 240 cubic meters per second for Rio Soledad at El Cantrabando; and 272 cubic meters per second for Rio Brito at Miramar.[64,65] The high flow season for the Pacific Coast drainage region is typically from May through November. Peak flows generally occur during July through October. During the high flow season, the marshes and swamps along the coast and the Estero Real (an estuary) increase in area. The region is subject to severe flash flooding. The low flow season is typically from December to April. Most streams are completely dry for many days during the low flow season.

Access is generally manageable. However, locally, access may be difficult because of rugged terrain, wet marshy ground, and lack of roads. Access along the Estero Real is very difficult because of wet marshy ground, heavy vegetation, and lack of roads.

3. Lakes, Reservoirs, Swamps, and Lagoons

The Caribbean Coast drainage region contains several coastal lagoons. These lagoons include the Laguna Bismuna (Lago Wani), Laguna Pahara, Laguna Karata, Laguna de Wounta, and Laguna de Perlas. These lagoons are tidally influenced and generally brackish. During the height of the high flow season, the volumes of fresh water entering the lagoons from the large streams flush the brackish water out of the lagoons, causing them to become temporarily fresh. The drainage region also includes the country's largest manmade reservoir, Laguna de Apanas. This reservoir, with a surface area of about 51 square kilometers, was constructed for hydroelectric purposes on the Rio Tuma. Access to the coastal lagoons of the Caribbean Coastal drainage region is very difficult, because of the thick dense tropical forest, the vast wetlands, and the extremely sparse road network. Most roads become almost impassable during the wet season. Even during dry weather, access to potential water points is generally only feasible along the few roads.

The great lakes of Nicaragua--Lago de Managua (Lago Xolotlan) and Lago de Nicaragua (Lago Cocibolca)--dominate the Rio San Juan drainage region. These lakes cover almost 10 percent of the surface area of Nicaragua. Other important lakes in this drainage region include Laguna de Apoyeque, Laguna de Apoyo, Laguna de Asososca, Laguna de Jiloa, and Laguna de Masaya.

Lago de Managua has a surface area of about 1,016 square kilometers, a mean depth of 7.8 meters, and a maximum depth of 26 meters. The estimated average volume of Lago de Managua is 7,970 million cubic meters. The normal elevation of Lago de Managua is about 39 meters above mean sea level. Maximum elevation is 43.44 meters above mean sea level, and minimum elevation is 35.6 meters above mean sea level.[66] The lake receives water from Rio Maderas, Rio Pacora, Rio Sinecapa, and Rio Grande (also Rio Viejo). Lago de Managua has average total dissolved solids of about 900 milligrams per liter. Water entering the lake from the surrounding steams has total dissolved solids of about 400 milligrams per liter. During the low flow season, Lago de Managua can become temporarily brackish with total dissolved solids greater than 1,200 milligrams per liter. Lago de Managua is of special concern because it is severely polluted. Inadequate wastewater treatment allows the improperly treated sewage from the 1 million people who live along the shore to pour into the lake. About 300 industries discharge their untreated chemical wastes into the lake. These wastes include phenols, benzene, carbon tetrachloride, methylene chloride, mercury, lead, cyanide, and other heavy metals. Agrochemicals including pesticides, herbicides, and fertilizer and other agricultural runoff freely flow into the streams that empty into the lake. Sediments that are mostly fine particles and rich in organic matter also enter the lake. Due to the level of pollution, the waters from Lago de Managua are not adequate for human consumption or irrigation. Since little water flows out of Lago de Managua, the contaminants are concentrated in the lake.[67] In 1974 the lake's average total dissolved solids were increasing at a rate of 18 milligrams per year. At that rate, in a hundred years the average total dissolved solids for the lake will be 3,000 milligrams per liter. Although Rio Tipitapa flows from Lago de Managua to Lago de Nicaragua, it rarely receives water from Lago de Managua. Since 1954 Rio Tipitapa has received water from Lago de Managua in only 3 years.

Lago de Nicaragua has a surface area of about 8,157 square kilometers, a mean depth of 13.2 meters, and a maximum depth of 60 meters. The estimated average volume of Lago de Nicaragua is 108,000 million cubic meters.[68] The normal elevation of Lago de Nicaragua is between 31 and 32 meters above mean sea level. The level varies with the season. Maximum elevation is 33.13 meters above mean sea level. Minimum elevation is 30.73 meters above mean sea level.[69] The lake receives water from many streams including Rio Acoyapa, Rio Malacatoya, Rio Mayales, Rio Ochomogo, Rio Oyate, Rio Tipitapa, and Rio Tule. Lago de Nicaragua has average total dissolved solids of between 150 and 175 milligrams per liter.[70] Currently, the waters of the lake do not present limitations for human consumption or irrigation. However, several situations could affect the quality of Lago de Nicaragua. The impact of the heavily contaminated water entering the lake from Lago de Managua is unknown. Growth of cities and the increased use of agrochemicals in the lake's drainage basin are gradually contaminating the lake. Lago de Nicaragua drains into the Caribbean Sea through Rio San Juan.

Several important lakes are in the volcanic calderas within the Rio San Juan drainage region. These volcanic lakes include Laguna de Apoyeque, Laguna de Apoyo, Laguna de Asososca, Laguna de Jiloa, and Laguna de Masaya. Laguna de Asososca and Laguna de Masaya contain fresh water with total dissolved solids ranging from 235 to 378 milligrams per liter. Laguna de Asososca, with only a surface of about 0.8 square kilometer, is important because it is a source of water for the city of Managua.

In the Rio San Juan drainage region, access to the great lakes is generally manageable. However, locally, access may be difficult because of rugged terrain, wet marshy ground, and lack of roads. Access to the volcanic lake is generally difficult because of rugged terrain and lack of roads.

No significant lakes exist in the Pacific Coast drainage region.

See table C-1 and figure C-1 for further details on surface water resources.

4. Deforestation

Deforestation is a major environmental problem that is adversely affecting the surface and ground water resources in Nicaragua. Central America had the second highest deforestation rate (1.5 percent) in the world during the 1980's.[71] Nicaragua has a very high rate of deforestation, estimated at about 150,000 hectares of forest per year.[72] Both the commercial sector and individual citizens contribute to deforestation.

The removal of trees and vegetation allow for increased and faster runoff of rainfall. The faster runoff causes a rapid increase in the amount of water entering the stream, resulting in water levels that rise faster with larger peak discharges. The impact is worst immediately after logging, particularly in smaller watersheds. Then for the first 3 or 4 years, runoff and erosion are greatly increased. These occurrences also cause less rainwater to infiltrate into the soil to recharge the aquifers. Deforestation has also been associated with changes in rainfall patterns.

Deforestation, combined with the heavy agricultural activity on marginal farmlands, accelerates soil erosion. This erosion increases the volume of sediment carried by the streams and degrades the water quality of the upland and downstream areas. All streams have high sediment loads due to erosion in the upper parts of the basins. Soil from eroded slopes clogs streams, drainage channels, impoundments, and water systems, resulting in higher operation and maintenance costs. As the erosion increases, the river regime becomes steeper, which increases the amount of runoff and decreases the amount of infiltration. The flow regime and total river discharge may be permanently altered. Rate, volume, and sediment loads may complicate forestry, agriculture, and downstream activities. With each passing year, the rivers and streams flow more erratically and seasonally in torrents and less like stable, permanent rivers. Therefore, surface water use as a water supply for the increasing population is continuously decreasing, and less water is available when it is needed during the dry season. For all areas, current river discharges are probably larger than historical figures, since evapotranspiration and infiltration losses are less with lower vegetation density, resulting in higher runoff. More than 40 percent of the land in Nicaragua has been affected by the resulting changes in hydrology, soils, and biology.[73]

The major causes of deforestation are logging and clearing of the land for ranching. Deforestation is a social and economic problem. For generations, the population has practiced a slash-and-burn method of agriculture. Conservation is not part of the culture. Rural areas do not have access to electricity for cooking or the means to pay for alternate sources of fuel. Therefore, citizens contribute to deforestation by cutting down trees to burn for domestic needs.

Decades of land abuse and environmental neglect, with deforestation playing a major role, exacerbated the devastation of Hurricane Mitch in 1998. Where there was no tree cover and little plant life to slow the runoff, the rain during that hurricane (as much as 40 inches in 3 days) caused sharp surges of water to rush off mountains and fields into the rivers. The results were flooding and mudslides of unprecedented proportions.[74]

The former Nicaraguan Institute for Natural Resources and Environment, created in the 1980's, established the Bosawas nature preserve. This preserve encompasses about 14,000 square kilometers in northern Nicaragua, making it Central America's largest protected natural area. In the 1990's another protected area was established in southeast Nicaragua. It is the Indio-Maiz Biological Reserve, between the San Juan and Punta Gorda rivers, which encompasses about 4,500 square kilometers. Nicaragua became the largest holder of forest reserves in Central America. However, the rain forests continued to be cut at an accelerated rate during the 1990's. In comparison, Nicaragua's tropical forests were still less than 1 percent the size of the South American Amazon rain forest of Brazil. However, the Nicaraguan rain forests were disappearing at a rate 10 times faster than that of the Amazon. One cause was the illegal logging and exporting of mahogany, which still occurs in the Bosawas region.[75,76,77]

In 1992 the Government passed the plan of Forest Action with the objectives of increasing forest production while guaranteeing the sustainability of the resource, increasing the supply of wood for national consumption and exportation, and conserving a source of wood for energy.[78] In April 1998, the president announced that there would be no logging of mahogany, cedar, and pochote for the next 5 years as a result of the comptroller general's outraged response to the region's deforestation and the Ministry of Environment and Natural Resources' lack of action.

B. Ground Water Resources

The ground water resources are used in all sectors of the economy. About 90 percent of the water production is from wells. Variations in the geological structures, geomorphology, rock types, and precipitation contribute to the widely varying ground water conditions in different parts of the country. The most productive sources of ground water are in the Quaternary age alluvial aquifers, which are interbedded with pyroclastic materials, and the Tertiary to Quaternary age volcanic deposits, which consist of basalt and andesite lava flows, pyroclastic flows, and fall deposits. Springs issuing along fracture and contact zones yield enormous quantities of water. These sources are in the northwest Pacific Lowlands, in the Nicaraguan Depression with the interior Lago Managua and Lago Nicaragua, and in the area up to 100 kilometers inland of the Caribbean coast. Throughout the rest of the country, especially in the Interior Highlands, ground water conditions are generally unfavorable due to the geologic formations that have low primary permeability and porosity. Development of the ground water resources is difficult due to contamination of the shallow ground water near settlements, saltwater intrusion in areas along the Pacific and Caribbean coasts, and poor access to sites due to dense vegetation, steep slopes, and lack of an established road network.[79] Deforestation has a negative impact on the ground water resources of the country by reducing the amount of water that recharges the aquifers, resulting in lower ground water levels. Most hand pumps cannot produce water from depths greater than 90 meters.

Water from springs and wells is used for agricultural, industrial, public, and private purposes. In the arid areas, ground water is important for agricultural needs as well as for water supply, livestock, and domestic purposes. The capital city of Managua depends upon a mixed system of 83 drilled wells and the Asososca crater lake. Fresh ground water is generally available throughout the country in varying quantities year-round.[80]

Ground water is generally plentiful from alluvial aquifers interbedded with pyroclastic deposits throughout the Nicaraguan Depression and the Pacific and Caribbean coasts. However, in the mountainous areas, the availability of fresh ground water varies considerably from locally plentiful to unsuitable. The most productive sources of ground water are in the Quaternary age alluvial aquifers, which are interbedded with pyroclastic materials, and in the Tertiary to Quaternary age volcanic deposits, which consist of basalt and andesite lava flows, pyroclastic flows, and fall deposits. Springs issuing from fracture and contact zones within the volcanic deposits yield enormous quantities of water. These sources are in the northwest Pacific Lowlands, in the Nicaraguan Depression, and in the Caribbean coast. Throughout the rest of the country, ground water conditions are generally unfavorable due to the geological formations that have little or no primary permeability resulting in the lack of ground water. The mountains and hills contain many types of aquifers, including low permeability igneous, metamorphic, and sedimentary rocks. In the Interior Highlands and scattered parts of the Pacific Lowlands, Tertiary and Cretaceous age sedimentary aquifers are low yielding. Tertiary to Quaternary age volcanic rocks in the Interior Highlands are poor aquifers, except where weathering and fracturing have enhanced the permeability. Paleozoic age metamorphic and igneous aquifers in the northwestern Interior Highlands are practically impermeable. They have unsuitable to meager yields, except locally where fractures have enhanced the permeability and porosity. The alluvial plains, the lowlands, and the Nicaraguan Depression make up about 55 percent of the country but contain about 80 percent of the available ground water reserves.[81] See table C-2 and figure C-2, map units 1 and 2 for further details.

The alluvial areas (map unit 1) make up about 35 percent of the country and contain about 50 percent of the available ground water reserves. Areas containing volcanic deposits of basaltic to andesitic pyroclastic deposits and basaltic lava flows (map unit 2) make up about 20 percent of the country and contain about 35 percent of the available ground water reserves. Aquifers with poor permeability (map units 3, 4, and 5) make up about 45 percent of the country and contain about 15 percent of the available ground water reserves.

The ground water resources are difficult to develop. Although ground water is generally safer than untreated surface water supplies, many shallow aquifers are biologically contaminated near populated areas, primarily due to improper waste disposal. Chemical contamination by industrial products occurs in and around Managua. Contamination of the shallow ground water by pesticides occurs in the agricultural areas of the Nicaraguan Depression and Pacific Lowlands. Saltwater intrusion can be a problem in areas along the Pacific and Caribbean coasts. Accessibility to drilling sites is difficult in many areas due to dense forests and the steep slopes of volcanoes, hills, and mountains. Wells in all areas should be cased and screened, especially where aquifers are composed of unconsolidated sediments or volcanic ash.[82]

1. Aquifer Definition and Characteristics

To understand how ground water hydrology works and where the most likely sources of water may be located, a short aquifer definition and aquifer characteristics are presented and followed by specific country attributes.

Ground water supplies are developed from geologic formations that qualify as aquifers. An aquifer is made up of saturated beds or formations, either individual or in groups that yield water in sufficient quantities to be economically useful. To qualify as an aquifer, a geologic formation must contain pores or open spaces (interstices) that are filled with water, and these interstices must be large enough to transmit water toward wells at a useful rate. An aquifer may be imagined as a huge natural reservoir or system of reservoirs in rock whose capacity is the total volume of interstices that are filled with water. Ground water may be found in one continuous body or in several distinct rock or sediment layers within the borehole, at any one location. It exists in many types of geologic environments, such as intergrain pores in unconsolidated sand and gravel, cooling fractures in basalts, solutions cavities in limestone, and systematic joints and fractures in metamorphic and igneous rock. Unfortunately, rock masses are rarely homogeneous, and adjacent rock types may vary significantly in their ability to hold water. In certain rock masses, such as some types of consolidated sediments and volcanic rock, water cannot flow, for the most part, through the mass; the only water flow sufficient to produce usable quantities of water may be through fractures or joints in the rock. Therefore, if a borehole is drilled in a particular location and the underlying rock formation (bedrock) is too compact (consolidated with little or no primary permeability) to transmit water through the pore spaces and the bedrock is not fractured, then little or no water will be produced. However, if a borehole is drilled at a location where the bedrock is compact and the rock is highly fractured and has water flowing through the fractures, then the borehole could yield sufficient water to be economically useful.

Since it is difficult or impossible to predict precise locations that will have fractures in the bedrock, photographic analysis can be employed to assist in selecting more suitable well site locations. Other methods are available but are generally more expensive. Geologists use aerial photography in combination with other information sources to map lithology, faults, fracture traces, and other features that aid in well site selection. In hard rock, those wells sited on fractures and especially on fracture intersections generally have the highest yields. Correctly locating a well on a fracture may not only make the difference between producing high versus low water yields but may make the difference between producing some water versus no water at all. On-site verification of probable fractures further increases the chance of siting successful wells.

Overall, the water table surface is analogous to but considerably flatter than the topography of the land surface. Ground water elevations are typically only slightly higher than the elevation of the nearest surface water body within the same drainage basin. Therefore, the depth to water is greatest near drainage divides and in areas of high relief. During the dry season, the water table drops significantly and may be marked by the drying up of many smaller surface water bodies fed by ground water. The drop can be estimated based on the land elevation, on the distance from the nearest perennial stream or lake, and on the permeability of the aquifer. Areas that have the largest drop in the water table during the dry season are those that are high in elevation, far from perennial streams, and consist of fractured material. In general, some of these conditions can be applied to calculate the amount of drawdown to be expected when wells are pumped.

2. Hydrogeology

Variations in the geological structures, geomorphology, rock types, and precipitation contribute to the wide variety of ground water conditions in different parts of the country. The primary aquifer systems in Nicaragua are as follows:

- Quaternary to Recent age alluvial aquifers interbedded with pyroclastic deposits (map unit 1);
- Tertiary to Quaternary age volcanic deposits consisting of basaltic to andesitic pyroclastic rocks and basaltic lavas (map unit 2);
- Cretaceous to Tertiary age thin- to massive-bedded sedimentary rocks, tuffaceous in part (map unit 3);
- Tertiary to Quaternary age igneous rocks interbedded with sedimentary and metamorphic rocks (map unit 4); and
- Paleozoic age metamorphic and igneous rocks (map unit 5).

Descriptions are based upon interpretation of the most current hydrogeological information available.[83] See table C-2 and figure C-2 for further details.

In the Nicaraguan Depression and Pacific and Caribbean Lowlands, depth to water generally ranges from 15 to less than 150 meters. In the Interior Highlands and mountainous areas, depth to water is generally less than 200 meters but locally may be as great as 600 meters. In many areas, the depth to water may be too deep and yields too low for economic use. Throughout the country, the water table is subject to seasonal fluctuations. The water table may drop as much as 8 meters in western Nicaragua during the dry season, which extends from early November to late April. In eastern Nicaragua, the water table may drop a few meters during the dry season, which lasts from February to April. Aquifers in the mountains are generally recharged by rainfall, while those in the lowlands are primarily recharged by rainfall and aquifers originating in the mountains.

Access to well sites is generally easy in the Nicaraguan Depression and Pacific and Caribbean Lowlands. However, the lack of an established road network and dense vegetation throughout the Caribbean coastal area may make site access difficult. In the Central Highlands and mountainous areas in the northwest and west, and along the volcanic range separating the Pacific Lowlands and Nicaraguan Depression, steep slopes make ground water exploration difficult. The lack of an established road network throughout the country is a hindrance to ground water exploration.

Wells in all areas should be cased and screened, especially where aquifers are composed of unconsolidated sediments or volcanic deposits.

a. <u>Alluvial Aquifers (Map Unit 1)</u>

Fresh water is generally plentiful from productive Quaternary to Recent age alluvial aquifers that are composed of the following: unconsolidated sand and gravel with sandstone lenses; and sand and gravel interbedded with clay, silt, and pyroclastics consisting of fine ashes, pumice, and lapilli. These aquifers are in the Nicaraguan Depression and Pacific and Caribbean Lowlands. Ground water in these aquifers is generally at depths ranging from 15 to less than 150 meters.

b. <u>Volcanic Pyroclastic and Lava Aquifers (Map Unit 2)</u>

Fresh water is generally plentiful from Tertiary to Quaternary age volcanic deposits consisting of basaltic to andesitic pyroclastic rocks and basaltic lavas. Small to enormous quantities of fresh water are generally plentiful from springs issuing from fractures and contact zones of the volcanic deposits. These aquifers are in the volcanic range separating the Pacific coastal plain and the Nicaraguan Depression, and they are important aquifers for the Managua metropolitan area. Ground water in these aquifers is generally at depths ranging from 15 to less than 150 meters.

c. Other Aquifers (Map Units 3, 4, and 5)

Fresh water is scare or lacking in areas containing Cretaceous to Tertiary age thin- to massive-bedded sandstone, limestone, shale, conglomerate, and breccia that are tuffaceous in part (map unit 3). Coquina, pyroclastics, and diabase are present locally. Unsuitable to small quantities of ground water are available from these low-permeability aquifers in the mountainous areas of the north-central and northwestern parts of the country, in the southeast near the border with Costa Rico, and in scattered areas in the Pacific Lowlands. Locally, wells drilled into fracture zones may have higher yields. Ground water is at depths ranging from 20 to 200 meters but may range up to 600 meters in the western part of the country.

Fresh water is scare or lacking in areas containing Tertiary to Quaternary age igneous rock consisting of andesite, basalt, ignimbrite, tuff, and volcanic ash interbedded with sandstone, siltstone, and limestone (map unit 4). These low-permeability aquifers yield meager to moderate quantities of ground water from depths ranging from 15 to 150 meters, and they exist in the Central Highlands and in scattered areas in the Pacific Lowlands. Locally, wells drilled into fracture zones may have higher yields. Unsuitable to small quantities of fresh water are also available from unconsolidated coarse gravels and lateritic soils overlying bedrock at depths generally less than 6 meters.

Fresh water is scare or lacking in areas containing Paleozoic age igneous and metamorphic rocks consisting of granite, diorite, granodiorite, phyllite, schist, slate, marble, and quartzite (map unit 5). These low-permeability rocks make poor aquifers, and they yield unsuitable to meager quantities of ground water at depths ranging from 20 to 200 meters. They are not favorable sites for ground water production, except in places where they are highly fractured or weathered. These aquifers are in the Central Highlands area near and along the border with Honduras.[84]

C. Water Quality

Water quality in Nicaragua was monitored from 1971 to 1986. Due to economics, the monitoring ceased in 1986. Since then, the only information available on water quality is obtained from site-specific studies. It is recommended that an Environmental Water Monitoring system be established.[85]

1. Surface Water

Pollution of the surface water resources is a major problem. The streams are generally biologically contaminated from human and agricultural runoff near and downstream of populated areas. Inadequate wastewater treatment in cities and towns allow for the untreated or partially treated sewage to enter the streams. Mining and ore-refining activities in the mountains are leading sources of chemical and heavy metal pollution, especially mercury and cyanide. The runoff associated with the use of agrochemicals including pesticides and fertilizer in intensive farming areas for coffee, bananas, vegetables and other crops is a growing problem. The growth of industry is adding to the chemical pollution load. Another pollution problem is the additional sediment loading caused by deforestation.

Generally, the surface water in the Caribbean Coast drainage region is fresh with total dissolved solids ranging from 9 to 600 milligrams per liter. Along the Caribbean coast, the surface water becomes brackish to saline because of saltwater intrusion and tidal effects. In streams that do not empty into a coastal lagoon, saltwater intrusion can occur inland for some distance. Saltwater intrudes 25 kilometers in the Rio Prinzapolka, 30 kilometers in the Rio Grande de Matagalpa, and 80 kilometers upstream in the Rio Escondido.[86]

Most streams have heavy sediment loads, high turbidity, and large amounts of organic debris. The Caribbean Coast drainage region has few major sources of pollution. Biological contamination from human and agricultural runoff is common near and downstream of populated areas. Mining and ore-refining activities are the leading sources of chemical pollution. Another pollution problem is the additional sediment loading from deforestation caused by slash-and-burn agriculture and timber cutting.

Water quality is highly variable throughout the Rio San Juan drainage region. Most of the streams in the drainage region have total dissolved solids of about 400 milligrams per liter. The Rio San Juan has total dissolved solids of 360 milligrams per liter. The Rio Tipitapa is generally brackish with high total dissolved solids. Saltwater intrusion occurs inland for some 20 kilometers in the Rio San Juan.[87]

Pollution is a major problem. Streams are generally biologically contaminated from human and agricultural runoff near and downstream of populated areas. Mining and ore-refining activities in the mountains are leading sources of chemical and heavy metal pollution especially mercury and cyanide. Runoff of agrochemicals in intensive farming areas for coffee, bananas, vegetables, and other crops is a growing problem. The growth of industry is adding to the chemical pollution load.

Generally, the surface water in the Pacific Coast drainage region is fresh with total dissolved solids ranging up to 792 milligrams per liter. In the marshes and swamps along the Pacific coast and in the Estero Real, the surface water can become brackish to saline because of saltwater intrusion and tidal effects. Pollution is a major problem. The streams of the drainage region are generally biologically contaminated from human and agricultural runoff near and downstream of populated areas. Inadequate wastewater treatment in cities and towns allows for the untreated or partially treated sewage to enter the streams. The growth of industry and the increased use of agrochemicals, including pesticides and fertilizers, are adding to the chemical pollution load.

Lago de Managua is of special concern, because it is severely polluted. Inadequate wastewater treatment allows the untreated or partially treated sewage from the 1 million people who live along the shore of Lago de Managua to pour into the lake. About 300 industries discharge untreated chemical wastes including, phenols, benzene, carbon tetrachloride, methylene chloride, mercury, lead, cyanide, and other heavy metals into the lake. Agrochemicals including pesticides, herbicides, and fertilizer and other agricultural runoff freely flow into the streams that empty into the lake. Due to the level of pollution, water from Lago de Managua is not adequate for human consumption or irrigation.

Laguna de Masaya is receiving wastewater from Managua and is highly contaminated. Biological contamination is also threatening Laguna de Asososca. Laguna de Apoyeque, Laguna de Apoyo, and Laguna de Jiloa are all brackish with total dissolved solids ranging from 2,600 to 4,972 milligrams per liter.[88] The quality of the water in these lakes is poor and not recommended for human consumption.

2. Ground Water

Except for brackish or saline ground water near the Pacific and Caribbean coasts, ground water is suitable for most uses. Both natural and manmade factors affect the ground water quality. Natural factors include hardness, phosphates, sodium, bacteria, chlorides, dissolved solids, organic material, and dissolved oxygen content. Manmade pollutants include nitrates, phosphates, sodium, potassium, chlorides, bacteria, ammonia, nitrogen, oil and grease, heavy metals, dissolved solids, chlorine, pesticides, and fertilizer. These pollutants result from agricultural runoff, livestock production, industrial effluent, urban runoff, soil leaching, marine water inflow, erosion, road construction, mining, forestry, slash-and-burn agriculture, and domestic wastewater. Biological and chemical contaminations occur in shallow aquifers near population centers. Chemical contamination of shallow aquifers by pesticides occurs in the agricultural areas surrounding Managua and in the Pacific Lowlands and the Nicaraguan Depression.[89] Ground water from the igneous and metamorphic aquifers may be distasteful and discolored due to high iron and manganese content. Treatment of saline ground water by reverse-osmosis desalination equipment is necessary before the water is suitable for human consumption.

3. Domestic Waste Disposal

The water and sewage systems declined significantly during the Sandinista years, because of lack of funds. An estimated 30 to 50 percent of the urban areas have working sewage systems, but none of the rural areas have these services.[90,91] In the rural areas, sanitary disposal methods are limited to latrines and sewage ditches or drains.[92]

Recently, the INAA started a rehabilitation program of the sewage lagoon systems with funding from an international organization. The program consists of rehabilitating and installing new treatment systems in Esteli, Somoto, Leon, Chinandega, Masaya, and Granada. Table 5 outlines the number of sewage lagoons and amount of wastewater treated in the urban areas.[93]

Table 5. Cities with Treatment Systems for Urban Wastewater

City	Number of Existing Sewage Lagoons	Approximate Volume of Treated Wastewater (m^3/yr)
Esteli	6	867,000
Somoto	1	92,250
Leon	3	3,433,300
Chinandega	1	1,983,000
Masaya	6	2,004,480
Granada	2	1,036,330
San Juan del Sur	1	31,680
Rivas	3	245,980
Total	**23**	**10,194,020**

Source: Ministerio del Ambiente y Recursos Naturales, *Plan de Accion de los Recursos Hidricos en Nicaragua*, "Evaluacion Rapida de los Recursos Hidricos, Anexo B, Calidad de Agua Informacion Adicional," Managua, No date, p. B-11.

V. Water Resources Departmental Summary

A. Introduction

This chapter summarizes the water resources information of Nicaragua, which can be useful to water planners as a countrywide overview of the available water resources. Figure C-1, Surface Water Resources, divides the country into surface water categories identified as map units 1 through 5. Table C-1, which complements figure C-1, details the quantity, quality, and seasonality of the significant water features within each map unit and describes accessibility to these water sources. Figure C-2, Ground Water Resources, divides the country into ground water categories identified as map units 1 through 5. Table C-2, which complements figure C-2, details predominant ground water characteristics of each map unit including aquifer materials, aquifer thickness, yields, quality, and depth to water. A summary based on these figures and tables is provided for each of the 15 departments and 2 autonomous regions.

B. Water Conditions by Map Unit

Figure C-1, Surface Water Resources, divides the country into five map unit categories based on water quantity, water quality, and seasonality. Map units 1 through 2 depict areas where fresh surface water is perennially available in small to enormous quantities. Map units 3 and 4 depict areas where fresh surface water is seasonally available in small to very large quantities during high flows. Map unit 5 depicts areas where fresh surface water is scarce or lacking and meager to enormous quantities of brackish to saline water are perennially available. Figure C-1 also divides the country into three drainage regions, the Caribbean Coast drainage region, the Rio San Juan drainage region, and the Pacific Coast drainage region. The locations of selected river gaging stations and water quality sampling points are also depicted on figure C-1.

Figure C-2, Ground Water Resources, divides the country into five map unit categories based on hydrogeological characteristics. Map units 1 through 2 depict areas where ground water development appears to be most favorable and fresh water is generally available. Map units 3 through 5 depict areas where fresh water is scarce or lacking or areas where the ground water is brackish to saline.

In the text, surface and ground water quantity and quality for each department is described by the following terms:

Surface Water Quantitative Terms:

Enormous	= >5,000 cubic meters per second (m^3/s) (176,550 cubic feet per second (ft^3/s))
Very large	= >500 to 5,000 m^3/s (17,655 to 176,550 ft^3/s)
Large	= >100 to 500 m^3/s (3,530 to 17,655 ft^3/s)
Moderate	= >10 to 100 m^3/s (350 to 3,530 ft^3/s)
Small	= >1 to 10 m^3/s (35 to 350 ft^3/s)
Very small	= >0.1 to 1 m^3/s (3.5 to 35 ft^3/s)
Meager	= >0.01 to 0.1 m^3/s (0.35 to 3.5 ft^3/s)
Unsuitable	= $\leq$0.01 m^3/s (0.35 ft^3/s)

Ground Water Quantitative Terms:

Enormous	= >100 liters per second (L/s) (1,600 gallons per minute (gal/min))
Very large	= >50 to 100 L/s (800 to 1,600 gal/min)
Large	= >25 to 50 L/s (400 to 800 gal/min)
Moderate	= >10 to 25 L/s (160 to 400 gal/min)
Small	= >4 to 10 L/s (64 to 160 gal/min)
Very small	= >1 to 4 L/s (16 to 64 gal/min)
Meager	= >0.25 to 1 L/s (4 to 16 gal/min)
Unsuitable	= ≤0.25 L/s (4 gal/min)

Qualitative Terms:

Fresh water	= maximum total dissolved solids (TDS) ≤1,000 milligrams per liter (mg/L); maximum chlorides ≤600 mg/L; and maximum sulfates ≤300 mg/L
Brackish water	= maximum TDS >1,000 mg/L but ≤15,000 mg/L
Saline water	= TDS >15,000 mg/L

C. Water Conditions by Department and Autonomous Region

The following information was compiled for each department from figures C-1 and C-2 and tables C-1 and C-2. The write-up for each department or autonomous region consists of a general and regional summary of the surface water and ground water resources, derived from a country-scale overview. Locally, the conditions described may differ. The department summaries should be used in conjunction with figures C-1 and C-2 and tables C-1 and C-2. Additional information is necessary to adequately describe the water resources of a particular department or region. Specific well information was limited and for many areas unavailable. For all areas that appear to be suitable for tactical and hand pump wells, local conditions should be investigated before beginning a well-drilling program.

Departamento de Boaco

Area and relative size:	4,244 square kilometers (3.5 percent of the country)
Estimated Population (1995):	136,949 (3.0 percent of the population)
Population Density:	32 people per square kilometer
Departmental Capital:	Boaco
Location:	The department is located in the central part of the country and borders the northeastern part of Lago de Nicaragua.

Surface Water:

Fresh surface water is perennially available in small to very large quantities in the small part of the department that extends along the Rio Grande de Matagalpa, and its tributaries. Enormous quantities are available from Lago de Nicaragua. These areas are depicted by map units 1 and 2. Fresh surface water is seasonally available from streams and lakes in the rest of the department as depicted by map units 3 and 4. Small to very large quantities are available during the high flow season from May through November. The low flow season is from December to April when meager to very small quantities are available. Within map unit 4, all but the largest streams go dry for extended periods of time during the low flow season. The departmental capital of Boaco is in map unit 4.

Access to and the development of water sources is generally not difficult in the western half of the department but locally may be hindered by the lack of all-weather roads, rough terrain, and seasonally marshy ground. In the eastern half of the department, access is difficult because of dense vegetation and steep rugged terrain.

Ground Water:

The best areas for ground water exploration are the alluvial aquifers in the southern part of the department along Lago de Nicaragua as depicted by map unit 1. About 10 percent of the department is in map unit 1. Small to very large quantities of fresh water are available from the Quaternary to Recent age alluvial aquifers. These aquifers are composed of unconsolidated sand and gravel with sandstone lenses. Sand and gravel is often interbedded with clay and silt at depths ranging from 5 to 60 meters. Greater quantities are available as the percentage of clay and silt in the aquifer decreases. Ground water is soft to moderately hard. Shallow aquifers may be biologically contaminated near settlements. Alluvial aquifers, when properly developed, are suitable for municipal and irrigation wells.

Map unit 2 covers a small area (10 percent) and is located in the southwestern part of the department. Small to enormous quantities of fresh water are available from springs issuing from fractures and contact zones within volcanic deposits in the areas covered by map unit 2. The ground water quality is generally fresh but slightly alkaline and varies in temperature from hot to cold due to geothermal activity. Hardness ranges from soft to hard. The quality of some of the springs can be brackish to saline and range from slightly alkaline to strongly acidic. Meager to very large quantities of fresh water are also available from Tertiary to Quaternary age volcanic rocks. Primary aquifers include: Las Sierras Group consisting of basaltic to andesitic pyroclastic rocks, the Masaya Group Volcanics composed of basaltic to andesitic lavas and pyroclastic materials (volcanic breccia, scoria and ash) and the Apoyo Volcanics consisting of pyroclastic dacite pumice and dacitic lavas.

Most of the Departamento de Boaco is within map unit 4 (80 percent). Meager to moderate quantities of fresh water are available from Tertiary to Quaternary age andesite, basalt, ignimbrite, tuff, and volcanic ash interbedded with sandstone, siltstone, and limestone at depths ranging from 15 to 150 meters. Major aquifers include: Miocene Tamarindo Formation (ignimbrites, basalts, andesites), Matagalpa Group (ignimbrites, basalts, andesites), Coyol Group (ignimbrites, basalts, andesites), Machucha Group (sandstone, siltstone, and crystallized limestone). Unsuitable to small quantities of fresh water are also available from unconsolidated coarse gravels and lateritic soils overlying bedrock at depths generally greater than 6 meters. Aquifers are suitable for hand pump wells and most are suitable for 3.3-liters-per-second (50 gallons per minute) tactical wells and wells equipped with small submersible pumps. Accessibility is difficult in dense vegetation and steep terrain. The shallow ground water is often biologically contaminated near settlements. Due to the low permeability and yields, and restricted accessibility, ground water exploration is not recommended during military exercises in these areas without site-specific reconnaissance. Successful wells may depend upon encountering water-bearing fractures.

Departamento de Carazo

Area and relative size:	1,050 square kilometers (0.9 percent of the country)
Estimated Population (1995):	149,407 (4 percent of the population)
Population Density:	142 people per square kilometer
Departmental Capital:	Jinotepe
Location:	The department is located in the western part of the country and borders the Pacific Ocean.

Surface Water:

Fresh surface water is seasonally available from streams, small lakes, and marshes throughout the entire Departamento de Carazo as depicted by map unit 4. Small to very large quantities are available during the high flow season from May through November. During the low flow season from December to April, most streams are dry for extended periods of time. The departmental capital of Jinotepe is in map unit 4.

Access to and the development of water sources is generally easy, but may be locally difficult because of dense vegetation and the lack of all-weather roads.

Ground Water:

The best areas for ground water exploration are the alluvial aquifers in the southern part of the department along the Pacific Coast as depicted by map unit 1. About 20 percent of the department is in map unit 1. Small to very large quantities of fresh water are available from Quaternary to Recent age alluvial aquifers. These aquifers are composed of unconsolidated sand and gravel with sandstone lenses and sand and gravel interbedded with clay and silt at depths ranging from 5 to 60 meters. Larger quantities are available as the percentage of clay and silt in the aquifer decreases. Ground water is soft to moderately hard. Saline water zones underlie the fresh water zones in the coastal area and caution should be exercised in pumping to prevent saline water intrusion. Saline water wells would require reverse osmosis/desalination equipment. Shallow aquifers may be biologically contaminated near settlements. Accessibility is generally easy, but may be locally difficult in areas of dense forest and areas along the coast subject to seasonal inundation. Alluvial aquifers, when properly developed, are suitable for municipal or irrigation wells.

Map unit 2 covers about 40 percent of the department and is located in the northern part of the department. Small to enormous quantities of fresh water are available from springs issuing from fractures and contact zones within volcanic deposits in the areas covered by map unit 2. The ground water quality is generally fresh but slightly alkaline and varies in temperature due to geothermal activity. Hardness ranges from soft to hard. The quality of some of the springs can be brackish to saline and range from slightly alkaline to strongly acidic. Meager to very large quantities of fresh water are also available from Tertiary to Quaternary age volcanic rocks. Primary aquifers include: Las Sierras Group consisting of basaltic to andesitic pyroclastic rocks; the Masaya Group Volcanics composed of basaltic to andesitic lavas and pyroclastic materials (volcanic breccia, scoria, and ash); and the Apoyo Volcanics consisting of pyroclastic dacite pumice and dacitic lavas.

Map unit 3 covers about 40 percent of the department and is present along the Pacific Coast. Unsuitable to small quantities of fresh water are available from Cretaceous to Tertiary age thin to massive bedded sandstone, limestone, shale, conglomerate, and breccia, tuffaceous in part. Locally, coquina, pyroclastics, and diabase are found. Depth to aquifer is generally between 20 and 200 meters. Major aquifers include: Eocene Machuca Formation (limestones, gravels), Oligocene Masachapa Formation (sandstones, tuffaceous sands, conglomerates), Eocene Brito Formation (sands, coquinas, volcanics), and Cretaceous Rivas Formation (sandstones, shales). Water hardness ranges from soft, from the sandstones, to hard, from the limestones. Locally, water may smell foul due to high hydrogen sulfide content. Shallow wells are subject to seasonal fluctuations of the water table and may become dry November to April in the Pacific region. Well siting is generally difficult since many wells yield only meager quantities. Wells sited in coarse to sandy material with low clay percentages will yield the largest quantities of ground water. Drilling in the breccia requires hard rock drilling techniques. Wells should be cased and screened. Accessibility is hindered by dense vegetation and mountainous terrain. Aquifers are suitable for hand pump wells; most are suitable for 3.3-liters-per-second (50 gallons per minute) tactical wells and wells equipped with small submersible pumps. The shallow ground water may be biologically contaminated near settlements. The departmental capital of Jinotepe is in this unit.

Departamento de Chinandega

Area and relative size:	4,926 square kilometers (4.1 percent of the country)
Estimated Population (1995):	350,212 (8 percent of the population)
Population Density:	71 people per square kilometer
Departmental Capital:	Chinandega
Location:	The department is located in the western part of the country along the Pacific Ocean and the border with Honduras.

Surface Water:

Fresh surface water is seasonally available from streams, lakes, and marshes in most of the department as depicted by map units 3 and 4. Map unit 3 covers the northwestern and coastal parts of the department, while map unit 4 covers the eastern part of the department. Small to very large quantities are available during the high flow season from May through November. During the low flow season from December to April, most streams are dry for extended periods of time. Fresh surface water is scarce or lacking in the coastal wetlands and the estuary of the Estero Real as depicted by map unit 5. Meager to enormous quantities of brackish to saline water are available from estuaries, coastal lagoons, tidal marshes, and mangroves. The departmental capital of Chinandega is in map unit 3.

Access to and the development of water sources is generally not difficult. Locally, rough terrain, dense vegetation and the lack of roads can hinder access. Access is very difficult in the estuary of the Estero Real and in coastal marshes because of the dense vegetation, wet ground, and the lack of roads.

Ground Water:

The best areas for ground water exploration are the alluvial aquifers as depicted by map unit 1. About 45 percent of the department is in map unit 1. Small to very large quantities of fresh water are available from the Quaternary to Recent age alluvial aquifers. These aquifers are composed of unconsolidated sand and gravel with sandstone lenses and sand and gravel interbedded with clay and silt at depths ranging from 5 to 60 meters. Larger quantities are available as the percentage of clay and silt in the aquifer decreases. Wells in the Chinandega area are reported to yield over 67 liters per second. Ground water is soft to moderately hard. Saline water zones underlie the fresh water zones in the coastal area and caution should be exercised in pumping to prevent saline water intrusion. Saline water wells would require reverse osmosis/desalination equipment. Accessibility is generally easy, but may be locally hindered in areas of dense forest and areas along the coast subject to seasonal inundation. Alluvial aquifers, when properly developed, are suitable for municipal and irrigation wells. The departmental capital of Chinandega is in this unit.

Map unit 2 trends northwest to southeast and covers about 20 percent of the area. Small to enormous quantities of fresh water are available from springs issuing from fractures and contact zones within volcanic deposits in the areas covered by map unit 2. The ground water quality is generally fresh but slightly alkaline and varies in temperature from hot to cold. Hardness ranges from soft to hard. The quality of some of the springs can be brackish to saline and range from slightly alkaline to strongly acidic. Meager to very large quantities of fresh water are also available from Tertiary to Quaternary age volcanic rocks. Primary aquifers include: Las Sierras Group consisting of basaltic to andesitic pyroclastic rocks; the Masaya Group Volcanics composed of basaltic to andesitic lavas and pyroclastic materials (volcanic breccia, scoria, and ash); and the Apoyo Volcanics consisting of pyroclastic dacite pumice and dacitic lavas.

About 25 percent of the department is in map unit 4. Meager to moderate quantities of fresh water available from Tertiary to Quaternary age andesite, basalt, ignimbrite, tuff, and volcanic ash interbedded with sandstone, siltstone, and limestone at depths ranging from 15 to 150 meters. Major aquifers include: Miocene Tamarindo Formation (ignimbrites, basalts, andesites); Matagalpa Group (ignimbrites, basalts, andesites); Coyol Group (ignimbrites, basalts, andesites); and Machucha Group (sandstone, siltstone, and crystallized limestone). Water hardness ranges from slightly to moderately hard. Wells drilled in the unconsolidated materials overlying the bedrock should be screened. Drilling in the basalts requires hard-rock drilling techniques. Accessibility is difficult in dense vegetation and mountainous terrain. Unsuitable to small quantities of fresh water are also available from unconsolidated coarse gravels and lateritic soils overlying bedrock at depths generally greater than 6 meters. Aquifers are suitable for hand pump wells and most are suitable for 3.3-liters-per-second tactical (50 gallons per minute) wells and wells equipped with small submersible pumps.

About 10 percent of the department is in map unit 5 where ground water exploration is not recommended. Unsuitable to meager quantities of fresh water are seasonally available from Paleozoic age granite, diorite, granodiorite, phyllite, schist, slate, marble, and quartzite at depths ranging from 20 to 200 meters. Water hardness is generally soft. Locally the ground water may be distasteful and discolored due to high iron and manganese content. Well siting is difficult and most wells are unproductive. Hard-rock drilling techniques are required. Accessibility is hindered by dense vegetation and hilly, mountainous terrain. The shallow ground water is often biologically contaminated near settlements.

Departamento de Chontales

Area and relative size:	6,378 square kilometers (5.3 percent of the country)
Estimated Population (1995):	144,635 (3 percent of the population)
Population Density:	23 people per square kilometer
Departmental Capital:	Juigalpa
Location:	The department is located in the south-central part of the country along the northeast side of Lago de Nicaragua.

Surface Water:

Fresh surface water is perennially available in small to very large quantities in the small part of the department that lie along the Rio Mico and the Rio Siquia. Enormous quantities are available from Lago de Nicaragua. These areas are depicted by map units 1 and 2. Fresh surface water is seasonally available from streams and lakes in the rest of the department as depicted by map units 3 and 4. Small to very large quantities are available during the high flow season from May through November. The low flow season is from December to April when meager to very small quantities are available. Within map unit 4, all but the largest streams go dry for extended periods of time during the low flow season. The departmental capital of Juigalpa is in map unit 3, along the Rio Mayales.

Access to and the development of water sources is generally difficult because of the steep and rugged terrain, the dense vegetation, wet ground, and the lack of roads. Along the shore of Lago de Nicaragua, access is not difficult; however, dense vegetation and the lack of roads hinder access.

Ground Water:

The best areas for ground water exploration are the alluvial aquifers in the southwest part of the department and a small area in easternmost extension as depicted by map unit 1. About 25 percent of the department is in map unit 1. Small to very large quantities of fresh water are available from the Quaternary to Recent age alluvial aquifers. These aquifers are composed of unconsolidated sand and gravel with sandstone lenses and sand and gravel interbedded with clay and silt at depths ranging from 5 to 60 meters. Larger quantities of water are available as the percentage of clay and silt in the aquifer decreases. Ground water is soft to moderately hard. Accessibility is generally easy, but may be locally hindered in areas of dense forest and steep terrain. Shallow aquifers may be biologically contaminated near settlements. Alluvial aquifers, when properly developed, are suitable for municipal and irrigation wells.

About 75 percent of the department is in map unit 4. Meager to moderate quantities of fresh water are available from Tertiary to Quaternary age andesite, basalt, ignimbrite, tuff, and volcanic ash interbedded with sandstone, siltstone, and limestone at depths ranging from 15 to 150 meters. Major aquifers include: Miocene Tamarindo Formation (ignimbrites, basalts, andesites); Matagalpa Group (ignimbrites, basalts, andesites); Coyol Group (ignimbrites, basalts, andesites); and Machucha Group (sandstone, siltstone, and crystallized limestone). Water hardness ranges from slightly to moderately hard. Wells drilled in the unconsolidated materials overlying the bedrock should be screened. Drilling in the basalt requires hard-rock drilling techniques. Accessibility is difficult in dense vegetation and mountainous terrain. Unsuitable to small quantities of fresh water are also available from unconsolidated coarse gravels and lateritic soils overlying bedrock at depths generally greater than 6 meters. Aquifers are suitable for hand pump wells and most are suitable for 3.3-liters-per-second (50 gallons per minute) tactical wells and wells equipped with small submersible pumps. The departmental capital of Juigalpa is in this unit.

Departamento de Esteli

Area and relative size: 2,335 square kilometers (1.9 percent of the country)

Estimated Population (1995): 174,894 (4 percent of the population)

Population Density: 75 people per square kilometer

Departmental Capital: Esteli

Location: The department is located in the northwestern part of the country.

Surface Water:

Fresh surface water is seasonally available from streams, small lakes, and marshes throughout most of the department as depicted by map unit 4. Map unit 3 is along the Rio Esteli. Small to very large quantities are available during the high flow season from May through November. During the low flow season from December to April, most streams are dry for extended periods of time. The departmental capital of Esteli is in map unit 4.

Access to and the development of water sources is generally difficult because of the steep and rugged terrain, the dense vegetation, wet ground, and the lack of roads.

Ground Water:

The best areas for ground water exploration are the alluvial aquifers located in three small areas scattered throughout the department as depicted by map unit 1. About 25 percent of the department is in map unit 1. Small to very large quantities of fresh water are available from the Quaternary to Recent age alluvial aquifers. These aquifers are composed of unconsolidated sand and gravel with sandstone lenses and sand and gravel interbedded with clay and silt at depths ranging from 5 to 60 meters. Larger quantities are available as the percentage of clay and silt in the aquifer decreases. Ground water is soft to moderately hard. Accessibility is generally easy, but may be locally hindered in areas of dense forest and steep terrain. Shallow aquifers may be biologically contaminated near settlements. Alluvial aquifers, when properly developed, are suitable for municipal and irrigation wells. The departmental capital of Esteli is in this unit.

About 75 percent of the department is in map unit 4. Areas where only meager to moderate quantities of fresh water are available from Tertiary to Quaternary age andesite, basalt, ignimbrite, tuff, and volcanic ash interbedded with sandstone, siltstone, and limestone at depths ranging from 15 to 150 meters. Major aquifers include: Miocene Tamarindo Formation (ignimbrites, basalts, andesites); Matagalpa Group (ignimbrites, basalts, andesites); Coyol Group (ignimbrites, basalts, andesites); and Machucha Group (sandstone, siltstone, and crystallized limestone). Unsuitable to small quantities of fresh water are also available from unconsolidated coarse gravels and lateritic soils overlying bedrock at depths generally greater than 6 meters. Water hardness ranges from slightly to moderately hard. Wells drilled in the unconsolidated materials overlying the bedrock should be screened. Drilling in the basalt requires hard-rock drilling techniques. Accessibility is difficult in dense vegetation and mountainous terrain. Aquifers are suitable for hand pump wells and most are suitable for 3.3-liters-per-second (50 gallons per minute) tactical wells and wells equipped with small submersible pumps.

Departamento de Granada

Area and relative size:	929 square kilometers (0.8 percent of the country)
Estimated Population (1995):	155,683 (4 percent of the population)
Population Density:	168 people per square kilometer
Departmental Capital:	Granada
Location:	The department is located in the southeastern part of the country along the northwestern side of Lago de Nicaragua.

Surface Water:

Fresh surface water is perennially available in enormous quantities from Lago de Nicaragua as depicted by map unit 1. Fresh surface water is seasonally available from streams, lakes, and marshes in most of the department as depicted by map units 3 and 4. Small to very large quantities are available during the high flow season from May through November. During the low flow season from December to April, most streams are dry for extended periods of time. Fresh surface water is scarce or lacking in the parts of the department as depicted by map unit 5 and areas too small to be shown on a country-scale map. Meager to enormous quantities of brackish to saline water are available in the Rio Tipitapa valley and from lakes in the calderas of some volcanoes. The departmental capital of Granada is in map unit 1.

Access to and the development of water sources is generally not difficult. Locally, dense vegetation and the lack of roads hinder access. Along the Rio Tipitapa, wet marshy ground, dense vegetation, and the lack of roads hinder access.

Ground Water:

The best areas for ground water exploration are the alluvial aquifers located in the northern and southern sections as depicted by map unit 1. About 50 percent of the department is in map unit 1. Small to very large quantities of fresh water are available from the Quaternary to Recent age alluvial aquifers. These aquifers are composed of unconsolidated sand and gravel with sandstone lenses and sand and gravel interbedded with clay and silt at depths ranging from 5 to 60 meters. Larger quantities are available as the percentage of clay and silt in the aquifer decreases. Ground water is soft to moderately hard. Accessibility is generally easy, but may be locally hindered in areas of dense forest and steep terrain. Shallow aquifers may be biologically contaminated near settlements. Alluvial aquifers, when properly developed, are suitable for municipal and irrigation wells. The departmental capital of Granada is in this unit.

About 30 percent of the department south of the town of Granada and Isla Zapatera is in map unit 2. Small to enormous quantities of fresh water are available from springs issuing from fractures and contact zones within volcanic deposits in the areas covered by map unit 2. The ground water quality is generally fresh, but slightly alkaline and varies in temperature from hot to cold. Hardness ranges from soft to hard. The quality of some of the springs can be brackish to saline and range from slightly alkaline to strongly acidic. Meager to very large quantities of fresh water are also available from Tertiary to Quaternary age volcanic rocks. Primary aquifers include: Las Sierras Group consisting of basaltic to andesitic pyroclastic rocks; Masaya Group Volcanics composed of basaltic to andesitic lavas and pyroclastic materials (volcanic breccia, scoria and ash); and Apoyo Volcanics consisting of pyroclastic dacite pumice and dacitic lavas.

Map unit 3 covers about 20 percent of the department and is located at the southernmost tip. Unsuitable to small quantities of fresh water are available from Cretaceous to Tertiary age thin to massive bedded sandstone, limestone, shale, conglomerate, and breccia; tuffaceous in part. Locally, coquina, pyroclastics, and diabase are found. Depth to water is generally between 20 and 200 meters. Major aquifers include: Eocene Machuca Formation (limestones, gravels); Oligocene Masachapa Formation (sandstones, tuffaceous sands, conglomerates); Eocene Brito Formation (sands, coquinas, volcanics); and Cretaceous Rivas Formation (sandstones, shales). Water hardness ranges from soft from the sandstones to hard from the limestones. Locally, water may smell foul due to high hydrogen sulfide content. Shallow wells are subject to seasonal fluctuations of the water table and may become dry November to April in the Pacific region. Well siting is generally difficult since many wells yield only meager quantities. Wells sited in coarse to sandy material with low clay percentages will yield the largest quantities of ground water. Drilling in the breccia requires hard rock drilling techniques. Wells should be cased and screened. Accessibility is hindered by dense vegetation and mountainous terrain. Aquifers are suitable for hand pump wells and most are suitable for 3.3-liters-per-second (50 gallons per minute) tactical wells and wells equipped with small submersible pumps. The shallow ground water may be biologically contaminated near settlements.

Departamento de Jinotega

Area:	9,755 square kilometers (8.0 percent of the country)
Estimated Population (1995):	257,933 (6 percent of the population)
Population Density:	26 people per square kilometer
Departmental Capital:	Jinotega
Location:	The department is located in the northwestern part of the country along the border with Honduras.

Surface Water:

Fresh surface water is perennially available in very small to small quantities along the Rio Bocay, Rio Coco, the Rio Siquia, and their tributaries. Enormous quantities are available from Lago de Apanas. These areas are depicted by map units 1 and 2. Fresh surface water is seasonally available from streams and lakes in the rest of the department as depicted by map units 3 and 4. Map unit 3 is generally in the eastern part of the department, while map unit 4 is in the western part. Small to very large quantities are available during the high flow season from May through November. The low flow season is from December to April when meager to very small quantities are available. Within map unit 4, all but the largest streams go dry for extended periods of time during the low flow season. The departmental capital of Jinotega is in map unit 4.

Access to and the development of water sources is generally difficult, because of the steep and rugged terrain, the dense vegetation, wet ground, and the lack of roads.

Ground Water:

The best areas for ground water exploration are the alluvial aquifers trending northeast to southwest across the central part of the department as depicted by map unit 1. About 25 percent of the department is in map unit 1. Small to very large quantities of fresh water are available from Quaternary to Recent age alluvial aquifers. These aquifers are composed of unconsolidated sand and gravel with sandstone lenses and sand and gravel interbedded with clay and silt at depths ranging from 5 to 60 meters. Larger quantities are available as the percentage of clay and silt in the aquifer decreases. Ground water is soft to moderately hard. Saline water zones underlie the fresh water zones in the coastal area and caution should be exercised in pumping to prevent saline water intrusion. Saline water wells would require reverse osmosis/desalination equipment. Accessibility is generally easy, but may be locally hindered in areas of dense forest and areas along the coast subject to seasonal inundation. Alluvial aquifers, when properly developed, are suitable for municipal and irrigation wells.

Map unit 3 covers about 25 percent of the department and occurs in the central and northern parts. Unsuitable to small quantities of fresh water are available from Cretaceous to Tertiary age thin to massive bedded sandstone, limestone, shale, conglomerate, and breccia; tuffaceous in part. Locally, coquina, pyroclastics, and diabase are found. Depth to aquifer is generally between 20 and 200 meters. Major aquifers include: Eocene Machuca Formation (limestones, gravels); Oligocene Masachapa Formation (sandstones, tuffaceous sands, conglomerates); Eocene Brito Formation (sands, coquinas, volcanics); and Cretaceous Rivas Formation (sandstones, shales). Water hardness ranges from soft in the sandstones to hard in the limestones. Locally, water may smell foul due to high hydrogen sulfide content. Shallow wells are subject to seasonal fluctuations of the water table and may become dry November to April. Well siting is generally difficult and many wells yield only meager quantities. Wells sited in coarse to sandy material with low clay percentages will yield the largest quantities of ground water. Drilling in the breccia requires hard rock drilling techniques. Wells should be cased and screened. Accessibility is hindered by dense vegetation and mountainous terrain. Aquifers are suitable for hand pump wells and most are suitable for 3.3-liters-per-second (50 gallons per minute) tactical wells and wells equipped with small submersible pumps. The shallow ground water may be biologically contaminated near settlements.

Map unit 4 covers about 45 percent of the department, mainly in the southern and eastern part of the department. Meager to moderate quantities of fresh water are available from Tertiary to Quaternary age andesite, basalt, ignimbrite, tuff, and volcanic ash interbedded with sandstone, siltstone, and limestone at depths ranging from 15 to 150 meters. Major aquifers include: Miocene Tamarindo Formation (ignimbrites, basalts, andesites); Matagalpa Group (ignimbrites, basalts, andesites); Coyol Group (ignimbrites, basalts, andesites); and Machucha Group (sandstone, siltstone, and crystallized limestone). Water hardness ranges from slightly to moderately hard. Wells drilled in the unconsolidated materials overlying the bedrock should be screened. Drilling in the basalt requires hard-rock drilling techniques. Accessibility is difficult in dense vegetation and mountainous terrain. Unsuitable to small quantities of fresh water are also available from unconsolidated coarse gravels and lateritic soils overlying bedrock at depths generally greater than 6 meters. Aquifers are suitable for hand pump wells and most are suitable for 3.3-liters-per-second tactical wells and wells equipped with small submersible pumps. The departmental capital of Jinotega is in this unit.

Departamento de Leon

Area:	5,107 square kilometers (4.2 percent of the country)
Estimated Population (1995):	336,894 (8.0 percent of the population)
Population Density:	66 people per square kilometer
Departmental Capital:	Leon
Location:	The department is located in the western part of the country along the Pacific Ocean and Lago de Managua.

Surface Water:

Fresh surface water is perennially available in enormous quantities from Lago de Managua as depicted by map unit 1. Fresh surface water is seasonally available from streams and small lakes in the rest of the department as depicted by map units 3 and 4. Map unit 3 covers the northwestern coastal parts of the department, while map unit 4 covers most of the rest of the department. Small to very large quantities are available during the high flow season from May through November. The low flow season is from December to April when meager to very small quantities are available. Within map unit 4, all but the largest streams go dry for extended periods of time during the low flow season. Fresh surface water is scarce or lacking in the coastal wetlands as depicted by map unit 5 and areas too small to be shown on a country-scale map. Meager to enormous quantities of brackish to saline water are available from estuaries, coastal lagoons, tidal marshes, mangroves, and from lakes in the calderas of some volcanoes. During the low flow period, some marshy areas along the shore of Lago de Managua can become temporarily brackish. The departmental capital of Leon is in map unit 3.

Access to and the development of water sources is generally not difficult. Locally, rough terrain, dense vegetation and the lack of roads can hinder access.

Ground Water:

The best areas for ground water exploration are the alluvial aquifers present along Lago de Managua, the Pacific Coast, and several small scattered areas throughout the department as depicted by map unit 1. About 35 percent of the department is in map unit 1. Small to very large quantities of fresh water are available from Quaternary to Recent age alluvial aquifers. These aquifers are composed of unconsolidated sand and gravel with sandstone lenses and sand and gravel interbedded with clay and silt at depths ranging from 5 to 60 meters. Larger quantities are available as the percentage of clay and silt in the aquifer decreases. Wells in the Leon area are reported to yield over 67 liters per second (1,000 gallons per minute). Ground water is soft to moderately hard. Saline water zones underlie the fresh water zones in the coastal area and caution should be exercised in pumping to prevent saline water intrusion. Saline water wells would require reverse osmosis/desalination equipment. Accessibility is generally easy, but may be locally hindered in areas of dense forest and areas along the coast subject to seasonal inundation. Alluvial aquifers, when properly developed, are suitable for municipal and irrigation wells. The departmental capital of Leon is in this unit.

About 25 percent of the department is in map unit 2. Map unit 2 is present in an area that extends northwest to southeast from Lago de Managua. Small to enormous quantities of fresh water are available from springs issuing from fractures and contact zones within volcanic deposits in the areas covered by map unit 2. The ground water quality is generally fresh, but slightly alkaline and varies in temperature from hot to cold. Hardness ranges from soft to hard. The quality of some of the springs can be brackish to saline and range from slightly alkaline to strongly acidic. Meager to very large quantities of fresh water are also available from Tertiary to

Quaternary age volcanic rocks. Primary aquifers include: Las Sierras Group consisting of basaltic to andesitic pyroclastic rocks; Masaya Group Volcanics composed of basaltic to andesitic lavas and pyroclastic materials (volcanic breccia, scoria, and ash); and Apoyo Volcanics consisting of pyroclastic dacite pumice and dacitic lavas.

Map unit 4 is located in scattered areas throughout the department and occupies about 35 percent of the department. Meager to moderate quantities of fresh water available from Tertiary to Quaternary age andesite, basalt, ignimbrite, tuff, and volcanic ash interbedded with sandstone, siltstone, and limestone at depths ranging from 15 to 150 meters. Major aquifers include: Miocene Tamarindo Formation (ignimbrites, basalts, andesites); Matagalpa Group (ignimbrites, basalts, andesites); Coyol Group (ignimbrites, basalts, andesites); and Machucha Group (sandstone, siltstone, and crystallized limestone). Water hardness ranges from slightly to moderately hard. Wells drilled in the unconsolidated materials overlying the bedrock should be screened. Drilling in the basalts requires hard-rock drilling techniques. Accessibility is difficult in dense vegetation and mountainous terrain. Unsuitable to small quantities of fresh water are also available from unconsolidated coarse gravels and lateritic soils overlying bedrock at depths generally greater than 6 meters. Aquifers are suitable for hand pump wells and most are suitable for 3.3-liters-per-second (50 gallons per minute) tactical wells and wells equipped with small submersible pumps.

Departamento de Madriz

Area and relative size: 1,602 square kilometers (1.3 percent of the country)

Estimated Population (1995): 107,567 (2 percent of the population)

Population Density: 67 people per square kilometer

Departmental Capital: Somoto

Location: The department is located in the northwestern part of the country along the border with Honduras.

Surface Water:

Fresh surface water is available in moderate to large quantities during the wet season and in very small to small quantities during the dry season in the area along the Rio Coco (map unit 2). Fresh surface water is seasonally available from streams and lakes in the rest of the department as depicted by map units 3 and 4. Map unit 3 is along some of the tributaries of the Rio Coco. Map unit 4 covers the rest of the department. Small to very large quantities are available during the high flow season from May through November. The low flow season is from December to April when meager to very small quantities are available. Within map unit 4, all but the largest streams go dry for extended periods of time during the low flow season. The departmental capital of Somoto is in map unit 4.

Access to and the development of water sources are generally difficult due to rough terrain, steep slopes, deep gorges, dense vegetation, and the lack of all-weather roads.

Ground Water:

The best areas for ground water exploration are the alluvial aquifers as depicted by map unit 1. About 10 percent of the department is in map unit 1. Small to very large quantities of fresh water are available from Quaternary to Recent age alluvial aquifers. These aquifers are composed of unconsolidated sand and gravel with sandstone lenses and sand and gravel interbedded with clay and silt at depths ranging from 5 to 60 meters. Larger quantities are available as the percentage of clay and silt in the aquifer decreases. Ground water is soft to moderately hard. Accessibility is generally easy, but may be locally hindered in areas of dense forest and steep terrain. Shallow aquifers may be biologically contaminated near settlements. Alluvial aquifers, when properly developed, are suitable for municipal and irrigation wells.

About 25 percent of the department is in map unit 3. Unsuitable to small quantities of fresh water are available from Cretaceous to Tertiary thin to massive bedded sandstone, limestone, shale, conglomerate, and breccia; tuffaceous in part. Locally, coquina, pyroclastics, and diabase are found. Depth to water is generally between 20 and 200 meters. Major aquifers include: Eocene Machuca Formation (limestones, and gravels); Oligocene Masachapa Formation (sandstones, tuffaceous sands, and conglomerates); Eocene Brito Formation (sands, coquinas, and volcanics); and Cretaceous Rivas Formation (sandstones and shales). Water hardness ranges from soft from the sandstones to hard from the limestones. Locally, water may smell foul due to high hydrogen sulfide content. Shallow wells are subject to seasonal fluctuations of the water table and may become dry from November to April. Well siting is generally difficult since many wells yield only meager quantities. Wells sited in coarse to sandy material with low clay percentages will yield the largest quantities of ground water. Drilling in the breccia requires hard rock drilling techniques. Wells should be cased and screened. Accessibility is hindered by dense vegetation and mountainous terrain. Aquifers are suitable for hand pump wells and most are suitable for 3.3-liters-per-second (50 gallons per minute) tactical wells and wells equipped with small submersible pumps. The shallow ground water may be biologically contaminated near settlements.

About 30 percent of the department is in map unit 4. Meager to moderate quantities of fresh water available from Tertiary to Quaternary age andesite, basalt, ignimbrite, tuff, and volcanic ash interbedded with sandstone, siltstone, and limestone at depths ranging from 15 to 150 meters. Major aquifers include: Miocene Tamarindo Formation (ignimbrites, basalts, andesites); Matagalpa Group (ignimbrites, basalts, andesites); Coyol Group (ignimbrites, basalts, andesites); and Machucha Group (sandstone, siltstone, and crystallized limestone). Water hardness ranges from slightly to moderately hard. Wells drilled in the unconsolidated materials overlying the bedrock should be screened. Drilling in the basalts requires hard-rock drilling techniques. Accessibility is difficult in dense vegetation and mountainous terrain. Unsuitable to small quantities of fresh water are also available from unconsolidated coarse gravels and lateritic soils overlying bedrock at depths generally greater than 6 meters. Aquifers are suitable for hand pump wells and most are suitable for 3.3-liters-per-second tactical wells and wells equipped with small submersible pumps. The departmental capital of Somoto is in this unit.

About 35 percent of the Departamento de Madriz is in map unit 5 where ground water exploration is not recommended. Unsuitable to meager quantities of fresh water are seasonally available from Paleozoic age granite, diorite, granodiorite, phyllite, schist, slate, marble and quartzite at depths ranging from 20 to 200 meters. Water hardness is generally soft, but locally may be distasteful and discolored due to high iron and manganese content. Well siting is difficult. Most wells are unproductive. Hard-rock drilling techniques are required. Accessibility is hindered by dense vegetation, hilly, and mountainous terrain. The shallow ground water is often biologically contaminated near settlements.

Departamento de Managua

Area and relative size:	3,672 square kilometers (3.0 percent of the country)
Estimated Population (1995):	1,093,760 (25 percent of the population) The most populated department in Nicaragua
Population Density:	298 people per square kilometer
Departmental Capital:	Managua
Location:	The department is located in the west-central part of the country along the Pacific Ocean and Lago de Managua.

Surface Water:

Fresh surface water is perennially available in enormous quantities from Lago de Managua as depicted by map unit 1. Fresh surface water is seasonally available from streams, lakes, and marshes in most of the department as depicted by map unit 4. Small to very large quantities are available during the high flow season from May through November. During the low flow season from December to April, most streams are dry for extended periods of time. Fresh surface water is scarce or lacking in small parts of the department depicted by map unit 5 and areas too small to be shown on a country-scale map. Meager to enormous quantities of brackish to saline water are available in the Rio Tipitapa valley and from lakes in the calderas of some volcanoes. During the low flow period, some marshy areas along the shore of Lago de Managua can become temporarily brackish. The departmental capital of Managua is in map unit 1.

Access to and the development of water sources is generally not difficult. Locally, dense vegetation and the lack of roads hinder access. Wet marshy ground, dense vegetation and the lack of roads hinder access in the Rio Tipitapa valley.

Ground Water:

The best areas for ground water exploration are the alluvial aquifers located along Lago de Managua and scattered areas along the Pacific Coast as depicted by map unit 1. About 20 percent of the department is in map unit 1. Small to very large quantities of fresh water are available from Quaternary to Recent age alluvial aquifers. These aquifers are composed of unconsolidated sand and gravel with sandstone lenses and sand and gravel interbedded with clay and silt at depths ranging from 5 to 60 meters. Larger quantities are available as the percentage of clay and silt in the aquifer decreases. Ground water is soft to moderately hard. Saline water zones underlie the fresh water zones in the coastal area and caution should be exercised in pumping to prevent saline water intrusion. Saline water wells would require reverse osmosis/desalination equipment. Accessibility is generally easy, but may be locally hindered in areas of dense forest and areas along the coast subject to seasonal inundation. Alluvial aquifers are suitable for municipal and irrigation wells.

About 50 percent of the department is in scattered areas as depicted by map unit 2. Small to enormous quantities of fresh water are available from springs issuing from fractures and contact zones within volcanic deposits in the areas covered by map unit 2. The ground water quality is generally fresh but slightly alkaline and varies in temperature from hot to cold. Hardness ranges from soft to hard. The quality of some of the springs can be brackish to saline and range from slightly alkaline to strongly acidic. Meager to very large quantities of fresh water are also available from Tertiary to Quaternary age volcanic rocks. Primary aquifers include: Las Sierras Group consisting of basaltic to andesitic pyroclastic rocks; Masaya Group Volcanics composed of basaltic to andesitic lavas and pyroclastic materials (volcanic breccia, scoria and ash); and Apoyo Volcanics consisting of pyroclastic dacite pumice and dacitic lavas. The capital city of

Managua is in this map unit. Wells drilled in Departamento de Managua south of Lago de Managua indicate the water levels of the shallow (penetrate static water level by greater than 15 meters) and deep (extend less than 15 meters beyond the static water level) aquifers are hydraulically connected. Although the deeper aquifers may be artesian at some locations, withdrawal of water will cause flow from the shallow aquifer creating a single water table aquifer. Thus, the entire area is considered to be underlain by a water table aquifer, recharged by the rainfall that is not lost by evapotranspiration or surface runoff. Specific capacities for wells in the Managua area south of Lago de Managua range from 25 to 4,000 liters per minute per meter with a mean of 1,130 liters per minute per meter. Total dissolved solids concentrations are greater than 400 milligrams per liter throughout most of the Managua area with higher values north of Laguna de Asososca. East of a North-South line through the Las Mercedes Airport, total dissolved solid concentrations are up to 900 milligrams per liter. The high total dissolved solid values may be due to volcanic activity. The source of the mineralization east of Las Mercedes is probably the Volcán Santiago, active until 1961.

Mean chemical concentrations for wells in the Managua area south of Lago de Managua are:

- Ca = 32 mg/L
- Cl = 118 mg/L
- Mg = 12 mg/L
- SO_4 = 53 mg/L

Aquifer depth ranges from greater than 6 to 150 meters. Static water levels in wells in the Departamento de Managua south of Lago de Managua ranged from greater than 40 to 154 meters.

Map unit 3 covers about 25 percent of the department, along the Pacific coast. Meager to moderate quantities of fresh water are available from Cretaceous to Tertiary age thin to massive bedded sandstone, limestone, shale, conglomerate, and breccia; tuffaceous in part. Locally, coquina, pyroclastics, and diabase are found. Depth to aquifer is generally between 20 and 200 meters. Major aquifers include: Eocene Machuca Formation (limestones, gravels); Oligocene Masachapa Formation (sandstones, tuffaceous sands, and conglomerates); Eocene Brito Formation (sands, coquinas, and volcanics); and Cretaceous Rivas Formation (sandstones, and shales). Water hardness ranges from soft from the sandstones to hard from the limestones. Locally, water may smell foul due to high hydrogen sulfide content. Shallow wells are subject to seasonal fluctuations of the water table and may become dry from November to April in the Pacific region. Well siting is generally difficult and many wells yield only meager quantities. Wells sited in coarse to sandy material with low clay percentages will yield the largest quantities of ground water. Drilling in the breccia requires hard rock drilling techniques. Wells should be cased and screened. Accessibility is hindered by dense vegetation and mountainous terrain. Aquifers are suitable for hand pump wells and most are suitable for 3.3-liters-per-second (50 gallons per minute) tactical wells and wells equipped with small submersible pumps. The shallow ground water may be biologically contaminated near settlements.

Departamento de Masaya

Area and relative size:	590 square kilometers (0.5 percent of the country) The smallest department in Nicaragua
Estimated Population (1995):	241,354 (6 percent of the population)
Population Density:	409 people per square kilometer
Departmental Capital:	Masaya
Location:	The department is located in the southwestern part of the country.

Surface Water:

Fresh surface water is seasonally available from streams, lakes, and marshes in the most of the department as depicted by map unit 4. Small to very large quantities are available during the high flow season from May through November. During the low flow season from December to April, most streams are dry for extended periods of time. Fresh surface water is scarce or lacking as depicted as map unit 5 and areas too small to be shown on a country-scale map. Meager to enormous quantities of brackish to saline water are available in the Rio Tipitapa valley and from lakes in the calderas of some volcanoes. The departmental capital of Masaya is in map unit 4.

Access to and the development of water sources is generally not difficult. However, wet marshy ground, dense vegetation, and the lack of roads hinder access to the Rio Tipitapa valley.

Ground Water:

The best areas for ground water exploration are the alluvial aquifers located in the northern part of the department as depicted by map unit 1. About 20 percent of the department is in map unit 1. Small to very large quantities of fresh water are available from Quaternary to Recent age alluvial aquifers. These aquifers are composed of unconsolidated sand and gravel with sandstone lenses and sand and gravel interbedded with clay and silt at depths ranging from 5 to 60 meters. Larger quantities are available as the percentage of clay and silt in the aquifer decreases. Ground water is soft to moderately hard. Accessibility is generally easy, but may be locally hindered in areas of dense forest and steep terrain. Shallow aquifers may be biologically contaminated near settlements. Alluvial aquifers, when properly developed, are suitable for municipal and irrigation wells.

Map unit 2 covers a large area (about 80 percent) and is located in the southern part of the department. Small to enormous quantities of fresh water are available from springs issuing from fractures and contact zones within volcanic deposits. The ground water quality is generally fresh but slightly alkaline and varies in temperature from hot to cold. Hardness ranges from soft to hard. The quality of some of the springs can be brackish to saline and range from slightly alkaline to strongly acidic. The departmental capital of Masaya is in this unit. Meager to very large quantities of fresh water are also available from Tertiary to Quaternary age volcanic rocks. Primary aquifers include: Las Sierras Group consisting of basaltic to andesitic pyroclastic rocks, the Masaya Group Volcanics composed of basaltic to andesitic lavas and pyroclastic materials (volcanic breccia, scoria and ash) and the Apoyo Volcanics consisting of pyroclastic dacite pumice and dacitic lavas.

Departamento de Matagalpa

Area and relative size: 8,523 square kilometers (7.0 percent of the country)

Estimated Population (1995): 383,776 (9 percent of the population)

Population Density: 45 people per square kilometer

Departmental Capital: Matagalpa

Location: The department is located in the central part of the country.

Surface Water:

Fresh surface water is perennially available in small to very large quantities in the area of the department along the Rio Grande de Matagalpa, the Rio Tuma, and their tributaries. These areas are depicted by map units 1 and 2. Fresh surface water is seasonally available from streams and lakes in the rest of the department as depicted by map units 3 and 4. Map unit 3 is in the eastern part of the department, while map unit 4 covers most of the western part of the department. Small to very large quantities are available during the high flow season from May through November. The low flow season is from December to April when meager to very small quantities are available. Within map unit 4, all but the largest streams go dry for extended periods of time during the low flow season. The departmental capital of Matagalpa is in map unit 4.

Access to and the development of water sources is generally difficult due to rough terrain, steep slopes, deep gorges, dense vegetation and the lack of all-weather roads.

Ground Water:

The best areas for ground water exploration are the alluvial aquifers as depicted by map unit 1. Map unit 1 comprises about 10 percent of the department. Small to very large quantities of fresh water are available from Quaternary to Recent age alluvial aquifers. These aquifers are composed of unconsolidated sand and gravel with sandstone lenses and sand and gravel interbedded with clay and silt at depths ranging from 5 to 60 meters. Larger quantities are available as the percentage of clay and silt in the aquifer decreases. Ground water is soft to moderately hard. Accessibility is generally easy, but may be locally hindered in areas of dense forest and steep terrain. Shallow aquifers may be biologically contaminated near settlements. Alluvial aquifers are suitable for municipal and irrigation wells.

Map unit 3 comprises about 25 percent of the department and is located in the northeastern part of the department. Unsuitable to small quantities of fresh water are available from Cretaceous to Tertiary age thin to massive bedded sandstone, limestone, shale, conglomerate, and breccia; tuffaceous in part. Locally, coquina, pyroclastics, and diabase are found. Depth to aquifer is generally between 20 and 200 meters. Major aquifers include: Eocene Machuca Formation (limestones, and gravels), Oligocene Masachapa Formation (sandstones, tuffaceous sands, and conglomerates), Eocene Brito Formation (sands, coquinas, and volcanics), and Cretaceous Rivas Formation (sandstones, and shales). Water hardness ranges from soft from the sandstones to hard from the limestones. Locally, water may smell foul due to high hydrogen sulfide content. Shallow wells are subject to seasonal fluctuations of the water table and may become dry. Well siting is generally difficult and many wells yield only meager quantities. Wells sited in coarse to sandy material with low clay percentages will yield the largest quantities of ground water. Drilling in the breccia requires hard rock drilling techniques. Wells should be cased and screened. Accessibility is hindered by dense vegetation and mountainous terrain. Aquifers are suitable for hand pump wells, and most are suitable for 3.3-liters-per-second (50 gallons per minute) tactical wells and wells equipped with small submersible pumps. The shallow ground water may be biologically contaminated near settlements.

About 60 percent of the department is in map unit 4. Meager to moderate quantities of fresh water available from Tertiary to Quaternary age andesite, basalt, ignimbrite, tuff, and volcanic ash interbedded with sandstone, siltstone, and limestone at depths ranging from 15 to 150 meters. Major aquifers include: Miocene Tamarindo Formation (ignimbrites, basalts, andesites); Matagalpa Group (ignimbrites, basalts, andesites); Coyol Group (ignimbrites, basalts, andesites); and Machucha Group (sandstone, siltstone, crystallized limestone). Water hardness ranges from slightly to moderately hard. Wells drilled in the unconsolidated materials overlying the bedrock should be screened. Drilling in the basalts requires hard-rock drilling techniques. Accessibility is difficult in dense vegetation and mountainous terrain. Unsuitable to small quantities of fresh water are also available from unconsolidated coarse gravels and lateritic soils overlying bedrock at depths generally greater than 6 meters. Aquifers are suitable for hand pump wells and most are suitable for 3.3-liters-per-second tactical wells and wells equipped with small submersible pumps. The departmental capital of Matagalpa is in this unit.

Departamento de Nueva Segovia

Area and relative size: 3,123 square kilometers (2.6 percent of the country)

Estimated Population (1995): 148,492 (3 percent of the population)

Population Density: 48 people per square kilometer

Departmental Capital: Ocotal

Location: The department is located in the northwestern part of the country along the border with Honduras.

Surface Water:

Fresh surface water is perennially available in small to very large quantities in small areas of the department along the Rio Coco and its tributaries. These areas are depicted by map unit 2. Fresh surface water is seasonally available from streams and lakes in the rest of the department as depicted by map units 3 and 4. Map unit 3 is along the valleys of the tributaries of the Rio Coco, while map unit 4 covers the most of the department. Small to very large quantities are available during the high flow season from May through November. The low flow season is from December to April when meager to very small quantities are available. Within map unit 4, all but the largest streams go dry for extended periods of time during the low flow season. The departmental capital of Ocotal is in map unit 4.

Access to and the development of water sources is generally difficult due to rough terrain, steep slopes, deep gorges, dense vegetation, and the lack of all-weather roads.

Ground Water:

About 90 percent of the department is in map unit 5 where ground water exploration is not recommended. Unsuitable to meager quantities of fresh water are seasonally available from Paleozoic granite, diorite, granodiorite, phyllite, schist, slate, marble and quartzite at depths ranging from 20 to 200 meters. Water hardness is generally soft, but locally may be distasteful and discolored due to high iron and manganese content. Well siting is difficult and most wells are unproductive. Hard-rock drilling techniques are required. Accessibility is hindered by dense vegetation and hilly and mountainous terrain. Aquifers are suitable for hand pump wells and most are suitable for 3.3-liters-per-second (50 gallons per minute) tactical wells and wells equipped with small submersible pumps. The shallow ground water is often biologically contaminated near settlements.

Region Autonomista Atlantico Norte (R.A.A.N.)

Area and relative size:	32,159 square kilometers (26.5 percent of the country) The largest department in Nicaragua
Estimated Population (1995):	192,716 (4 percent of the population)
Population Density:	6 people per square kilometer The least densely populated department in Nicaragua
Departmental Capital:	Puerto Cabezas
Location:	The region is located in the northeast part of the country along the Caribbean Sea and border with Honduras.

Surface Water:

Fresh surface water is perennially available in small to very large quantities in most of the region. Map unit 1 is along the Rio Coco, Rio Grande de Matagalpa, Rio Kukalaya, Rio Prinzapolka, Rio Wawa, and their major tributaries. Map unit 2 is between the major streams. Fresh surface water is seasonally available from streams and lakes in the rest of the region as depicted by map unit 3. Moderate to very large quantities are available during the high flow season from mid-May through February. During the rest of the year, very small to small quantities are available. Fresh surface water is scarce or lacking in the coastal wetlands, estuaries, lagoons, tidal marshes, and mangroves as depicted by map unit 5. Meager to enormous quantities of brackish to saline water are available. On the cays, surface water in the intermittent streams and ponds is generally fresh for only a few days after rains. In most of the region, fresh water runoff during the high flow season is sufficient to temporarily flush the brackish to saline waters out of the some of the marshes, lagoons, and estuaries. The departmental capital of Puerto Cabezas is in map unit 2.

Access to and the development of water sources is generally difficult due to rough terrain, dense vegetation, wet marshy ground, and the lack of roads.

Ground Water:

The best areas for ground water exploration are the alluvial aquifers located along the Caribbean Coast as depicted by map unit 1. Map unit 1 covers about 40 percent of the region. Small to very large quantities of fresh water are available from Quaternary to Recent age alluvial aquifers. These aquifers are composed of unconsolidated sand and gravel with sandstone lenses and sand and gravel interbedded with clay and silt at depths ranging from 5 to 60 meters. Bregman's Bluff Formation consisting of gravel and sand is a main aquifer in the Caribbean region. Larger quantities are available as the percentage of clay and silt in the aquifer decreases. Ground water is soft to moderately hard. Saline water zones underlie the fresh water zones in the coastal area and caution should be exercised in pumping to prevent saline water intrusion. Saline water wells would require reverse osmosis/desalination equipment. Accessibility is generally easy, but may be locally hindered in areas of dense forest and areas along the coast subject to seasonal inundation. Alluvial aquifers, when properly developed, are suitable for municipal and irrigation wells. The departmental capital of Puerto Cabezas is in this unit.

Map unit 3 covers about 25 percent of the region. Unsuitable to small quantities of fresh water are available from Cretaceous to Tertiary age thin- to massive-bedded sandstone, limestone, shale, conglomerate, and breccia; tuffaceous in part. Locally, coquina, pyroclastics, and diabase are found. Depth to water is generally between 20 and 200 meters. Major aquifers include: Eocene Machuca Formation (limestones, and gravels); Oligocene Masachapa Formation (sandstones, tuffaceous sands, and conglomerates); Eocene Brito Formation (sands, coquinas, and volcanics); and Cretaceous Rivas Formation (sandstones, shales). Water hardness ranges from soft from the sandstones to hard from the limestones. Locally, water may smell foul due to high hydrogen sulfide content. Shallow wells are subject to seasonal fluctuations of the water table and may become dry February to April. Well siting is generally difficult and many wells yield only meager quantities. Wells sited in coarse to sandy material with low clay percentages will yield the largest quantities of ground water. Drilling in the breccia requires hard rock drilling techniques. Wells should be cased and screened. Accessibility is hindered by dense vegetation and mountainous terrain. Aquifers are suitable for hand pump wells and most are suitable for 3.3-liters-per-second (50 gallons per minute) tactical wells and wells equipped with small submersible pumps. The shallow ground water may be biologically contaminated near settlements.

Map unit 4 covers about 25 percent of the region. Meager to moderate quantities of fresh water available from Tertiary to Quaternary age andesite, basalt, ignimbrite, tuff, and volcanic ash interbedded with sandstone, siltstone, and limestone at depths ranging from 15 to 150 meters. Major aquifers include: Miocene Tamarindo Formation (ignimbrites, basalts, andesites); Matagalpa Group (ignimbrites, basalts, andesites); Coyol Group (ignimbrites, basalts, andesites); and Machucha Group (sandstone, siltstone, crystallized limestone). Water hardness ranges from slightly to moderately hard. Wells drilled in the unconsolidated materials overlying the bedrock should be screened. Drilling in the basalt requires hard-rock drilling techniques. Accessibility is difficult in dense vegetation and mountainous terrain. Unsuitable to small quantities of fresh water are also available from unconsolidated coarse gravels and lateritic soils overlying bedrock at depths generally greater than 6 meters. Aquifers are suitable for hand pump wells and most are suitable for 3.3-liters-per-second tactical wells and wells equipped with small submersible pumps.

Map unit 5 covers about 10 percent of the region where ground water exploration is not recommended. Unsuitable to meager quantities, of fresh water are seasonally available from Paleozoic age granite, diorite, granodiorite, phyllite, schist, slate, marble, and quartzite at depths ranging from 20 to 200 meters. Water hardness is generally soft , but locally may be distasteful and discolored due to high iron and manganese content. Well siting is difficult and most wells are unproductive. Hard-rock drilling techniques are required. Accessibility is hindered by dense vegetation and hilly to mountainous terrain. The shallow ground water is often biologically contaminated near settlements.

Region Autonomista Atlantico Sur (R.A.A.S.)

Area and relative size:	27,407 square kilometers (22.6 percent of the country)
Estimated Population (1995):	272,252 (6 percent of the population)
Population Density:	10 people per square kilometer
Departmental Capital:	Bluefield
Location:	The region is located in the southeastern part of the country and along the Caribbean Sea.

Surface Water:

Fresh surface water is perennially available in small to very large quantities in most of the region. Map unit 1 is along the Rio Escondido, Rio Grande de Matagalpa, Rio Kurinwas, Rio Mico, Rio Punta Gorda, Rio Siqua, and their major tributaries. Map unit 2 is between the major streams. Fresh surface water is seasonally available from streams and lakes in the western part of the region as depicted by map units 3. Moderate to very large quantities are available during the high flow season from mid-May through February. During the rest of the year, very small to small quantities are available. Fresh surface water is scarce or lacking in the coastal wetlands, estuaries, lagoons, tidal marshes, and mangroves as depicted by map unit 5. Meager to enormous quantities of brackish to saline water are available. On the cays, surface water in the intermittent streams and ponds is generally fresh for only a few days after rains. In most of the region, fresh water runoff during the high flow season is sufficient to temporarily flush the brackish to saline waters out of the some of the marshes, lagoons, and estuaries. The departmental capital of Bluefield is in map unit 5.

Access to and the development of water sources is generally very difficult due to rough terrain, dense vegetation, wet marshy ground, and the lack of roads.

Ground Water:

The best areas for ground water exploration are the alluvial aquifers located along the Caribbean Coast as depicted by map unit 1. About 25 percent of the department is in map unit 1. Small to very large quantities of fresh water are available from Quaternary to Recent age alluvial aquifers. These aquifers are composed of unconsolidated sand and gravel with sandstone lenses and sand and gravel interbedded with clay and silt at depths ranging from 5 to 60 meters. Bregman’s Bluff Formation consisting of gravel and sand is a main aquifer in the Caribbean region. Larger quantities are available as the percentage of clay and silt in the aquifer decreases. Ground water is soft to moderately hard. Saline water zones underlie the fresh water zones in the coastal area and caution should be exercised in pumping to prevent saline water intrusion. Saline water wells would require reverse osmosis/desalination equipment. Accessibility is generally easy, but may be locally hindered in areas of dense forest and areas along the coast subject to seasonal inundation. Alluvial aquifers, when properly developed, are suitable for municipal and irrigation wells. Part of the departmental capital of Bluefield is in this unit.

Map unit 3 comprises about 20 percent of the area and is present near the border with Costa Rica and in the northern part of the region. Unsuitable to small quantities of fresh water are available from Cretaceous to Tertiary age thin to massive bedded sandstone, limestone, shale, conglomerate, and breccia; tuffaceous in part. Locally, coquina, pyroclastics, and diabase are found. Depth to water is generally between 20 and 200 meters. Major aquifers include: Eocene Machuca Formation (limestones, and gravels); Oligocene Masachapa Formation (sandstones, tuffaceous sands, conglomerates); Eocene Brito Formation (sands, coquinas, volcanics); and

Cretaceous Rivas Formation (sandstones, shales). Water hardness ranges from soft from the sandstones to hard from the limestones. Locally, water may smell foul due to high hydrogen sulfide content. Shallow wells are subject to seasonal fluctuations of the water table and may become dry February to April. Well siting is generally difficult and many wells yield only meager quantities. Wells sited in coarse to sandy material with low clay percentages will yield the largest quantities of ground water. Drilling in the breccia requires hard rock drilling techniques. Wells should be cased and screened. Accessibility is hindered by dense vegetation and mountainous terrain. Aquifers are suitable for hand pump wells and most are suitable for 3.3-liters-per-second (50 gallons per minute) tactical wells and wells equipped with small submersible pumps. The shallow ground water may be biologically contaminated near settlements.

Map unit 4 covers about 55 percent of the R.A.A.S. inland from the Caribbean Coast. Meager to moderate quantities of fresh water are available from Tertiary to Quaternary age andesite, basalt, ignimbrite, tuff, and volcanic ash interbedded with sandstone, siltstone, and limestone at depths ranging from 15 to 150 meters. Major aquifers include: Miocene Tamarindo Formation (ignimbrites, basalts, andesites); Matagalpa Group (ignimbrites, basalts, andesites), Coyol Group (ignimbrites, basalts, andesites); and Machucha Group (sandstone, siltstone, crystallized limestone). Water hardness ranges from slightly to moderately hard. Wells drilled in the unconsolidated materials overlying the bedrock should be screened. Drilling in the basalt requires hard-rock drilling techniques. Accessibility is difficult in dense vegetation and mountainous terrain. Unsuitable to small quantities of fresh water are also available from unconsolidated coarse gravels and lateritic soils overlying bedrock at depths generally greater than 6 meters. Aquifers are suitable for hand pump wells and most are suitable for 3.3-liters-per-second tactical wells and wells equipped with small submersible pumps.

Departamento de Rio San Juan

Area and relative size: 7,473 square kilometers (6.2 percent of the country)

Estimated Population (1995): 70,143 (2 percent of the population)
The least populated department in Nicaragua

Population Density: 9 people per square kilometer

Departmental Capital: San Carlos

Location: The department is located in the southern and southwestern parts of the country along the southern shore of Lago de Nicaragua, the Caribbean Sea, and the border with Costa Rica.

Surface Water:

The availability of fresh surface water within the department is variable. Fresh surface water is perennially available in small to very large quantities in the part of the department that extends along the Rio San Juan. Enormous quantities are available from Lago de Nicaragua as depicted by map unit 1. Fresh surface water is perennially available in moderate to very large quantities along the Caribbean coast as depicted by map unit 2. Fresh surface water is seasonally available from streams and lakes in the rest of the department as depicted by map units 3 and 4. Map unit 3 is in the central and southeastern part of the department, while map unit 4 covers the northwestern part of the department. Small to very large quantities are available during the high flow season from May through November. The low flow season is from December to April when meager to very small quantities are available. Within map unit 4, all but the largest streams go dry for extended periods of time during the low flow season. Fresh surface water is scarce or lacking in the coastal wetlands, estuaries, lagoons, tidal marshes, and mangroves as depicted by map unit 5. Meager to enormous quantities of brackish to saline water are available. In most of this part of the department, fresh water runoff during the high flow season is sufficient to temporarily flush the brackish to saline waters out of the some of the marshes, lagoons, and estuaries. The departmental capital of San Carlos is in map unit 1.

Access to and the development of water sources is generally difficult due to rough terrain, dense vegetation and the lack of roads. Along the shore of Lago de Nicaragua access is generally not difficult.

Ground Water:

The best areas for ground water exploration are the alluvial aquifers located along Lago de Nicaragua as depicted by map unit 1. About 20 percent of the department is in map unit 1. Small to very large quantities of fresh water are available from Quaternary to Recent age alluvial aquifers. These aquifers are composed of unconsolidated sand and gravel with sandstone lenses and sand and gravel interbedded with clay and silt at depths ranging from 5 to 60 meters. Larger quantities are available as the percentage of clay and silt in the aquifer decreases. Ground water is soft to moderately hard. Accessibility is generally easy, but may be locally hindered in areas of dense forest and steep terrain. Shallow aquifers may be biologically contaminated near settlements. Alluvial aquifers, when properly developed, are suitable for municipal and irrigation wells. The departmental capital of San Carlos is in this unit.

About 70 percent of the department is in map unit 4. Meager to moderate quantities of fresh water available from Tertiary to Quaternary age andesite, basalt, ignimbrite, tuff, and volcanic ash interbedded with sandstone, siltstone, and limestone at depths ranging from 15 to 150 meters. Major aquifers include: Miocene Tamarindo Formation (ignimbrites, basalts, andesites);

Matagalpa Group (ignimbrites, basalts, andesites); Coyol Group (ignimbrites, basalts, andesites); and Machucha Group (sandstone, siltstone, crystallized limestone). Water hardness ranges from slightly to moderately hard. Wells drilled in the unconsolidated materials overlying the bedrock should be screened. Drilling in the basalt requires hard-rock drilling techniques. Accessibility is difficult in dense vegetation and mountainous terrain. Unsuitable to small quantities of fresh water are also available from unconsolidated coarse gravels and lateritic soils overlying bedrock at depths generally greater than 6 meters. Aquifers are suitable for hand pump wells and most are suitable for 3.3-liters-per-second (50 gallons per minute) tactical wells and wells equipped with small submersible pumps.

Departamento de Rivas

Area and relative size:	2,155 square kilometers (1.8 percent of the country)
Estimated Population (1995):	140,432 (3 percent of the population)
Population Density:	65 people per square kilometer
Departmental Capital:	Rivas
Location:	The department is located in the southwestern part of the country along the western shores of Lago de Nicaragua and the Pacific Ocean.

Surface Water:

Fresh surface water is perennially available in enormous quantities from Lago de Nicaragua as depicted by map unit 1. Fresh surface water is seasonally available from streams and small lakes in most of the department as depicted by map unit 4. Small to very large quantities are available during the high flow season from May through November. The low flow season is from December to April when meager to very small quantities are available. During the low flow season, most streams are dry for extended periods of time. The departmental capital of Rivas is in map unit 4.

Access to and the development of water sources is generally not difficult. Locally, rough terrain, dense vegetation and the lack of roads can hinder access.

Ground Water:

The best areas for ground water exploration are the alluvial aquifers located along Lago de Nicaragua and the Pacific Coast as depicted by map unit 1. About 30 percent of the department is in map unit 1. Small to very large quantities of fresh water are available from Quaternary to Recent age alluvial aquifers. These aquifers are composed of unconsolidated sand and gravel with sandstone lenses and sand and gravel interbedded with clay and silt at depths ranging from 5 to 60 meters. Larger quantities are available as the percentage of clay and silt in the aquifer decreases. Ground water is soft to moderately hard. Saline water zones underlie the fresh water zones in the coastal area and caution should be exercised in pumping to prevent saline water intrusion. Saline water wells would require reverse osmosis/desalination equipment. Accessibility is generally easy, but may be locally hindered in areas of dense forest and areas along the coast subject to seasonal inundation. Alluvial aquifers, when properly developed, are suitable for municipal and irrigation wells. The departmental capital of Rivas is in this unit.

About 60 percent of the department is in map unit 3. Unsuitable to small quantities of fresh water are available from Cretaceous to Tertiary age thin to massive bedded sandstone, limestone, shale, conglomerate, and breccia; tuffaceous in part. Locally, coquina, pyroclastics, and diabase are found. Depth to water is generally between 20 and 200 meters. The major aquifers include: Eocene Machuca Formation (limestones and gravels); Oligocene Masachapa Formation (sandstones, tuffaceous sands, conglomerates); Eocene Brito Formation (sands, coquinas, volcanics); and Cretaceous Rivas Formation (sandstones and shales). Water hardness ranges from soft from the sandstones to hard from the limestones. Locally, water may smell foul due to high hydrogen sulfide content. Shallow wells are subject to seasonal fluctuations of the water table and may become dry November to April. Well siting is generally difficult and many wells yield only meager quantities. Wells sited in coarse to sandy material with low clay percentages will yield the largest quantities of ground water. Drilling in the breccia requires hard rock drilling techniques. Wells should be cased and screened. Accessibility is hindered by dense vegetation and mountainous terrain. Aquifers are suitable for hand pump wells, and most are suitable for 3.3-liters-per-second (50 gallons per minute) tactical wells and wells equipped with small submersible pumps. The shallow ground water may be biologically contaminated near settlements.

About 10 percent of the department is in map unit 4, which is along the border with Costa Rica. Meager to moderate quantities of fresh water are available from Tertiary to Quaternary age andesite, basalt, ignimbrite, tuff, and volcanic ash interbedded with sandstone, siltstone, and limestone at depths ranging from 15 to 150 meters. Major aquifers include: Miocene Tamarindo Formation (ignimbrites, basalts, andesites); and Matagalpa Group (ignimbrites, basalts, andesites); Coyol Group (ignimbrites, basalts, andesites); and Machucha Group (sandstone, siltstone, crystallized limestone). Water hardness ranges from slightly to moderately hard. Wells drilled in the unconsolidated materials overlying the bedrock should be screened. Drilling in the basalt requires hard-rock drilling techniques. Accessibility is difficult in dense vegetation and mountainous terrain. Unsuitable to small quantities of fresh water are also available from unconsolidated coarse gravels and lateritic soils overlying bedrock at depths generally greater than 6 meters. Aquifers are suitable for hand pump wells and most are suitable for 3.3-liters-per-second tactical wells and wells equipped with small submersible pumps.

VI. Recommendations

A. General

Most of the agencies and organizations interviewed during the country visit are keenly aware of the need to apply more resources to planning, development, and management of Nicaragua's water resources. A water law, a national water sector, and a national strategy are critically needed. Many agencies and organizations are responsible for overseeing the water resources of the country. The primary ones are: ENEL, ENACAL, and MARENA. Providing technical and administrative training to the institutions involved in the management of water resources is recommended. They need to know what is happening with the water resources, the limitations of the water resources, and the quality and quantity of the nation's water.[94]

Surface water contamination is prevalent throughout the country. Much of the cause and source of this contamination is untreated domestic and industrial waste disposal, as most effluent is released into the rivers without treatment. Regulation and enforcement of waste disposal are necessary to slow the increasing discharge of pollutants into the nation's waterways. Among other devastating consequences, the indiscriminate clearing of the rain forests causes excessive sediment loads in the rivers.

Some specific recommendations and suggestions are as follows:

- Establish an Environmental Water Monitoring System.
- Obtain an accurate assessment of the water quality.
- Create maps delineating various water quality problems (e.g.; metals, sulfates, nitrates, etc.).
- Characterize water contamination risks.
- Measure the volumes of extraction and releases for all uses and for all users.
- Establish, support, and regulate a permit system for wastewater discharge.
- Develop adequate technology.
- Develop hydrologic plans by watershed.
- Delineate flooding, other hydrologic risk zones;
    1. Establish three potential flood zones; frequent, occasional, and exceptional;
    2. Identify and classify the watershed flood areas;
    3. Establish a classification of the uses of the land, limits in the use and hydrologic studies of the drawdown avenues;
    4. Identify black points, and establish an action program for their elimination.
- Establish protection zones in each watershed.[95]

B. National Water Resources Management and Policy

Water resources development and management programs are decentralized. The primary problem is the lack of a national commission for potable water supply and sanitation. Data related to wells and the various agencies and users responsible for water resources maintain surface water systems separately. As a result, lack of coordination exists between agencies and users, as well as within the different sectors. This creates duplication of effort and a lack of exchange of technical knowledge and data.

The potential benefits of improved the water resources management and policy would be enormous. The broad goals would focus on public health, economic development, social well being, and environmentally sustainable development. With an established framework, certain national policy issues and management strategies would emerge. This would require an assessment of the purposes of various water resources projects such as water supply, water quality, irrigation, navigation, hydropower, and fish and wildlife. The in-country evaluation of all needs could lead to a restructuring of the water resources management and to a more defined national interest and policy.

Water resources management and policy are the core of efficient and equitable development. Recommended approaches for gradual improvement of the current management system are as follows:

- Form a national commission for potable water and sanitation;
- Establish a national water law;
- Form a water resources council;
- Conduct comprehensive water resources evaluations;
- Establish a national clearinghouse;
- Sponsor national and international meetings;
- Form task forces to address water resources issues.

These approaches are explained in the following paragraphs.

1. National Water Commission

The other sectors of the country, such as agriculture, environment, health, and electricity have a national commission, but none exists for potable water and sanitation. Due to the lack of a national commission, the water users of the country act and use the water resources independently. Ideally, the different users should be unified under one commission. The users would include hydropower, domestic water supply, irrigation, industry, and tourism.

2. National Water Law

For the past 10 years, a water law has been proposed but failed to pass. It is expected to pass in the new Government by the year 2001. Meetings and discussions with managers have indicated a good, practical water law is needed, but this law must be uncomplicated and enforceable.

3. Water Resources Council

Formation of a water resources council at the national or international level would encourage information exchange and possibly shared organizational funding for common needs. The council should be made up of high-level executives from member entities. At the national level, candidate members would be heads of national offices and development corporation presidents. At the international level, candidate members would include the heads of the USAID, CARE, and the European Economic Community. Each of the members could assign staff to help with special studies and evaluations. The focus of this council would be to discuss water resources activities in Nicaragua and act as a policy advisor to the Nicaraguan President. It is conceivable that member nations or other entities could contribute to a fund that would finance common water resources development or interrelated needs. Examples of common needs are (1) development of a national database for hydrology and hydraulics information, (2) conservation of soil and water resources, and (3) environmental enhancement. The permanent establishment of a Water Resources Council to oversee the water resources policy is encouraged.

4. Comprehensive Water Resources Evaluations

The potential savings that could result from conducting comprehensive evaluations of all water resources and interrelated activities are enormous. These evaluations would require staffing for several years or a significant outside staffing contract. Objectives would be to analyze all ongoing and proposed water resources activities in the country. This would require discussions with hundreds of entities involved. These discussions would be followed with extensive field evaluations. After all the necessary field information is collected, the long and arduous task of research and analysis can begin. This task would uncover many commonalities and duplications, which could then be eliminated, allowing for a more cost-effective operation. Potential exists for significant savings due to economy of scale, such as consolidating numerous similar or identical efforts into one.

5. National Clearinghouse

Another method of assimilating information among various national and international entities would be through the establishment of a clearinghouse. The first duty of this office would be to develop a mailing list of all entities with shared interests in a particular subject matter. Next, the parties involved in water resources development would be encouraged to forward their respective water resources proposals. Then the office would simply mail pertinent data to appropriate parties upon request. A primary difficulty with this alternative would be the high expenses for the staffing required. Another difficulty would be the process of obtaining uniform cooperation from all those involved. The only known examples of success with clearinghouses are in environments where the use of the process is mandated by force of law.

6. National and International Meetings

National and international symposia or meetings are established formats for encouraging the exchange of information. These meetings can be an excellent forum for scientists, engineers, and water managers to exchange ideas, concepts, and proven water resources management experiences. However, for effectiveness, the subject matter must not be too theoretical. Proposals should be realistic and able to be immediately implemented, and suggestions for long-range projects established. A national gathering, with selected international participation, would be a good initial meeting. This meeting would also be a good forum to discuss other national water policy alternatives, i.e., water resources council, comprehensive water resources evaluations, and national clearinghouses. The meeting with a suggested duration of 3 to 7 days should be held in an easily accessible place such as Managua. Suggested topics and workshops to be covered include: national water policy issues, water conservation, drought management, major water resources projects either planned or under construction, experiments in changing crops, reforestation, soil erosion, irrigation techniques, well drilling, water quality, water treatment, and hydropower.

7. Formulation of Task Forces

This idea is somewhat similar to others previously discussed. The difference is that one major national agency would have to take the initiative to lead the program. The first step would be to identify the national needs that would be of widespread interest to entities operating in Nicaragua. Such needs might include a national water law, a national education program, a national database for technical data, national surveys and mapping, and a national program for soil and water conservation.

The lead agency would then need to correspond with the various national and international entities to co-sponsor the project by assigning members of their organization to the task force.

Another variation of the task force and the water resources council concepts is to establish a water resources commission. The task of this commission would be to evaluate the same national water policy issues discussed in the previous paragraph, with a view toward making recommendations on water policy and the appropriate level of federal involvement. These recommendations should be documented in a report by the commission. The commission would consist of three to six high-level officials in Nicaragua. The President would appoint the commission members for 1 to 3 years with staggered terms for consistency and fresh approaches. They should have a blend of various backgrounds; engineers, scientists, agricultural scientists, university professors, politicians, economists, and geologists are all good candidates. This commission would need a small staff to manage the details of the commission operation and to prepare and disseminate reports. The commission members would hold a series of public meetings and/or use a format of requesting testimony from a wide spectrum of professionals, agencies, and the public. They would also solicit input from various national and international agencies. This, in effect, could result in a cost-free (to Nicaragua) task force representing a variety of entities. From this pool of manpower, several committees and subcommittees could be formed to thoroughly evaluate various subjects related to national water policy, water agencies involvement, and other national water resources needs.

8. Suggested Strategy

It is difficult to suggest a strategy because of a lack of knowledge of the reality of the bureaucracy and the political arena in Nicaragua. A well-designed program in any of the areas discussed could conceivably be worthwhile. From the perspective of an outsider, it appears a two-pronged approach consisting of the permanent establishment of a National Water Commission and the passing of a National Water Law would produce the greatest results.

C. Watershed Protection and Management

A common concern of most government officials and technical experts is the impact of deforestation on the environment and on water resources. Integral watershed management is needed to control deforestation and the resulting erosion and sedimentation. Development of comprehensive watershed and basin management plans is needed to curb these impacts. The intent of a watershed management plan is to achieve a comprehensive view of water and land resource problems within a watershed and to identify opportunities and authorities to address such problems. Watershed planning is a systematic approach to (1) evaluating alternative uses of water and land resources, (2) identifying conflicts and trade-offs among competing uses, and (3) making contemplated changes through informed decisions.

Plans should include (1) short-term measures (i.e., erosion stabilization, small water supply systems, hydrologic and meteorological stations, including the repair of the existing gages); (2) interim measures (i.e., sediment control programs, flood plain management, small reservoirs); and (3) long-term measures (i.e., reforestation, large impoundment for flood control, hydropower, and water supply).

D. Troop Exercise Opportunities

1. Well Exercises

Particularly because many of the rivers are contaminated and surface water availability is declining, more of the water supply needs of Nicaragua will be dependent upon ground water resources. Overall, the quality of ground water is good throughout the country. Small hand pump wells are in great demand, particularly in rural areas. Installing small hand pump wells, especially in rural areas as part of U.S. troop engineering exercises, could be of great benefit. New wells installed should be designed to protect against surface water contamination. The wells should have a minimum 30-meter-thick (100-foot) grout seal to protect the aquifer from becoming contaminated from surface water runoff or from the shallow aquifer. These wells could be a source of safe potable water to replace contaminated surface water supplies in certain areas of the country.

2. Small Surface Impoundments

In certain areas of the country, the construction of small impoundments for capturing water for water supply may be considered. Mountain ranges cover much of the land surface. In these mountainous areas, depth to aquifers may be too great for troop exercises, and accessibility may be difficult. Other places where small impoundments may be considered are areas where aquifer drawdown is associated with the impacts of deforestation and where ground water exploration may be too difficult for troop exercises. Surface impoundments may also be beneficial for decreasing surface runoff and erosion and aiding aquifer recharge. Extreme caution should be exercised in site selection because of the potential for water contamination. These impoundments should be considered only in areas where the surface water is not heavily polluted, such as in the volcanic highlands, upstream from populated places, away from untreated domestic wastewater discharge, and away from industrial sites and major cities. The impoundments should be sited where water contamination would not be a problem. Design of these impoundments will not be difficult, and construction techniques will be very similar to local construction techniques. The other main factors are selecting a suitable site, sizing the embankment, and designing the outlet structures. The construction of these sites can be accomplished by U.S. troops.

E. Water Quality and Supply Improvement

Much of the population lacks access to water supply and sanitation services, which directly affects the quality of life. Wastewater treatment is also lacking throughout the country, with much effluent discharged into the waterways without treatment. Wastewater treatment is needed to improve the quality of the surface water resources of the country, because much of the population uses surface water for water supply needs. As the quantity of available surface water decreases and the population continues to grow, the need for ground water resources increases.

The establishment of an Environmental Water Monitoring System is recommended. Water is critical as a main source of life and of the socio-economic development of a country. Water and its intended use should be protected and managed responsibly and in a sustainable way. The following is a list of recommended actions:

- Obtain a general perspective of the quality of surface and ground water;
- Prepare elaborate maps with different water quality problems (metals, sulfates, nitrates, etc.);
- Estimate the nutrient transportation in rivers;
- Characterize the potential water contamination risks;
- Reinforce and modernize the activities of the evaluation of the water resources with respect to quantity and quality in order to know their availability and use;
- Measure the volumes of extraction and releases for all uses and for all users, to increase the efficiency in using water;
- Establish a permit system for waste water discharge, and support the institutional capacity for the exercise of the monitoring.[96]

VII. Summary

The water resources situation of the country is critical and of great concern. Many reasons for this include:

- Uneven rainfall distribution;
- Degradation of the watersheds caused by an extremely high rate of deforestation;
- No single agency responsible for management of water resources;
- Lack of wastewater collection and treatment, and proper solid waste disposal;
- Poor water resources management;
- Lack of adequate data needed to make informed decisions;
- Poor irrigation supply network leading to underdevelopment of sector;
- Rapid growth in urban areas increasing demand beyond system capacity;
- Lack of a national water law to protect and preserve the resources; and
- Poor distribution networks.

Critical issues are the lack of access to water and sanitation, the extensive environmental damage caused by rampant deforestation, the lack of a national water sector and a comprehensive and enforceable water law. Solutions to these issues present significant challenges to the managers of the water resources of Nicaragua.

The lack of policy and the lack of a water law constitute one of the largest weaknesses in managing the water resources. This results in uncontrolled exploitation and use of the water. The impacts to downstream users from surface water withdrawals upstream are not measured due to lack of regulation on withdrawals.[97]

The recommendations offered in this report present some opportunities to improve the water resources situation. If adopted, these actions can have positive long-term impacts. Many of the other issues discussed in this report will require long-term institutional commitments to effect change. Proper management of the abundant water resources of Nicaragua can provide adequately for the needs of the country.

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APPENDIX A

List of Officials Consulted
and
List of Agencies Contacted

Many individuals in the public and private sectors were consulted and provided exceptional cooperation and support:

List of Officials Consulted

Name, Title	Agency/Firm	Address	Tel/Fax/Email
Richard Adams, Advisor, Water and Sanitation Programs	USAID	American Embassy Unit 2712, Box 9 APO AA 34021	Tel: (505) 267-0502, ext 206 Fax: (505) 278-3828 Email: radams@BARRB0203.usaid.gov
Rodger Garner, Deputy Director	USAID	American Embassy Unit 2712, Box 9 APO AA 34021	
Ray Baum, Chief, Office of Enterprise and Rural Development	USAID	American Embassy Unit 2712, Box 9 APO AA 34021	Tel: (505) 267-0502 Fax: (505) 277-0210 Email: rbaum@usaid.gov
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Maria Elena Vivas, Field Manager, Hurricane Mitch Reconstruction Project	USDA	American Embassy Unit 2712, Box 22 APO AA 34021	Tel: (505) 265-2605 ext 207 Fax: (505) 265-2612 Email: mvivas@humr.org.ni
Luis Palacios Ruiz, Director, Recursos Hidricos	INETER	Apartado 2110 Managua	Tel: (505) 249-2756 Fax: (505) 240-0042 Email: rhidrico@ibw.com.ni
David Ogden, National Director	EHP	De la Funeraria Don Bosco 1 1/2 c. Arriba Casa #19, Los Robles Managua	Tel: (505) 270-2378 (505) 270-2380 Fax: (505) 278-4961 Email: EHP@ibw.com.ni
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Fernando Martinez, Director of Drilling	ENACAL	Contigua al la Casona Apartados Postales 3599 y 9867 Managua	Tel: (505) 265-0861 Fax: (505) 266-7895
Benjamin Berrios	ENACAL	Contigua al la Casona Apartados Postales 3599 y 9867 Managua	Tel: (505) 265-0861 Fax: (505) 266-7895
Cidar Cardenas	MAGFOR	Km 8 1/2 Carreterra a Masaya Managua	Tel: (505) 276-1489
José Toruño, Coordinator of Water and Sanitation	CARE	Sandy's Carretera a Masaya 1 c. abajo 1/2 c. al lago P O Box 3084 Managua	Tel: (505) 267-8395 (502) 278-2099 Fax: (505) 267-0386 Email: jtoruno@care.org.ni

List of Agencies Contacted

Organization	Acronym	Translation	Area of Responsibility
Cooperative for American Relief to Everywhere	CARE		U.S. relief organization.
Environmental Health Project	EHP		Administers $12 million USAID work through PVO's.
Empresa Nicaragüense de Acueductos y Alcantarillados	ENACAL	National Water Authority	Water supply distribution to the population, urban and rural.
Instituto Nicaragüense de Estudios Territoriales, Dirección de Recursos Hídricos	INETER	Nicaraguan Institute of Territorial Research, Water Resources	For water resources, INETER observes, collects, processes and publishes data about coastal and inland surface water and ground water and evaluates their availability. Operates hydrometric, piezometric and hydrographic networks.
Ministerio Agropecuario y Forestal	MAGFOR	Ministry of Forestry and Ranching	
Ministerio del Ambiente y Recursos Naturales	MARENA	Ministry of the Environmental and Natural Resources	To prevent the deterioration of the quality of surface water and ground water through the establishment of plans and strategies to protect against possible sources of contamination.
U.S. Department of Agriculture	USDA		Study and implement projects due to Hurricane Mitch damage.

APPENDIX B

Glossary

Glossary

acidic rock	A type of igneous rock (e.g. granite) that consists predominantly of light colored minerals and more than 66 percent free of combined silica.
agricultural runoff	That portion of precipitation that flows over the ground surface draining farmlands and feedlots. Usually is polluted by agricultural wastes. Wastes include pesticides and fertilizers, animal manure and carcasses, crop residues, sediment from erosion, and dust from plowing.
agrochemicals	Chemicals used in agricultural practices; includes pesticides, herbicides, and fertilizers.
alluvial	Pertaining to processes or materials associated with transportation or deposition by running water.
alluvium	Sediment deposited by flowing water, as in a riverbed, flood plain, or delta.
alkaline rock	A rock containing more than average amounts of potassium and sodium-bearing minerals.
andesite	A fine- to medium-grained, hard, dense, brown to gray, volcanic igneous rock.
aquifer	A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.
artesian	Describes ground water which is under sufficient pressure that it can rise above the aquifer containing it. Flowing artesian wells are produced when the pressure is sufficient to force the water above the land surface.
ash	A volcanic sediment of rock detritus, usually glass, that is less than 4 millimeters in diameter. Ash usually blows out of a volcano.
bankfull	A river stage at which a stream first overflows its natural banks.
basalt	A very fine-grained, hard, dense, dark-colored igneous rock which occurs widely in lava flows. Basalt is very difficult to drill through.
basin	A low area toward which streams flow from adjacent hills. Ordinarily, a basin opens either toward the sea or toward a downstream outlet; but in an arid region without an outlet, a basin can be completely surrounded by higher land.
bicarbonate (HCO_3)	A negatively charged ion which is the dominant carbonate system species present in most waters having a hydrogen-ion concentration (pH) value between 6.4 and 10.3. Excessive concentrations typically result in the formation scale.
biological contamination	The presence in water of significant quantities of disease-producing organisms.
brackish water	Water that contains more than 1,000 milligrams per liter but not more than 15,000 milligrams per liter of total dissolved solids.

braided	A stream that divides into or follows an interlacing or tangled network of several small branching and reuniting shallow channels separated from each other by islands or channel bars, resembling in plan the strands of a complex braid.
breccia	Gravel-size or larger angular rock fragments in a finer grained material.
calcium (Ca)	An abundant alkali metal found in natural waters.
caldera	A basin-shaped volcanic depression, more or less circular, formed by volcanic explosion or the collapse or erosion of a volcanic cone.
carbonate rock	A rock, such as limestone or dolomite, that consists mainly of carbonate minerals.
cay	A comparatively small and low coastal island of sand and coral. Cay is pronounced “key,” and is also spelled caye.
channel	A perceptible natural or artificial water which periodically or continuously contains moving water or which forms a connecting link between two water bodies.
chemical contamination	The presence in water of a significant quantity of chemicals that may be a health risk.
chloride (Cl)	A negatively charged ion present in all natural waters. Excessive concentrations are undesirable for many uses of water. Chloride may be used as an indicator of domestic and industrial contamination.
clay	Individual rock or mineral particles less than 0.002 millimeter in diameter.
coastal plain	Any plain which has its margin on the shore of a large body of water, particularly the sea, and generally represents a strip of recently submerged sea bottom.
conglomerate	Gravel-size or larger, consolidated, rounded to semirounded rock fragments in a finer-grained material. Depending upon the degree of cementation, the drillability and ground water potential can vary significantly.
consolidated	Once loosely aggregated, soft, or liquid earth materials that have become firm and coherent rock.
contaminant or pollutant	As applied to water, any dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological material, radioactive material, heat, wrecked or discarded equipment, rock, sand, dirt or industrial, municipal, and agricultural wastes discharged into water.
coquina	Limestone composed of broken shells, coral, and other organic debris.
crater lake	A lake formed by the accumulation of rain and ground water in a volcanic crater or caldera.
Cretaceous period	A division of geologic time from 66 to 138 million years ago, during which certain rocks were formed. The Cretaceous period falls chronologically after the Jurassic and before the Tertiary periods. It is the youngest division of the Mesozoic era.

debris flow	The general designation for all types of rapid flowage involving debris of various kinds and conditions.
desalination	A water purification complex that removes dissolved salts from brackish or saline water to improve water quality.
diabase	An intrusive rock consisting essentially of labradorite and pyroxene.
diorite	A medium- to coarse-grained, dark-colored, hard, intrusive igneous rock.
discharge	Quantity of flow.
drainage basin	The land area from which water drains into a stream, lake, or other body of water.
drought	An extended period of dry weather or a period of deficient rainfall that may extend over an indefinite period of time.
dry season	The period of the year when there is little to no rainfall or when rainfall is at a minimum.
effluent	Solid, liquid, or gas wastes which enter the environment as a by-product of man-oriented processes. The discharge or outflow of water from ground or subsurface storage.
Eocene	A division of geologic time between 38 and 55 million years ago. Falls chronologically after the Paleocene and before the Oligocene. Included in the Tertiary period.
estuary	A passage in which the tide meets a river current; an arm of the sea that extends inland to meet the mouth of a river; that part of a stream influenced by the tide of the body of water into which it flows.
evapotranspiration	A term embracing that portion of the precipitation returned to the air through direct evaporation or by transpiration of vegetation.
fault	A fracture or fracture zone of the Earth along which there has been displacement of one side with respect to the other.
fertilizer	Any organic or inorganic material of natural or synthetic origin that is added to a soil to supply elements essential to plant growth.
flash flood	Flood of short duration with a relatively high peak rate of flow, usually resulting from a high-intensity rainfall over a small area.
flashy	Stream in which flow collects rapidly from the steep slopes of the catchment, thus causing the flood peak to occur soon after the rain. The flow in such streams usually subside as rapidly as they collect.
fluvial	Of or pertaining to rivers or produced by river actions.
fracture	A break in a rock with no significant displacement across the break.
freshwater	Water that contains 600 milligrams per liter or less of chlorides, 300 milligrams per liter or less of sulfates, and 1,000 milligrams per liter or less of total dissolved solids.
gaging station	A particular site on a stream, canal, lake, or reservoir where systematic observations of height or discharge are obtained.
gorge	A narrow, deep valley with nearly vertical rocky walls.
gradient (slope)	The inclined surface of a hill, mountain, ridge, or any other part of the Earth's surface.

granodiorite	A hard crystalline, hard igneous rock that is massively bedded, light to dark grey, medium to coarse grained, and often foliated.
granite	A coarsely crystalline, hard, massive, light-colored igneous rock. If not highly fractured or weathered, granite is difficult to drill through and normally yields little ground water.
gravel	Individual rock or mineral particles that range in diameter from the upper limit of sands (4.76 millimeters) to a diameter of 76 millimeters according to the Unified Soil Classification.
ground water	Water beneath the Earth's surface, often between saturated soil and rock, that supplies wells and springs.
gully	A small, elongated, usually eroded depression in the land surface that is usually dry except after a rainstorm. A gully is smaller than a ravine but larger than a rill.
hand pump well	A well, designed to supply water for domestic use, that is powered by a hand-drawn piston pump.
hard water	Water that has a high concentration of calcium and magnesium.
hardness	A measurement of the amount of calcium carbonate ($CaCO_3$) in the water which can form an insoluble residue.
headwaters	The upper reaches of a stream near its source. Streams in headwater areas are typically very small and may only flow in response to rain or melting snow.
herbicide	A class of substances used to destroy plants. In small amounts, it may be harmful to human health.
high flow season	The period of time when a stream's discharge is greater than average.
hurricane	A severe weather phenomenon with violent rotating winds in which the maximum sustained surface wind is 119 kilometers per hour (74 miles per hour) or more. The term hurricane is used for Northern Hemisphere cyclones east of the International Dateline to the Greenwich Meridian.
hydrographic data	Records of observation and measurements of physical facts, occurrences, and conditions related to precipitation, stream flow, ground water, quality of water, and water use.
igneous	A class of rock formed by the solidification of molten material. If the material is erupted onto the Earth's surface, the rock is called an extrusive or volcanic rock; if the material solidifies within the Earth, the rock is called an intrusive or plutonic rock.
ignimbrite	A silicic volcanic rock forming thick, massive, compact, lava-like sheets. Ignimbrite consists mainly of a fine-grained rhyolitic tuff, and it often displays well-developed prismatic jointing.
impermeable	Bed or stratum of material through which water will not move.
incise	A channel or notch that has been downcut or entrenched into the ground surface.
incision	To cut into a material, as a stream cuts into a plain.

insecticide	A class of substances used to destroy insects. In small amounts, insecticides may be harmful to human health.
intake	The place at which fluid is taken into a pipe.
interbedded	Occurring between beds or lying in a bed parallel to other beds of a different material.
intermittent (lake)	A lake or small water body that contains water only during certain times of the year, as when it receives water from streams, springs, or from some surface source such as rain.
intermittent (stream)	A stream or reach of a stream that flows only at certain times of the year, as when it receives water from springs or from some surface source such as rain.
iron (Fe)	Iron dissolved in natural ground water from rocks. Iron concentrations as low as 0.3 milligrams per liter cause reddish-brown stains on fixtures and fabrics washed in the water, as well as an unpleasant taste in drinking water.
joint	A fracture in a rock where there has been no movement of the two sides.
lagoon	A body of shallow water similar to a lake with a restricted inlet from the sea that contains both brackish and saline water.
lapilli	Deposit of loose to lightly compacted, typically scoriaceous volcanic fragments 2 to 64 millimeters in diameter.
lateritic soil	Red and reddish soil leached of soluble minerals and of alumina and silica, but retaining oxides and hydroxides of iron.
lava	Fluid rock such as that which issues from a volcano or a fissure in the Earth's surface. Lava is also the same material solidified by cooling.
lens	A body of rock with a general convex form, thick in the central part and thinning toward the edges.
limestone	Soft to moderately hard rock composed of calcium carbonate. Limestone is often highly fractured and solutioned, and it often yields significant volumes of ground water.
low flow season	The period of time when a stream’s discharge is less than average.
lowland	A general term for extensive plains that are not far above sea level.
magnesium (Mg)	An abundant alkali metal found in natural waters that is essential in plant and animal nutrition.
manganese (Mn)	A hard, brittle, grayish metallic element used as an alloying agent in steel to give it toughness.
mangroves	A group of plants that grow in a tropical or subtropical marine swamp. Also, a marine swamp dominated by a community of these plants.
marble	A relatively soft, fine- to coarse-grained, massive, crystalline rock which forms from limestone or dolomite.
marsh	A shallow lake, usually stagnant, filled with rushes, reeds, sedges, and trees.
meander	One of a series of somewhat regular and looplike bends in the course of a stream.

Mesozoic period	A division of geologic time from 66 to 240 million years ago, during which certain rocks were formed. This era falls chronologically after the Paleozoic and before the Cenozoic eras. It includes the Triassic, Jurassic, and Cretaceous periods.
metamorphic	Rocks formed in the solid state from previously existing rocks in response to pronounced changes in temperature, pressure, and chemical environment.
milliequivalent	A chemical analysis expression where the concentration is represented by taking the formula weight of the ion and dividing it by the ionic charge.
Miocene	A division of geologic time from 5 and 24 million years ago, during which certain rocks were formed. The Miocene falls chronologically after the Oligocene and before the Pliocene. Included in the Tertiary period.
nitrate (NO_3)	A mineral compound characterized by a fundamental anionic structure of NO_3. Nitrate may be an indicator of ground water pollution.
Oligocene	A division of geologic time from 24 to 38 million years ago. Falls chronologically after the Eocene and before the Miocene. Included in the Tertiary period.
ore	A mineral or aggregate of minerals from which a valuable constituent, especially a metal can be profitably extracted.
ore refining	A general term for various chemical and manufacturing processes which removes the impurities from raw ore.
organic material	Includes plant and animal residues in various stages of decomposition.
Paleozoic era	A division of geologic time from 570 to 240 million years ago during which certain rocks were formed. The Paleozoic era falls chronologically after the Proterozoic and before the Mesozoic eras. Includes the Cambrian, Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, and Permian periods.
peak flow (flood peak)	The highest value of the stage or discharge attained by a flood; thus peak stage or peak discharge.
perennial	Pertaining to water that is available throughout the year.
perennial stream	A stream that flows year-round. A perennial stream is usually fed by ground water, and its water surface generally starts at a lower level than that of the water table in the area.
permeability (rock)	The property or capacity of a porous rock for transmitting a fluid. Permeability is a measure of the relative ease of fluid flow under unequal pressure. The customary unit of measure is a millidarcy.
pesticides	A class of substances used to destroy insects, weeds, and other pests like rodents. Includes insecticides and herbicides. In small amounts, pesticides may be harmful to human health.
pH	Hydrogen-ion concentration: a measure of the acidity or basicity of a solution. A measure of the acidity or alkalinity of a solution, numerically equal to 7 for neutral solutions, increasing with increasing alkalinity and decreasing with increasing acidity. The pH scale

	commonly in use ranges from 0 to 14.
phenol	A white crystalline compound, corrosive and poisonous, used to make synthetic resins.
phyllite	A foliated rock that is intermediate in composition and fabric between slate and schist.
pollution (water)	The addition to a natural body of water of any material that diminishes the optimal economic use of the water body and has an adverse effect on the surrounding environment.
porosity	The ratio of the volume of the openings (voids, pores) in a rock or soil to its total volume. Porosity is usually stated as a percentage.
potable (potable water)	Describes water that does not contain objectionable pollution, contamination, minerals, or infective agents and is considered satisfactory for domestic consumption.
precipitation	Water droplets as rain or ice particles as snow that fall to the Earth's surface.
pumice	An excessively cellular, glassy, extrusive volcanic rock.
pyroclastic	A type of rock formed by the accumulation of fragments of volcanic rock scattered by volcanic explosions.
quartzite	An extremely hard, fine to coarsely granular massive rock which forms from sandstone. Quartzite is one of the hardest, toughest, and most durable rocks. Quartzite is poor as an aquifer unless highly fractured.
Quaternary period	A division of geologic time from the present to 1.6 million years ago, during which certain rocks were formed or sediments deposited. The Quaternary period falls chronologically after the Tertiary period. It is generally broken down into the Pleistocene and Holocene, and is the youngest division of the Cenozoic Era.
reach	An extended part of a stream, generally from points where there are major changes in the stream's overall slope. A stream may be divided into three reaches, an upper with the highest slope, a middle with moderate slopes, and a lower with the lowest slope.
Recent	The most recent geologic time division, from the present to 10,000 years ago, during which certain rocks were formed or sediments deposited. This age is the youngest division of the Quaternary period. It falls chronologically after the end of the Pleistocene, and is synonymous with Holocene.
recharge	Addition of water to the zone of saturation from precipitation, infiltration from surface streams, and other sources.
reservoir	A pond, lake, basin or other space either natural or created that is used for storage, regulation, and control of water for a variety of uses.
return period or recurrence interval	The average time interval between actual occurrences of hydrological events of a given or greater magnitude.
rift valley	A valley that has developed along a long, narrow, continental trough that is bounded by normal faults, generally formed by extension or the pulling apart of land masses.
rill	A very small stream.

runoff	That portion of the precipitation in a drainage area that is discharged from the area in stream channels. Types include surface runoff, ground water runoff, and seepage.
saline water	Water containing greater than 15,000 milligrams per liter of total dissolved solids. Saline water is undrinkable without treatment.
saline water marsh (saltwater marsh)	A marsh that is periodically flooded by saltwater. Contains salt-tolerant plants.
salinity	A measure of the concentration of dissolved mineral substances in water.
salt	A general term for naturally occurring halite or sodium chloride ($NaCl$).
saltwater intrusion or saline water intrusion	Displacement of fresh surface or ground water by the advance of saltwater due to its greater density. Saltwater intrusion usually occurs in coastal and estuarine areas where it contaminates freshwater wells.
sand	Individual rock or mineral particles that range in diameter from the upper limit of fines (0.08 millimeter) to the lower limit of gravel (5 millimeters).
sandstone	A soft to moderately hard sedimentary rock composed primarily of cemented quartz grains. Many aquifers and oil reservoirs are sandstone.
schist	A fine- to coarse-grained, foliated, metamorphic rock composed of discontinuous thin layers of parallel minerals. Schist has a tendency to split along these layers into thin slabs or flakes.
sedimentary (rocks)	A class of rocks formed from the accumulation and solidification of a variety of sediments.
sediment	Solid mineral and organic materials that are (1) in suspension in air or water, or (2) resting after suspension on the Earth’s surface, be it on land or in water.
sediment load	The solid material that is transported by a stream.
sewage	The spent or used water of a community or industry which contains dissolved and suspended matter.
shale	A soft to moderately hard sedimentary rock composed of very fine-grained quartz particles. Shale often weathers or breaks into very thin platy pieces or flakes. Shale is a confining bed to many aquifers in sedimentary rock.
sheetwash or sheet erosion	The gradual, uniform removal of the Earth’s surface without the formation of rills or gullies. This type of erosion may occur when water flows in a sheet down a sloping surface and removes material from the surfaces.
silica (SiO_2)	The chemically resistant dioxide of silicon. It occurs naturally in several forms including quartz and chert.
silt	As a soil separate, the individual mineral particles that range in diameter from the upper limit of clay (0.002 millimeter) to the lower limit of sand (0.05 millimeter).

siltstone	A fine-grained, moderately hard, sedimentary rock that is thin bedded to massive. Siltstone is distinguished from shale because it has a slightly larger grain size.
slash-and-burn agriculture	A farming practice where the jungle is cut down and the vegetation is burned to make room for new fields.
slate	A fine-grained metamorphic rock possessing a well-developed secondary cleavage, which allows it to break into sheets that have smooth surfaces.
sodium (Na)	Most important and abundant alkali metal found in natural waters. Sodium can be an indicator of sewage and industrial waste contamination.
specific capacity	The yield of a well per unit of drawdown.
stage	The height of the surface of a river or other fluctuating body of water above a set point.
stagnant water	In a stream, water that is or appears to be standing or still.
storm surge	Wind-driven oceanic waves that flood low coasts not ordinarily subject to overflow.
sulfate (SO_4)	A salt of sulfuric acid containing the divalent, negative radical SO_4.
suspended solids	Insoluble solids that either float on the surface of or are suspended in water, wastewater, or other liquids.
swamp	An area of moist or wet land with water standing on or just below the surface of the ground. A swamp is usually covered with a heavy, dense growth of vegetation.
tactical well	A well designed to support military operations and typically used for short periods of time.
tectonic plate	One of the massive blocks that the Earth's crust has been divided into. Movement and interactions of these plates at their boundaries causes earthquakes, volcanoes and other geologic processes.
Tertiary period	A division of geologic time from 1.6 to 66 million years ago, during which certain rocks were formed. The Tertiary period falls chronologically after the Cretaceous and before the Quaternary periods. It is generally broken down into the Paleocene, Eocene, Miocene, and Pliocene, and it is the oldest division of the Cenozoic era.
tidal	Affected by the tides.
tidal flats	An extensive, nearly horizontal, marshy or barren tract of land that is alternately covered and uncovered by the tides and consists of unconsolidated sediments, mostly mud and sand.
tidal influence stream or tidal stream	The lower part of a stream that the tide flows into and effects. The distance can be considerable.
total dissolved solids (TDS)	The sum of all dissolved solids in water or wastewater.
tributary	Stream or other body of water, surface or underground, which contributes its water to another and larger stream or body of water.

tropical storm	A severe weather phenomenon with violent rotating winds, in which the maximum sustained surface wind speed ranges from 63 kilometers per hour (39 miles per hour) to 118 kilometers per hour (73 miles per hour).
tuffaceous	Related or resembling tuff; sediment containing up to 50 percent tuff.
turbid	Stirred or disturbed, such as sediment; not clear or translucent, being opaque with suspended matter, such as a sediment-laden stream.
turbidity	A measure of the reduction in water clarity. Unclear or muddy water is caused by suspended particles of sand, silt, clay, or organic matter. Excessive turbidity must be removed to make water potable.
unconsolidated	Loose, soft, or liquid earth materials that are not firm or compacted.
volcanic ash	Fine pyroclastic matter that is less than 2 millimeters in diameter.
wastewater	A community or industry's spent or used water which contains dissolved and suspended matter.
water point	The point where equipment is set up to gather water for purification and distribution.
watershed	The area contained within a drainage divide above a specified point on a stream.
weathering	Physical and chemical changes that atmospheric agents produce in rocks or other deposits at or near the Earth's surface. These changes result in disintegration or decomposition of material into soil.
wetland	A lowland area, such as a marsh, swamp, or seasonally inundated area, that is saturated with moisture.
wet season	The period of the year when there is an abundance of rainfall or when rainfall is at a maximum.

APPENDIX C

Surface Water and Ground Water Resources

Tables and Figures

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Table C-1. Surface Water Resources

Map Unit (See Fig. C-1)	Sources	Quantity[1]	Quality[2]	Accessibility	Remarks
1 Fresh water perennially available	Major perennial streams, lakes, and reservoirs of the Caribbean Coast drainage region (1300N08400W)[3] and the large lakes of the Rio San Juan drainage region (1200N08600W). **Caribbean Coast drainage region (I):** Rio Bambana (1327N08350W), Rio Escondido (1204N08345W), Rio Grande de Matagalpa (1254N08332W), Rio Kukalaya (1339N08337W), Rio Kurinwas (1249N08341W), Rio Mico, (1210N08416W), Rio Prinzapolka (1324N08334W), Rio Punta Gorda (1130N08347W), Rio Siquia (1209N08413W), Rio Wawa (1353N08328W), lower reaches of Rio Coco (1500N08310W), Laguna de Apanas (1311N08559W). **Rio San Juan drainage region (II):** Rio San Juan (1056N08342W),	Small to very large quantities are available from major streams, and enormous quantities are available from lakes throughout the year. The high flow season for the Caribbean Coast drainage region generally occurs from mid-May through February, while the low flow season generally occurs from early March to early May. Rio Punta Gorda and other major streams in the southern Caribbean Coast drainage region have no pronounced seasonal variations. High water generally occurs in the great lakes of the Rio San Juan drainage region from May to November. A pronounced period of reduced precipitation from December through April causes the stream flow entering the great lakes to be at a minimum during March and April. Listed below, under their corresponding regions, are the minimum flow rates for selected gaging stations from various periods during 1971-79. Also listed are the surface areas and other data on selected lakes and reservoirs. **Caribbean Coast drainage region (I):** **1** Rio Escondido at Rama	Water is fresh with TDS ranging from 10 to 900 mg/L. TDS typically increases during the low flow season. Parts of Lago de Managua can become temporarily brackish during the low water season. High sediment loads and turbidity are common during the high flow season. In the Caribbean Coast drainage region, biological contamination from human and agricultural wastes is common near and downstream of populated areas. Chemical contamination is uncommon, except in areas with mining activities. In the Rio San Juan drainage region, biological and chemical contamination is common, especially near populated places. Parts of Lago de Managua are especially heavily contaminated with industrial wastes, and the water is not adequate for human consumption or irrigation. Contaminants include but are not limited to mercury, lead, phenols, benzene, carbon tetrachloride, methylene chloride and pesticides.	Access to and development of water points are principally influenced by topography, ground cover, and the transportation network. Conditions hindering access include high, steep banks, dense vegetation, and extensive wetlands. In the Caribbean Coast drainage region, the thick dense tropical forest, the extensive wetlands, and the extremely sparse road network make access very difficult. Most roads become almost impassable during the wet season. Even during dry weather, access to potential water points is most feasible along the few roads. Around the great lakes, access is generally feasible. But locally dense vegetation, marshy ground, and rough terrain can hinder access. The lack of all-weather roads can locally impede access during the wet season.	Protection of equipment against flooding and debris is required. After heavy rains, the streams rise rapidly with swift currents and floating debris that can damage or destroy water points. Streams can rise as much as 15 m during floods. Seasonal maintenance of intake equipment along channels carrying high sediment loads is advised to counter rapid silting. Hurricanes achieve landfall periodically along the Caribbean coast, causing extensive damage several kilometers inland. During droughts, tidal influences can extend several additional kilometers inland, causing the water near the mouth of the coastal streams to become temporarily brackish. In the higher elevations, the streams can be flashy.

Table C-1. Surface Water Resources (Continued)

Map Unit (See Fig. C-1)	Sources	Quantity[1]	Quality[2]	Accessibility	Remarks
1 Fresh water perennially available (continued)	Lago de Managua (Lago Xolotlan) (1220N08620W), Lago de Nicaragua (Lago Cocibolca) (1130N08530W).	(1209N08413W), 1.62 m^3/s. **2** Rio Grande de Matagalpa at Bocana de Paiwas (1248N08508W), 3.8 m^3/s. **3** Rio Grande de Matagalpa at Copalar (1254N08454W), 9.07 m^3/s. **4** Rio Grande de Matagalpa at San Pedro del Norte (1303N08444W), 17.8 m^3/s. **5** Rio Mico at Muelle de los Bueyes (1204N08432W), 1.2 m^3/s. **6** Rio Siquia at Salto Grande (1232N08436W), 5.38 m^3/s. **A** Laguna de Apanas, a reservoir, has a surface area of about 51 km^2. **Rio San Juan drainage region (II):** **7** Rio San Juan at El Castillo de la Concepcion (1101N08424W), 21.5 m^3/s. **8** Rio San Juan at Sitio de Presa de Sarapiqui (1043N08356W), 555 m^3/s. **B** Lago de Managua (1220N08620W) has a surface area of 1,016 km^2, a mean depth of 7.8 m, and a maximum depth of 26 m. The estimated	Water quality data from selected gaging stations and other sites are listed below under their corresponding regions. **Rio San Juan drainage region (II):** **41** San Juan below San Carlos (1107N08447W), TDS 360 mg/L, pH 7.5, Cl 32 mg/L, Ca 50 mg/L, Mg 8 mg/L, K 10 mg/L, Na 25 mg/L, CO_3 trace, HCO_3 209 mg/L, SO_4 22 mg/L. **B** Lago de Managua (1220N08620W), TDS 726 to 1,213 mg/L, temperature 24 to 27 ºC, pH 8.9, hardness 210 mg/L of $CaCO_3$, Cl 209 mg/L, Ca 48 mg/L, Mg 22 mg/L, K 69 mg/L, Na 258 mg/L, CO_3 30 mg/L, HCO_3 549 mg/L, SO_4 58 mg/L, a high-suspended sediment load, and salinity increasing at 18 mg/L per year. **C** Lago de Nicaragua (1130N08530W), TDS 114 to 298 mg/L, temperature 24ºC, pH 7.8, hardness 64 mg/L of $CaCO_3$, Cl 19 mg/L, Ca 15 mg/L, Mg 6 mg/L,		

Table C-1. Surface Water Resources (Continued)

Map Unit (See Fig. C-1)	Sources	Quantity[1]	Quality[2]	Accessibility	Remarks
1 Fresh water perennially available (continued)		volume is 7,970 Mm^3. **C** Lago de Nicaragua (1130N08530W) has a surface area of 8,157 km^2, a mean depth of 13.3 m, and a maximum depth of 60 m. The estimated volume is 108,000 Mm^3.	K 3 mg/L, Na 17 mg/L, HCO_3 74 mg/L, SO_4 9 mg/L, and high-suspended sediment load.		
2 Fresh water perennially available	Perennial streams, lakes, marshes, and swamps occupying the Caribbean Coast drainage region (1300N08400W). **Caribbean Coast drainage region (I):** Rio Bocay (1418N08510W), Rio Tuma (1303N08444W), Upper reaches of Rio Coco (1444N08425W), Tributaries of the major streams draining the region.	Moderate to very large quantities are available during the high flow season from mid-May through February, while very small to small quantities are available during the low flow season from early March to early May. Listed below, are the minimum flow rates for selected gaging stations from various periods during 1971-79. **Caribbean Coast drainage region (I):** **9** Rio Bocay at Uruskirna (1419N08509W), 5.67 m^3/s. **10** Rio Coco at Namasli (1328N08614W), 0.2 m^3/s. **11** Rio Coco at Guana (1331N08557W) 2.82 m^3/s. **12** Rio Coco at Corriente Lira (1333N08550W), 0.21 m^3/s. **13** Rio Coco at Waspam (1444N08358W), 0.22 m^3/s.	Water is fresh with TDS ranging from 9 to 600 mg/L. TDS typically increases during the low flow season. High sediment loads and turbidity are common during the high flow season. Biological contamination from human and agricultural wastes is common near and downstream of populated areas. Chemical contamination is uncommon, except near areas with mining activities. Water quality data from selected gaging stations and other sites are listed below. **Caribbean Coast drainage region (I):** **11** Rio Coco at Guana (1331N08557W), TDS 9 to 557 mg/L, temperature 18 to 26.5ºC. **12** Rio Coco at Corriente Lira (1333N08550W),	Access to and development of water points are principally influenced by topography, ground cover, and the transportation network. Conditions hindering access include high, steep banks, dense vegetation, and extensive wetlands. The thick dense tropical forest, the extremely sparse road network, the extensive wetlands, and the locally rugged terrain can make access very difficult. Most roads become almost impassable during the wet season. Even during dry weather, access to potential water points is generally only feasible along the few roads.	Protection of equipment against flooding and debris is required. After heavy rains, the streams rise rapidly with swift currents and floating debris that can damage or destroy water points. Hurricanes achieve landfall periodically, causing extensive damage several kilometers inland. Seasonal maintenance of intake equipment along channels carrying high sediment loads is advised to counter rapid silting. In the higher elevations, the streams can be flashy.

Table C-1. Surface Water Resources (Continued)

Map Unit (See Fig. C-1)	Sources	Quantity[1]	Quality[2]	Accessibility	Remarks
2 Fresh water perennially available (continued)		**14** Rio Grande de Matagalpa at Trapichito (1242N08522W), 0.84 m^3/s. **15** Rio Tuma at Yasica (1304N08545W), 0.41 m^3/s. **16** Rio Tuma at Masapa (1306N08531W), 0.11 m^3/s.	TDS 9 to 514 mg/L, temperature 22 to 28 °C. **14** Rio Grando de Matagalpa at Trapichito (1242N08522W), TDS 10 to 408 mg/L, temperature 24 to 26 °C. Rio Grande de Matagalpa (location of sample was not reported), TDS 287 mg/L, pH 7.7, Cl 18 mg/L, Ca 14 mg/L, Mg 57 mg/L, Na 49 mg/L, HCO_3 224 mg/L, SO_4 1 mg/L.		
3 Fresh water seasonally available	Streams and tributaries in the Caribbean Coast drainage region (1300N08400W), streams and lakes in the Rio San Juan drainage region (1200N08600W), and streams in the Pacific Coast drainage region (1230N08700W). **Caribbean Coast drainage region (I):** The headwaters of the Rio Grande de Matagalpa (1242N08522W), Other streams draining the higher elevations of this region. **Rio San Juan drainage region (II):** Rio Grande (Rio Viejo) (1228N08621W),	Moderate to very large quantities are available during the high flow season from May through November; meager to very small quantities are available during the low flow season from December to April. Listed below, under their corresponding regions, are the minimum flow rates for selected gaging stations from various periods during 1971-77. Also listed are the surface areas and other data on selected lakes. **Caribbean Coast drainage region (I):** **17** Rio Tuma at El Dorado (1315N08552W), 0.03 m^3/s.	Water is generally fresh but may be high in TDS during the low flow season. Shallow lakes and some smaller streams may temporarily become brackish during the low flow season. Water quality problems are most severe during the low flow season, because stream flow is insufficient to flush and dilute contaminants. High sediment loads are common during the high flow season. Most water sources, especially in the Rio San Juan drainage region (II) and the Pacific Coast drainage region (III), are heavily biologically and chemically contaminated.	Access to and development of water points are principally influenced by topography, ground cover, and the transportation network. Conditions hindering access include high, steep banks, dense vegetation, and extensive wetlands. In the Caribbean Coast drainage region (I) and the higher elevations of the Rio San Juan drainage region (II), access is difficult due to rugged terrain, steep gradients, deep gorges, and the lack of all-weather roads. In the lower elevations of the	Protection of equipment against flooding and debris from intense tropical storms is required. Streams can be extremely flashy, especially in the mountains of northern Nicaragua and east of Lago de Nicaragua. After heavy rains, the streams rise rapidly with swift currents and floating debris that can damage or destroy water points. Seasonal maintenance of intake equipment along channels carrying high sediment loads is advised to counter rapid silting.

Table C-1. Surface Water Resources (Continued)

Map Unit (See Fig. C-1)	Sources	Quantity[1]	Quality[2]	Accessibility	Remarks
3 Fresh water seasonally available (continued)	Rio Mayales (1152N08527W), Rio Ochomogo (1141N08554W), Rio Oyate (1138N08507W), Laguna de Asososca (1208N08619W), Laguna de Masaya (1158N08607W). **Pacific Coast drainage region (III):** Rio Atoya (1235N08715W), Rio San Cristobal (1220N08658W), Rio Soledad (1201N08639W).	**Rio San Juan drainage region (II):** **18** Rio Grande (Rio Viejo) at Las Brisas (1253N08608W), 0.06 m^3/s. **19** Rio Grande (Rio Viejo) at La Lima (1252N08607W), 0.31 m^3/s. **20** Rio Mayales at El Jicaral (1203N08521W), 0.03 m^3/s. **21** Rio Ochomogo at Las Enramadas (1140N08559W), 0.26 m^3/s. **D** Laguna de Asososca (1208N08619W) has a surface area of 0.8 km^2 and a maximum depth of 104 m. The lake supplies water to the city of Managua. **E** Laguna de Masaya (1158N08607W) has a surface area of 8.5 km^2. **Pacific Coast drainage region (III):** **22** Rio Atoya at Ceilan (1235N08714W), 0.16 m^3/s. **23** Rio San Cristobal at La Gallina (1238N08658W), 0.47 m^3/s. **24** Rio Soledad at El Cantrabando (1204N08640W), 0.02 m^3/s.	Water quality data from selected gaging stations and other sites are listed below under their corresponding regions. **Caribbean Coast drainage region (I):** **42** Rio Esteli (1330N08616W) along highway (about 1315N08621W), Cl 7 mg/L, Ca 59 mg/L, Mg 22 mg/L. **Rio San Juan drainage region (II):** **18** Rio Grande (Rio Viejo) at Las Brisas (1253N08608W), TDS 23.8 mg/L, temperature 25 °C. **21** Rio Ochomogo at Las Enramadas (1140N08559W), TDS 340 mg/L, pH 8.5, Cl 21 mg/L, Ca 43 mg/L, CO_3 10 mg/L, HCO_3 233 mg/L. **D** Laguna de Asososca (1208N08619W), TDS 256 to 378 mg/L, pH 8.7, hardness 79 mg/L of $CaCO_3$, Cl 23 mg/L, CO_3 22 mg/L, HCO_3 146 mg/L, SO_4 35 mg/L, NO_3 1.3 mg/L. Lake is used as a source of drinking water for the city of Managua (1209N08617W). **E** Laguna de Masaya	Rio San Juan drainage region (II) and the Pacific Coast drainage region (III), access is generally not difficult. Locally, access may be difficult because of rugged terrain, wet marshy ground, and lack of roads.	

Table C-1. Surface Water Resources (Continued)

Map Unit (See Fig. C-1)	Sources	Quantity[1]	Quality[2]	Accessibility	Remarks
3 Fresh water seasonally available (continued)			(1158N08607W), TDS 235 to 320 mg/L. Lake is heavily contaminated with organic contaminants.		
4 Fresh water seasonally available	Streams, tributaries, and small lakes in all three drainage regions. **Caribbean Coast drainage region (I):** Headwaters of Rio Coco (1444N08425W), Headwaters of Rio Grande de Matagalpa (1242N08522W), Rio Mancotal (1314N08555W). **Rio San Juan drainage region (II):** Rio Acoyapa (1148N08516W), Rio Grande (Rio Viejo) (1228N08621W) Rio Malacatoya (1207N08547W), Rio Pacora (1225N08617W), Rio Sinecapa (1228N08625W), Rio Tipitapa (1205N08553W), Rio Tule (1120N08452W). **Pacific Coast drainage region (III):** Rio Brito (1120N08559W),	Small to very large quantities are available during the high flow season from May through November. All but the largest streams go dry for extended periods during the low flow season from December to April. Listed below, under their corresponding regions, are the minimum flow rates for selected gaging stations from various periods from 1971 to 1977. (Some gaging station data is from the hydrographic reports of the Nicaragua Canal Commission of 1898 to 1900.) **Caribbean Coast drainage region (I):** **25** Rio Coco at Palmira (1336N08636W), no flow. **26** Rio Grande de Matagalpa at Esquipulas (1240N08549W), 0.01 m^3/s. **27** Rio Grande de Matagalpa at Ciudad Dario (1243N08608W), no flow. **28** Rio Mancotal at puente (bridge) (1314N08556W), no flow.	Water is generally fresh, but TDS increase as the flow rates decrease. Shallow lakes and smaller streams become temporarily brackish during the low flow season. High sediment loads are common during the high flow season. Most water sources are heavily polluted by biological and chemical contamination. Biological contamination from human and agricultural wastes is common near and downstream of populated areas. Chemical contamination is a problem near industrial plants and in areas with intense agriculture and mining activities. Water pollution problems are most severe during the low flow season, because stream flow is insufficient to flush and dilute the contaminants. The Rio Tipitapa is heavily polluted. Water quality data from selected gaging stations and other sites are listed below under their corresponding regions.	Access to and development of water points are principally influenced by topography, ground cover, and the transportation network. Conditions hindering access include high, steep banks, dense vegetation, and extensive wetlands. In the Caribbean Coast drainage region (I) and the higher elevations of the Rio San Juan drainage region (II), access is difficult because of rugged terrain, steep gradients, deep gorges, and lack of all-weather roads. In the lower elevations of the Rio San Juan drainage region (II) and the Pacific Coast drainage region (III), access is generally not difficult. Locally, access may be difficult because of rugged terrain, wet marshy ground, or lack of roads.	Protection of equipment against flooding and debris from intense tropical storms is required. Streams can be extremely flashy, especially in the mountains of northern Nicaragua and east of Lago de Nicaragua (1130N08530W). After heavy rains, the streams rise rapidly with swift currents and floating debris that can damage or destroy water points. Seasonal maintenance of intake equipment along channels carrying high sediment loads is advised to counter rapid silting.

Table C-1. Surface Water Resources (Continued)

Map Unit (See Fig. C-1)	Sources	Quantity[1]	Quality[2]	Accessibility	Remarks
4 Fresh water seasonally available (continued)	Rio Tamarindo (1212N08646W), Middle and upper reaches of Estero Real (1250N08707W), Middle and upper reaches of Rio Negro (1248N08659W).	**Rio San Juan drainage region (II):** **29** Rio Acoyapa at Santa Rosa (1150N08522W), no flow. **30** Rio Grande (Rio Viejo) at Santa Barbara (1246N08614W), no flow. **31** Rio Malacatoya at Las Banderas (1220N08557W), no flow. **32** Rio Pacora at Pacora (1228N08612W), no flow. **33** Rio Sincecapa at El Jicaral (1244N08623W), 0.01 m^3/s. **34** Rio Tipitapa at Tipitapa (1212N08606W), no flow (1898-1900 data). **35** Rio Tule (1120N08425W) at mouth, no flow (1898-1900 data). **Pacific Coast drainage region (III):** **36** Rio Brito at Miramar (1122N08556W), 0.06 m^3/s. **37** Rio Negro at La Canoa (1304N08659W), no flow. **38** Rio Tamarindo at El Tamarindo (1214N08643W), 0.006 m^3/s.	**Caribbean Coast drainage region (I):** **27** Rio Granda de Matagalpa at Ciudad Dario (1243N08608W), TDS 340 mg/L, temperature 25 ºC, hardness 175 mg/L of $CaCO_3$, Cl 21 mg/L, Ca 50 mg/L, Mg 12 mg/L, K 10 mg/L, Na 26 mg/L, CO_3 6 mg/L, HCO_3 220 mg/L, SO_4 38 mg/L, SiO_2 55 mg/L. **Rio San Juan drainage region (II):** **34** Rio Tipitapa at Tipitapa (1212N08606W), TDS 570 mg/L, pH 8.4, Cl 32 mg/L, Ca 42 mg/L, Mg 6 mg/L, K 14 mg/L, Na 106 mg/L, CO_3 5 mg/L, HCO_3 16 mg/L, SO_4 4 mg/L. **Pacific Coast drainage region (III):** **37** Rio Negro at La Canoa (1304N08659W), TDS 260 mg/L, pH 7.9, Cl 6 mg/L, Ca 56 mg/L, Mg 11 mg/L, K 6 mg/L, Na 13 mg/L, CO_3 4 mg/L, HCO_3 128 mg/L. **38** Rio Tamarindo at El Tamarindo (1214N08643W), TDS 792 mg/L, pH 8.2,		

Table C-1. Surface Water Resources (Continued)

Map Unit (See Fig. C-1)	Sources	Quantity[1]	Quality[2]	Accessibility	Remarks
4 Fresh water seasonally available (continued)		**39** Rio Villa Nueua at puente (bridge) (1256N08650W), no flow.	Cl 72.8 mg/L, Ca 45.6 mg/L, Mg 10.8 mg/L, K 50 mg/L, Na 241 mg/L, CO_3 53.7 mg/L, HCO_3 527.1 mg/L, SO_4 23.4 mg/L, NO_3 0.62 mg/L.		
5 Fresh water scarce or lacking	Saline water marshes, tidal flats, mangroves, estuaries, coastal lagoons, the marshes surrounding the Rio Tipitapa (1205N08553W), isolated lakes in volcanic calderas, and the intermittent streams on Islas del Maiz (1215N08300W) and on other cays. **Caribbean Coast drainage region (I):** Laguna Bismuna (Lago Wani) (1445N08320W), Laguna Karata (1356N08330W), Laguna Pahara (1418N08315W), Laguna de Perlas (1233N08340W), Laguna de Wounta (1338N08334W). **Rio San Juan drainage region (II):** Laguna de Apoyeque (1215N08621W), Laguna de Apoyo (1155N08602W),	Meager to enormous quantities of brackish to saline water are available year-round. During the high flow season, from mid-May to February, stream flow in the Caribbean Coast drainage region (I) and Rio San Juan drainage region (II) may be sufficient to temporally flush the brackish to saline waters out of the coastal lagoons, marshes, and swamps. This flushing makes enormous quantities of fresh water temporarily available. For a few days after rains in the rest of the country and especially on the islands, unsuitable to small quantities of fresh water are available from shallow ponds and small streams. Listed below, under their corresponding regions, are the surface areas and other data on selected lakes and lagoons. **Caribbean Coast drainage region (I):** **F** Laguna Bismuna (Lago Wani) (1445N08320W), 145 km^2.	Water is brackish to saline. In the Caribbean Coast drainage region (I), many of the lagoons are fresh to slightly brackish for several months during the height of the high flow season from May through December. Salinity decreases with distance from the ocean. During the low flow season, most of the lagoons are brackish to saline. On the Isles del Maiz (1215N08300W) and the other cays, surface water in the intermittent streams and ponds is generally fresh for only a few days after rains. In the Rio San Juan drainage region (II), many of the lakes found in the caldera of the volcanoes are brackish to saline. TDS range from 236 mg/L to over 24,111 mg/L. The TDS concentration is influenced by the mineralization and nature of the volcanic deposits surrounding the caldera. In the Pacific	Access and establishment of water points are influenced by topography, ground cover, and the amount of time nonoceanic surface water is available. In most areas, establishment of saline water points is not difficult. However, in the Caribbean Coast drainage region (I) and the estuary of the Estero Real (1255N08723W) in the Pacific Coast drainage region (III), heavy vegetation, wet ground, and the lack of roads makes access very difficult. Establishment of fresh water points on most of the cays is very difficult due to the very short time fresh water is available.	Most cays are only slightly above sea level. Rainfall is quickly absorbed into the ground. Storm surges and winter tides can cover the cays with saline oceanic water. Hurricanes are especially destructive to the cays.

Table C-1. Surface Water Resources (Continued)

Map Unit (See Fig. C-1)	Sources	Quantity[1]	Quality[2]	Accessibility	Remarks
5 Fresh water scarce or lacking (continued)	Laguna de Jiloa (1213N08619W). **Pacific Coast drainage region (III):** Lower reaches and estuaries of Estero Real (1255N08723W), Lower reaches and estuaries of Rio Negro (1302N08708W).	**G** Laguna Karata (1356N08330W), 33.6 km^2. **H** Laguna Pahara (1418N08315W), 98.6 km^2. **I** Laguna de Perlas (1233N08340W), 522 km^2. **J** Laguna de Wounta (1338N08334W), 81.5 km^2. **Rio San Juan drainage region (II):** **K** Laguna de Apoyo (1155N08602W), 21.5 km^2. **L** Laguna de Apoyeque (1215N08621W), 2.6 km^2. **M** Laguna de Jiloa: 3.9 km^2. **Pacific Coast drainage region (III):** **40** Estero Real (1255N08723W) at its mouth, 6.5 m^3/s (estimated flow from water balance model).	Coast drainage region (III), the estuary of the Estero Real (1255N08723W) and the mangroves and marshes are saline to brackish. In general, the surface water is of poor quality, containing large amounts of biological wastes, debris, decomposing vegetation, and oceanic minerals. Near populated places, the water is biologically and chemically contaminated. The marshes along the Rio Tipitapa (1205N08553W) are heavily polluted. Water quality data from selected gaging stations and other sites are listed below under their corresponding regions. **K** Laguna de Apoyo (1155N08602W), TDS 2,600 mg/L, pH 8.4, hardness 270 mg/L of $CaCO_3$, Ca 62 mg/L, Mg 28 mg/L, Na 715 mg/L, K 115 mg/L, SO_4 12 mg/L, HCO_3 140 mg/L, NO_3 0.2 mg/L. **L** Laguna de Apoyeque (1215N08621W), TDS 3,846 to 5,796 mg/L. **M** Laguna de Jiloa (1213N08619W), TDS 3,654 to 4,600 mg/L.		

Table C-1. Surface Water Resources (Continued)

[1]Quantitative Terms:
Enormous = >5,000 m^3/s (176,550 ft^3/s)
Very large = >500 to 5,000 m^3/s (17,655 to 176,550 ft^3/s)
Large = >100 to 500 m^3/s (3,530 to 17,655 ft^3/s)
Moderate = >10 to 100 m^3/s (350 to 3,530 ft^3/s)
Small = >1 to 10 m^3/s (35 to 350 ft^3/s)
Very small = >0.1 to 1 m^3/s (3.5 to 35 ft^3/s)
Meager = >0.01 to 0.1 m^3/s (0.35 to 3.5 ft^3/s)
Unsuitable = $\leq$0.01 m^3/s (0.35 ft^3/s)

[2]Qualitative Terms:
Fresh water = maximum TDS $\leq$1,000 mg/L; maximum chlorides $\leq$600 mg/L; and maximum sulfates $\leq$300 mg/L
Brackish water = maximum TDS >1,000 mg/L; but $\leq$15,000 mg/L
Saline water = TDS >15,000 mg/L

Hardness Terms:
Soft = 0 to 60 mg/L $CaCO_3$
Moderately hard = 61 to 120 mg/L $CaCO_3$
Hard = 121 to 180 mg/L $CaCO_3$
Very hard = 180 mg/L $CaCO_3$

[3]Geographic coordinates list latitude first for Northern (N) or Southern (S) Hemisphere and longitude second for Eastern (E) or Western (W) Hemisphere. For Example:

Caribbean Coast drainage region (1).......1300N08400W

Geographic coordinates for the Caribbean Coast drainage region that are given as 1300N08400W equal 13º00' N, 84º00' W and can be written as a latitude of 13 degrees and 0 minutes north and a longitude of 84 degrees and 0 minutes west. Coordinates are approximate. Geographic coordinates are sufficiently accurate for locating features on the country-scale map. Geographic coordinates for rivers are generally at the river mouth.

Note:
Ca = calcium
$CaCO_3$ = calcium carbonate
Cl = chloride
CO_3 = carbonate
ft^3/s = cubic feet per second
gal/min = gallons per minute
HCO_3 = bicarbonate
K = potassium
km^2 = square kilometers
L/min = liters per minute
m = meters
Mg = magnesium
mg/L = milligrams per liter
Mm^3 = million cubic meters
m^3/s = cubic meters per second
Na = sodium
pH = hydrogen-ion concentration
NO_3 = nitrate
SiO_2 = silica
SO_4 = sulfate
TDS = total dissolved solids

Conversion Chart:

To Convert	Multiply By	To Obtain
cubic meters per second	15,800	gallons per minute
cubic meters per second	60,000	liters per minute
cubic meters per second	35.31	cubic feet per second

Table C-2. Ground Water Resources

Map Unit (See Fig. C-2)	Aquifer Characteristics	Quantity[1]	Quality[2]	Aspects of Ground Water Development	Remarks
1 Fresh water generally plentiful	Quaternary to Recent age alluvial aquifers composed of unconsolidated sand and gravel with sandstone lenses, sand and gravel interbedded with clay, silt, and pyroclastics consisting of fine ashes, pumice, scoria, and lapilli. Bregman's Bluff Formation, consisting of gravel and sand, is a main aquifer in the Caribbean region. These aquifers are located in the following areas: Northwestern part of the Pacific Lowlands (1235N08635W)[3], Lago de Nicaragua (1130N08530W) and Lago de Managua (1220N08620W) plains, Nicaraguan Depression (1220N08620W), Up to 100 km inland of the Caribbean coast in the Departamento de Boaco (1230N08530W), Departamento de Carazo (1145N08615W), Departamento de Chinandega (1250N08705W), Departamento de Granada (1150N08555W), Departamento de Leon (1235N08635W),	Small to very large quantities of ground water are available from alluvial aquifers. Larger quantities are available as the percentage of clay and silt in the aquifer decreases. Wells in the Leon-Chinandega (1226N08653W-1237N08709W) area are reported to yield over 67 L/s. Existing wells in the Los Brasiles Valley (1216N08556W-1211N08622W) produce 23 to 69 L/s from depths of 120 to 150 m with a drawdown of about 5 m. Departamento de Chinandega (1250N08705W): yields from 34 drilled wells range from less than 1 to 82 L/s with an average well yield of 10 L/s. Departamento de Granada (1150N08555W): yields from 37 drilled wells range from less than 1 to 84 L/s with an average yield of 26 L/s. Departamento de Leon (1235N08635W): yields from drilled wells range from approximately 2 to 85 L/s. Region Autonomista Atlantico Norte (1400N08400W): yields from six drilled wells range from 2 to 8 L/s with an average of 4 L/s.	Ground water quality is fresh although aquifers underlying swamps, marshes, and along the coasts may be nonpotable. Ground water is soft to moderately hard.	Water table depth ranges from 5 to 150 m. Siting and drilling of wells is easy except in areas of swamps. Saltwater zones underlie the freshwater zones in both of the coastal areas, and caution should be exercised in pumping to prevent saltwater intrusion. Saline water wells would require reverse osmosis/ desalination equipment. Wells should be screened due to the unconsolidated nature of the material. Accessibility is generally easy, but may be locally hindered in areas of dense forest and areas along the coast subject to seasonal inundation. The shallow ground water is often biologically contaminated near settlements. Departamento de Chinandega (1250N08705W): well depths of 40 drilled wells range from 10 to 117 m with an average well depth of 54 m. Departamento de Granada (1150N08555W): well depths of 56 drilled wells range from 33 to 248 m with an average depth of 100 m.	Alluvial aquifers are suitable for municipal or irrigation wells.

Table C-2. Ground Water Resources (Continued)

Map Unit (See Fig. C-2)	Aquifer Characteristics	Quantity[1]	Quality[2]	Aspects of Ground Water Development	Remarks
1 Fresh water generally plentiful (continued)	Departamento de Managua (1200N08625W), Departamento de Matagalpa (1255N08540W), Departamento de Rivas (1118N08545W), Region Autonomista Atlantico Sur (1200N08400W), Region Autonomista Atlantico Norte (1400N8400W), and Other scattered areas throughout the country. The principal aquifer in alluvial deposits of the Los Brasiles Valley (1216N08556W-1211N08622W) consists of coarse sand, pumice, and scoria layers.	Region Autonomista Atlantico Sur (1200N08400W): yields from 24 drilled wells range from 1 to 6 L/s with an average yield of 4 L/s.		Departamento de Leon (1235N08635W): well depths range from approximately 24 to 153 m. Region Autonomista Atlantico Norte (1400N08400W): well depths of 11 drilled wells range from 50 to 134 m with an average well depth of 83 m. Region Autonomista Atlantico Sur (1200N08400W): well depths of 56 drilled wells range from 24 to 130 m with an average well depth of 82 m.	
2 Fresh water generally plentiful	Tertiary to Quaternary age volcanic rocks. Primary aquifers include: the Las Sierras Group consisting of basaltic to andesitic pyroclastic rocks, the Masaya Group Volcanics composed of basaltic to andesitic lavas and pyroclastic materials (volcanic breccia, scoria, and ash); and the Apoyo Volcanics consisting of pyroclastic dacite, pumice, and dacitic lavas. Numerous springs issue from fractures and porous interflow zones within volcanic deposits.	Meager to very large quantities of ground water are available. Specific capacities for wells in the Departamento de Managua (1200N08625W) south of Lago de Managua (1220N08620W) range from <0.4 to 67 L/s/m with a mean of 19 L/s/m. INAA wells drilled into the Las Sierra Group are concentrated in central Departamento de Managua (1200N08625W) and produce large quantities of ground water. The average yield of 53 wells in the area is 39 L/s.	Ground water is generally fresh. TDS concentrations are <400 mg/L throughout most of the Departamento de Managua (1200N08625W) area with higher values north of Laguna de Asososca (1226N08640W). East of a north-south line through the Las Mercedes Airport (1202N08621W), TDS concentrations are up to 900 mg/L. The high TDS values may be due to volcanic activity. Mean chemical concentrations for wells in the Departamento de Managua area	Static water levels in wells in the Departamento de Managua (1200N08625W) south of Lago de Managua (1220N08620W) range from <40 to 154 m. Siting of wells is generally easy. Wells drilled in the unconsolidated materials overlying the bedrock should be screened. Reconnaissance or exploratory drilling may be necessary to locate zones of best quality and maximum yield. Drilling in the basalts requires	Aquifers are suitable for hand pump wells, and most are suitable for 3.3 L/s tactical wells and small submersible pumps. Chemical contamination of the ground water by industrial products may occur. More than 80 percent of the country's industries are located in the Departamento de Managua (1200N08625W). Two major industrial zones exist. The first zone is located

Table C-2. Ground Water Resources (Continued)

Map Unit (See Fig. C-2)	Aquifer Characteristics	Quantity[1]	Quality[2]	Aspects of Ground Water Development	Remarks
2 Fresh water generally plentiful (continued)	These aquifers and springs are primarily located in the following areas: Pacific Lowlands (1235N08635W), Nicaraguan Depression (1220N08620W), with the interior lakes Lago de Managua (1220N08620W) and Lago de Nicaragua (1130N08530W), Departamento de Carazo (1145N08615W), Departamento de Chinandega (1250N08705W), Departamento de Leon (1235N08635W), Departamento de Managua (1200N08625W), Departamento de Masaya (1200N08610W), Isla de Ometepe (1130N08535W), and Isla Zapatera (1140N08550W). Wells drilled in the Departamento de Managua (1200N08625W), south of Lago de Managua (1220N08620W), indicate the water levels of the shallow (penetrate static water level by <15 m) and deep (extend >15 m beyond the static water level) aquifers are hydraulically	Main well fields producing from the Masaya Group Volcanics and Middle Las Sierras Group in the area produce the following quantities of water: Carlos Fonseca (16 wells) 53 L/s per well; Sabana Grande (5 wells) 35 L/s per well; and Veracruz (7 wells) 42 L/s per well. Yields of wells in the vicinity of Nagarote (1216N08634W) range from 35 to 67 L/s. Small to enormous quantities of ground water are perennially available from springs. The total discharge of many of the springs from the volcanic deposits is about 1,300 L/s. A hot spring also flows from the Las Sierras aquifer at Tipitapa (1212N08606W). Departamento de Carazo (1145N08615W): yields from 28 drilled wells range from 1 to 29 L/s with an average well yield of 13 L/s. Departmento de Masaya (1200N08610W): yields from 23 drilled wells range from 3 to 32 L/s with an average yield of 18 L/s.	(1200N08625W) south of Lago de Managua (1220N08620W) are: Ca 32 mg/L, Mg 12 mg/L, Cl 118 mg/L, SO_4 53 mg/L. Ground water quality is generally fresh but slightly alkaline, and varies in temperature from hot to cold due to geothermal activity. The ground water ranges in hardness from soft to hard. The quality of some of the hot and cold springs can be brackish to saline and range from slightly alkaline to strongly acidic.	hard-rock drilling techniques. Accessibility is difficult in dense vegetation and mountainous terrain. Aquifers which supply ground water to these springs are located at depths ranging from 90 to 300 m. Most springs are easily developed. Accessibility to springs near the base of the volcanic cones is easy, although access is difficult on steep slopes. Departamento de Carazo (1145N08615W): well depths of 48 drilled wells range from 24 to 454 m. Departmento de Masaya (1200N08610W): well depths of 51 drilled wells range from 35 to 458 m with an average well depth of 243 m.	between Laguna de Asososca (1208N08619W) and Lago de Managua (1220N08620W). Environmentally hazardous industries located here include a petroleum refinery, a pesticide plant, and a chlor-alkali plant. The second industrial zone, called Zona Franca, is located near the airport and includes mostly textile and metal industries. Besides being the main industrial zone of the country, Departamento de Manauga (1200N08625W) is also an important agricultural zone. Pesticides are a source of contamination of the ground water. The water supply for Departamento de Managua (1200N08625W) is a mixed system of 83 drilled wells and the Laguna de Asososca (1208N08619W).

Table C-2. Ground Water Resources (Continued)

Map Unit (See Fig. C-2)	Aquifer Characteristics	Quantity[1]	Quality[2]	Aspects of Ground Water Development	Remarks
2 Fresh water generally plentiful (continued)	interconnected. Although the deeper aquifers may be artesian at some locations, withdrawal of water will cause flow from the shallow aquifer creating a single water table aquifer. Thus, the entire area is considered to be underlain by a water table aquifer, recharged by the rainfall that is not lost by evaportranspiration or surface runoff.				
3 Fresh water scarce or lacking	Thinly to massively bedded Cretaceous to Tertiary age sandstone, limestone, shale, conglomerate, and breccia aquifers; tuffaceous in part. Locally, coquina, pyroclastics, and diabase are present. Major aquifers include: Oligocene Masachapa Formation (sandstones, tuffaceous sands, conglomerates), Eocene Brito Formation (sands, coquinas, volcanics), and Cretaceous Rivas Formation (arkosic sandstone, nodular marl, green shale, black tuff, brown tuffaceous shale interbedded with limestone and limy shale at the base). The Masachapa Formation has a total thickness of 2,600 m. The total thickness of the Brito Formation is 2,400 m.	Unsuitable to small quantities of ground water perennially available. Departamento de Rivas (1118N08545W): yields of drilled wells range from less than 1 to 19 L/s with average well yields less than 5 L/s.	Ground water is generally fresh, but locally may be brackish to saline. Water hardness ranges from soft in the sandstone to very hard in the limestone aquifers. Locally, water may smell foul due to high H_2S content.	Fresh ground water is generally available from depths ranging from 20 to 200 m, but may be as deep as 600 m along the Pacific coast. Shallow wells may become dry from November to April in the Pacific region and from February to April in the Caribbean Lowland region due to seasonal fluxuations of the water table. Well siting is generally difficult and many wells yield only meager quantities. Reconnaissance or exploratory drilling may be necessary to locate zones of best quality and maximum yield. Wells sited in coarse to sandy material with low clay percentages will yield the largest quantities of ground water. Drilling in the breccias requires	Aquifers are suitable for hand-pump wells and most are suitable for 3.3 L/s tactical wells and small submersible pumps.

Table C-2. Ground Water Resources (Continued)

Map Unit (See Fig. C-2)	Aquifer Characteristics	Quantity[1]	Quality[2]	Aspects of Ground Water Development	Remarks
3 Fresh water scarce or lacking (continued)	These aquifers are primarily located in the following areas: Pacific Hills (1145N08615W), Part of the northern Interior Highlands (1255N08540W), Part of the western Caribbean Lowlands (1400N8400W), Departamento de Carazo (1145N08615W), Departamento de Jinotega (1345N08535W), Departamento de Managua (1200N08625W), Departamento de Rio San Juan (1120N08435W), Departamento de Rivas (1118N08545W), Region Autonomista Atlantico Norte (1400N8400W), Region Autonomista Sur (1200N08400W), Isla Del Maiz (1215N08300W), and Isla Zapatera (1145N08550W).			hard rock drilling techniques. Wells should be cased and screened. Accessibility is hindered by dense vegetation and mountainous terrain. Departamento de Rivas (1118N08545W): well depths of drilled wells range from 18 to 55 m.	
4 Fresh water scarce or lacking	Tertiary to Quaternary age andesite, basalt, ignimbrite, tuff, and volcanic ash interbedded with sandstone, siltstone, and limestone.	Meager to moderate quantities of water are available throughout the interior of the country from tuff interbedded with basalt, from fracture zones in the basalt, and locally from sandstone and	Fresh to brackish water is available from fracture zones and locally from sandstone. Water hardness ranges from slightly to moderately hard.	Aquifer depth ranges from <6 to 150 m. Siting of wells is generally easy. Wells drilled in the unconsolidated materials overlying the bedrock should be screened. Extensive	Aquifers are suitable for hand pump wells, and most are suitable for 3.3 L/s tactical wells and small submersible pumps.

Table C-2. Ground Water Resources (Continued)

Map Unit (See Fig. C-2)	Aquifer Characteristics	Quantity[1]	Quality[2]	Aspects of Ground Water Development	Remarks
4 Fresh water scarce or lacking (continued)	Major aquifers include: the Miocene Tamarindo Formation (ignimbrites, basalts, andesites), Matagalpa Group (ignimbrites, basalts, andesites), Coyol Group (ignimbrites, basalts, andesites), and Machucha Group (sandstone, siltstone, crystallized limestone). These aquifers are primarily located in the following areas: Interior Highlands (1255N08540W), Pacific Hills (1145N08615W), in Departamento de Boaco (1230N08530W), Departamento de Carazo (1145N08615W), Departamento de Chinandega (1250N08705W), Departamento de Chontales (1205N08510W), Departamento de Esteli (1310N08620W), Departamento de Jinotega (1345N08535W), Departamento de Leon (1235N08635W), Departamento de Madriz (1330N08625W),	limestone at depths ranging from 15 to 150 m. Unsuitable to small quantities of ground water are also available from unconsolidated coarse gravels and lateritic soils overlying bedrock at depths generally <6 m. Departamento de Boaco (1230N08530W): yields from 61 drilled wells range from less than 1 to 8 L/s. Departamento de Chontales (1205N08510W): yields from 79 drilled wells range from less than 1 to 19 L/s with an average yield of 5 L/s. Departmento de Esteli (1310N08620W): yields from 104 drilled wells range from 1 to 12 L/s. Departamento de Madriz (1330N08625N): yields from 43 drilled wells range from less than 1 to 10 L/s with an average yield of 49 L/s. Departamento de Matagalpa (1255N08540W): yields from 82 drilled wells range from less than 1 to 38 L/s. Departamento de Rio San Juan (1120N08435W): yields from 13 drilled wells range from less than 1 to 12 L/s		reconnaissance or exploratory drilling may be necessary to locate zones of best quality and maximum yield. Drilling in the basalt requires hard-rock drilling techniques. Successful ground water exploration may depend upon encountering water bearing fractures and faults. Accessibility is difficult in dense vegetation, and mountainous terrain. Departamento de Boaco (1230N08530W): well depths of 88 drilled wells range from 15 to 237 m with an average well depth of 64 m. Departmento de Esteli (1310N08620W): well depths of 148 drilled wells range from approximately less than 10 to 77 m. Departamento de Madriz (1330N08625N): well depths of 51 drilled wells range from 12 to 92 m with an average depth of 57 m. Departamento de Matagapa (1255N08540W): well depths of 126 drilled wells range from 3 to 107 m with an average well depth of 48 m.	

Table C-2. Ground Water Resources (Continued)

Map Unit (See Fig. C-2)	Aquifer Characteristics	Quantity[1]	Quality[2]	Aspects of Ground Water Development	Remarks
4 Fresh water scarce or lacking (continued)	Departamento de Managua (1200N08625W), Departamento de Matagalpa (1255N08540W), Departamento de Nueva Segovia (1342N08610W), Departamento de Rio San Juan (1120N08435W), Region Autonomista Atlantico Norte (1400N8400W), Region Autonomista Sur (1200N08400W), and Archipielago de Solentiname (1110N08500W).	with an average yield of 5 L/s.		Departamento de Rio San Juan (1120N08435W): well depths of 25 drilled wells range from 13 to 83 m with an average well depth of 50 m.	
5 Fresh water scarce or lacking	Paleozoic age igneous and metamorphic rocks; granite, diorite, phyllite, schist, slate, quartzite, and marble. These aquifers are primarily located in the following areas: Part of the northern Caribbean coastal plain (1400N08400W), Northwestern part of the Interior Highlands (1255N08540W) in the Departamento de Jinotega (1345N08535W), Departamento de Nueva Segovia (1342N08610W), and Region Autonomista Atlantico Norte (1400N08400W).	Unsuitable to meager quantities of fresh water are seasonally available from various igneous and metamorphic rocks. Departamento de Nueva Segovia (1342N08610W): yields from 42 drilled wells range from less than 1 to 6 L/s with an average yield of less than 1 L/s.	Fresh water is available from joints and fracture zones within the igneous and metamorphic aquifers. Water hardness is generally soft, but locally may be distasteful and discolored due to high iron and manganese content.	Aquifer depth ranges from 20 to 200 m. Well siting is very difficult and most wells are unproductive. Extensive reconnaissance or exploratory drilling may be necessary to locate zones of best quality and maximum yield. Hard-rock drilling techniques are required. Wells should be cased and screened. Accessibility is hindered by dense vegetation, and hilly to mountain-ous terrain. Departamento de Nueva Segovia (1342N08610W): well depths of 60 drilled wells range from 15 to 87 m with an average well depth of 53 m.	Most areas are not suitable for ground water exploration.

Table C-2. Ground Water Resources (Continued)

[1]Quantitative Terms:

Enormous	= >100 liters per second (L/s) (1,600 gallons per minute (gal/min))
Very large	= >50 to 100 L/s (800 to 1,600 gal/min)
Large	= >25 to 50 L/s (400 to 800 gal/min)
Moderate	= >10 to 25 L/s (160 to 400 gal/min)
Small	= >4 to 10 L/s (64 to 160 gal/min)
Very small	= >1 to 4 L/s (16 to 64 gal/min)
Meager	= >0.25 to 1 L/s (4 to 16 gal/min)
Unsuitable	= ≤0.25 L/s (4 gal/min)

[2]Qualitative Terms:

Fresh water	= maximum total dissolved solids (TDS) ≤1,000 milligrams per liter (mg/L); maximum chlorides ≤600 mg/L; and maximum sulfates ≤300 mg/L
Brackish water	= maximum TDS >1,000 mg/L but ≤15,000 mg/L
Saline water	= TDS >15,000 mg/L

Hardness Terms:

Soft	= 0 to 60 mg/L $CaCO_3$
Moderately hard	= 61 to 120 mg/L $CaCO_3$
Hard	= 121 to 180 mg/L $CaCO_3$
Very hard	= >180 mg/L $CaCO_3$

[3]Geographic coordinates list latitude first for the Northern (N) or Southern (S) Hemisphere and longitude second for the Eastern (E) or Western (W) Hemisphere. For example:

Pacific Lowlands......1235N08635W

Geographic coordinates for the Pacific Lowlands that are given as 1235N08635W equal 12° 35' N 86° 35' W and can be written as a latitude of 12 degrees and 35 minutes north and a longitude of 86 degrees and 35 minutes west. Geographic coordinates are sufficiently accurate for locating features on the country-scale map. Coordinates are approximate.

Note:

Ca	= calcium	INAA	= Nicaraguan Institute of Aqueducts and Sewerage
$CaCO_3$	= calcium carbonate	m	= meters
Cl	= chloride	m^2/d	= square meters per day
gal/min	= gallons per minute	Mg	= magnesium
HCO_3	= bicarbonate	mg/L	= milligrams per liter
H_2S	= hydrogen sulfide	Na	= sodium
L/min	= liters per minute	NO_3	= nitrate
L/s	= liters per second	TDS	= total dissolved solids
L/s/m	= liters per second per meter		

Conversion Chart:

To Convert	Multiply By	To Obtain
liters per second	15.84	gallons per minute
liters per second	60	liters per minute
liters per second	950	gallons per hour
gallons per minute	0.063	liters per second
gallons per minute	3.78	liters per minute