Suriname Water Resources Assessment Report

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Suriname Water Resources Assessment Report

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WATER RESOURCES ASSESSMENT OF SURINAME

US Army Corps
of Engineers
Mobile District &
Topographic Engineering Center

DECEMBER 2001

Executive Summary

The growing deterioration of the socio-economic conditions and the reduction of investment in social and basic infrastructure have resulted in decreasing quality of life for the general population in Latin America and the Caribbean. The precarious quality of health services, drinking water, basic sanitation and environmental pollution and control represent a significant part of the social deficit in the countries of the region. Latin American and the Caribbean present an enormous problem concerning drinking water supply and sanitation services.

Suriname is rich in hydrologic resources. The abundance of water is considered ‘white gold’. Due to the lack of proper waste disposal throughout the country and mercury contamination in the surface water, the water is in danger of becoming unusable in areas. The lack of a national water sector and water law exacerbates this problem. Saltwater intrusion in coastal area wells is also contributing to water supply contamination.

The urban areas rely on ground water for their water supply, with a high percentage of residents having access. The overall quality is good, but saltwater intrusion in the wells from overpumping is increasing. Most of the rural areas use surface water for their water supply. However, mercury pollution from gold-mining processes in the Interior, and the lack of sanitation services contaminate the surface water. The abuse of the uncontrolled use of mercury in gold-mining processes is a serious problem in Suriname. There is very little effort being made to control or monitor this very grave threat to the health of the country's rivers.

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.

Suriname is densely forested. Eighty to ninety percent of the country is covered in forest, much of which is tropical rain forest, one of the most diverse ecosystems in the world. A fiscal crisis threatens these forests. Huge foreign timber consortiums have offered investment packages of more than $500 million for access to remote untouched forests in the Interior. Sustainable development of the Interior and alternatives, such as ecotourism, is encouraged.

If the recommendations for the creation of a national water and sanitation sector, and national water law is adopted, if progress is made toward reducing the untreated waste entering the water supply, and mercury contamination addressed, then positive, immediate, and long-term protection of water resources could be realized.

Preface

The Engineer's Office of U.S. Southern Command commissioned the U.S. Army Corps of Engineers District in Mobile, Alabama, and the U.S. Army Corps of Engineers Topographic Engineering Center in Alexandria, Virginia, to conduct a water resources assessment of Suriname. 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 Suriname to maximize the use of these resources. The other objective is to provide Suriname 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.

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List of Acronyms and Abbreviations

Acronyms

ALCOA	Aluminum Company of America
CARE	Cooperative for American Relief to Everywhere
CDB	Caribbean Development Bank
EU	European Union
GDP	Gross domestic product
GNP	Gross national product
IDB	Inter-American Development Bank
NGO	Non-government organization
NIMOS	National Institute of Environment and Development of Suriname
NH/DW	Ministry of Natural Resources/Water Supply Service
PAHO	Pan American Health Organization
Sf	Suriname Guilders
SWM	Surinaamsche Waterleiding Maatschappij (Suriname Water Company)
UNICEF	United Nation's Children's Fund
USACE	U.S. Army Corps of Engineers (referred to in text as *Corps*)
SAID	U.S. Agency for International Development
USSOUTHCOM	United States Southern Command
WHO	World Health Organization

Abbreviations

ºC	degrees Celsius
Ca	calcium
$CaCO_3$	calcium carbonate
Cl	chloride
CO_3	carbonate
ºF	degrees Fahrenheit
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
m^2/d	square meters per day
$m^3/h/m$	cubic meters per hour per meter
m^3/s	cubic meters per second
Mg	magnesium
mg/L	milligrams per liter
mL	milliliters
mm	millimeters
Mm^3	million cubic meters
MPN	most probable numbers
meq/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

List of Place Names

Place Name	Geographic Coordinates
Afobaka	0500N05459W
Albina	0531N05403W
Anapaike	0325N05402W
Anoemafoetoe	0456N05530W
Apoera	0512N05710W
Apura	0512N05710W
Arawarra Kreek	0520N05627W
Atlantic Ocean	0610N05600W
Avanavero Vallen	0449N05724W
Batavia	0542N05552W
Belumo	0341N05750W
Benzdorp	0341N05405W
Berg en Dal	0509N05504W
Bigi Pan	0558N05651W
Bitagron	0510N05606W
Blanche Marie Vallen	0444N05653W
Brazil	0200N05500W
Brokopondo Distrikt	0504N05458W
Brokopondo Lake (also Brokopondo Stuwmeer)	0445N05500W
Brownsweg	0501N05510W
Brownsbert Nature Park	0453N05513W
Burnside	0555N05624W
Coastal Plain	0550N05600W
Commewijne Distrikt	0545N05455W
Commewijne Rivier	0554N05505W
Coppename Rivier	0548N05555W
Corantijn Kanaal	0530N05715W
Corantijn Rivier (also Courantyne Riviere)	0557N05706W
Coeroenie Airfield	0322N05721W
Coesewijne Rivier	0546N05552W
Coronie Distrikt	0535N05615W
Coronie Swamp	0536N05614W
Cottica Rivier	0552N05452W
Courantyne (Coeroeni) Rivier	0323N05736W
Cow Vallen	0500N05739W
Dalbana Kreek	0448N05727W
Destombesburg	0542N05443W

List of Place Names, Continued

Place Name	Geographic Coordinates
Domburg	0542N05505W
Dramhosso Soela	0454N05534W
Drietabbetje	0407N05441W
Galibi Park	0545N05400W
Goddo	0401N05528W
Gransanti Val	0419N05424W
Groningen	0548N05528W
Henar	NOT AVAILABLE
Interior Precambrian Shield	0400N05600W
Jai Kreek	0358N05449W
Kabalebo Rivier	0502N05721W
Kleine Saramacca Rivier	0458N05533W
Kwakoegron	0515N05520W
Langatabbetje	0500N05431W
Lawa Rivier	0422N05426W
Lelydorp	0542N05514W
Litani Rivier	0318N05406W
Lucie Rivier	0335N05740W
MacClemen Eiland	0536N05710W
Majoli Twee	0239N05528W
Maksita Kreek	0455N05607W
Marienburg	0553N05503W
Marowijne Distrikt	0530N05420W
Marowijne Rivier (also Maroni Rivier)	0545N05358W
Meerzorg	0549N05509W
Meeteiland	0324N05739W
Moengo	0537N05424W
Mongotapoe	0535N05415W
Mungo	0537N05424W
Nani Kreek	0553N05705W
Nani Meer (Lake)	0524N05701W
Nickerie Distrikt	0540N05650W
Nickerie Rivier	0559N05700W
Nieuw Amsterdam	0553N05505W
Nieuw Nickerie	0557N05659W
Oelemari Rivier	0313N05409W
Onverdacht	0536N05509W

List of Place Names, Continued

List of Place Names, Continued

Note:
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 the Northern (N) or Southern (S) Hemisphere and longitude second for the Eastern (E) or Western (W) Hemisphere. For example:

Afobaka... 0500N05459W

Geographic coordinates for Afobaka that are given as 0500N0545W equal 5º0' N 54º59' W and can be written as a latitude of 5 degrees and 0 minutes north and as a longitude of 54 degrees and 59 minutes west. Coordinates are approximate. Geographic coordinates are sufficiently accurate for locating features on the country-scale map. Geographic coordinates for rivers are generally given at the river mouth.

Figure 1. – Country Map

I. Introduction

Water 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. The projected short supply of usable potable water could result in the most devastating natural disaster since history has been recorded, unless something is done to stop it.[1]

There is a direct relationship between the abundance of water, population density, and quality of life. 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.[2] 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.[3] 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 water resources situation in Suriname. 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 resulted from an in-country information-gathering trip and from information obtained in the United States on the part of two water resources professionals. The scope was 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 Suriname.

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 exercises and theater engagement planning. 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 potable water by much of the population in the rural areas, the low density of the population, the high mortality rate, the lack of wastewater treatment, mercury contamination of the surface water, and the lack of hydrologic data.

Responsibility for overseeing the water resources of Suriname 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

Suriname, with its 163,270 square kilometers of territory, is slightly larger than the U.S. state of Georgia. It is in Northern South America, bordering the North Atlantic Ocean, between French Guiana and Guyana. Brazil lies to the south.[4]

Figure 2. – Vicinity Map

The country consists predominantly of tropical rain forest and rolling hills with a narrow, swampy coastal plain. It has a central plateau region containing broad savannahs, tracts of dunes and forested areas; and to the south, a densely forested, mountainous region.[5] The physical geography of the country is divided into three areas: the Coastal Plain (Province I) (also known as the young coastal plain, or the old coastal plain), the Savannah Belt (Province II), and the Interior Precambrian Shield (also called the Interior) (Province III). The Interior makes up 80 to 85 percent of the total land area, consisting of hills, mountains, and tropical rainforest. Suriname is part of the Amazon Province. [6]

Before 1975, Suriname was a dependency of The Netherlands and was called Dutch Guiana. The relatively small population lives along the coast in or near the national capital of Paramaribo. The Interior Precambrian Shield is relatively uninhabited and covered with undisturbed Neotropical Amazonian forest.[7,8] The Interior is not easily accessible because it is densely forested and the road network into the Interior is only about 1,520 kilometers. There are four main rivers running north south, providing 4,656 kilometers of inland waterways, along which most rural settlements are scattered.[9]

Suriname has a tropical climate, with daily temperatures varying between 23 and 31 degrees Celsius (ºC).[10] The average annual rainfall in Paramaribo is 2,200 millimeters. In the whole country, the rainfall varies from less than 1,750 to greater than 3,000 millimeters annually.[11] The year can be roughly divided in two wet seasons (April to mid-August and December to February) and two dry seasons (February to April and mid-August to December).[12]

The country is divided into 10 distrikts, established by a decree issued in 1985. The 10 distrikts are:

1) Paramaribo: the national capital, i.e. the urbanized area on the left bank of the Suriname Rivier;
2) Wanica: the urbanized rural area, south and west of Paramaribo;
3) Para: the mining and forestry area of central Suriname;
4) Brokopondo: the reservoir area with its dependant area of large-scale agriculture;
5) Commewijne: the populated, agricultural urban area along the right bank of the Suriname Rivier;
6) Saramacca: the traditional area of small farms and fishing already noticably affected by urban growth and the introduction of modern methods of rice and banana;
7) Coronie: the populated coastal area suitable for both coconuts and rice;
8) Nickerie: the populated coastal area in the northwest suitable for rice (includes the Corantijn Kanaal) cultivation;
9) Marowijne: the populated part of northeastern Suriname, having the potential to support mining, large-scale agriculture and recreation; and
10) Sipaliwini: the upriver area populated in part, the western Suriname development area, and the rest of the nation that is as yet unused.[13]

B. Population and Social Impacts

Suriname is one of the few countries that have not experienced any significant population growth since the 1970's. From 1972 to 1980, population growth was negative, mostly as a consequence of emigration around independence in 1975. During the 1980's the population grew slightly. In the early 1990's emigration evened out with natural population increase, thereby reducing the growth to zero.[14]

Most of the inhabitants are concentrated along the roads and rivers of the coastal area and a southward-running area in the Para and Brokopondo Distrikts. Only in the vicinity of Paramaribo is there a relatively high population density.[15] Suriname is one of the least densely populated countries in Latin America. In 1980, the average population density was approximately two inhabitants per square kilometer, which is very low. When looking at the distrikts, Paramaribo has the highest population density, although it only covers approximately 0.02 percent of the area of the country. It can be concluded that the population is predominantly concentrated in areas around the distrikts Paramaribo and Wanica.[16]

Nearly all the inhabitants live within a 30-kilometer wide coastal region. The capital Paramaribo lies about 20 kilometers south of the coast at the west bank of the Suriname Rivier.[17] The Interior is inhabited mainly by tribal people. Demographic statistics of the coastal areas have always been much more reliable than those of the Interior. Fertility levels and population growth in the Interior seem higher than in the coastal areas.

Large parts of the country, the most infertile and swampy areas that are not easily accessible, are uninhabited. In some regions, vast fields of rice, banana and oil palm extend from horizon to horizon with hardly any sign of human habitation. In other areas, the landscape is dotted with small farms that raise cattle and dryland crops.

There are a few rural villages with a relatively high population density near the industrial centers in the areas between Lelydorp and Paranam and around Moengo. Isolated fishing villages and tribes having a tradition of migration account for the remainder of the population.[18]

The population has hardly grown since its independence in 1975, mainly due to emigration.[19] Since the 1950's, the growth rate has varied between 3.1 percent and -1.0 percent.[20] Some sources indicate growth rates of greater disparity. According to the Population Reference Bureau, the 2000 World Population Data Sheet, the total population in 2000 was 434,000. The population is expected to decrease to 380,000 by the year 2050.[21]

See table 1 below for population figures by distrikt, probably from the 1980's.

Table 1. - Population Distribution**

Distrikt	**Population**	**Capital**	**Approximate Area (km^2)**
Paramaribo	170,000	Paramaribo	183
Wanica	61,000	Lelydorp	443
Para	12,000	Onverwacht	5,393
Brokopondo	6,500	N/a	7,364
Commewigne	20,000	Mariënburg	2,353
Saramacca	11,000	Groningen	3,636
Coronie	2,800	Totness	3,902
Nickerie	32,500	Nieuw Nickerie	5,353
Marowijne	16,000	Albina	4,627
Sipaliwini	23,000		130,566
Total	**354,800**		†† **163,820**

Source: Internet, http://ourworld.compuserve.com/homepages, Accessed 12/27/00.
**Year of data unknown, but believed to be in the 1980's.
††Most sources indicate an approximate area of 163,270 square kilometers.

C. Economy

Suriname has a good starting point for a sustainable social-economical development. The availability of many natural resources and the potential of fertile land and freshwater provide a solid base for the economical development of the country.[22] The country has substantial bauxite reserves, extensive tropical forests, large unexploited resources of gold and kaolin and good water and air quality.[23]

The coastal zone is of great importance to the economic development of the country. About 95 percent of the population are living and working in this area. Important economic sectors such as agriculture (rice farming, banana plantations and the majority of other agricultural activities except for oil palm plantations), the oil industry, and fisheries are concentrated in the coastal zone. The four international harbors (Paranam, Paramaribo, Nieuw Nickerie, and Moengo) are located in the coastal zone. Other activities in the coastal zone are firewood collecting, bee-keeping, collecting and selling of turtle eggs (of nests that otherwise would be lost), hunting, recreation, and (eco)tourism.[24]

For decades, the pillars of the economy were bauxite mining, aluminum production, and the cultivation of rice, bananas, vegetables, and fruits.[25] The bauxite industry accounts for more than 15 percent of GDP and 70 percent of export earnings.[26] Suriname formerly exported palm oil. Agriculture is confined mainly to the coastal plains area and the river valleys and has great potential for expansion. Rice is the chief crop.[27] All of these exports, including shrimp and timber, decreased in 1989 due to lack of competitiveness of Suriname's products and insurgencies in the Interior which effectively closed access to timber and most palm oil plantations.[28]

During the 1980's, the country experienced political and economic problems as a result of falling bauxite and aluminum prices, and the suspension of development aid from The Netherlands. Suriname was admitted to CARICOM in 1995, but to participate in the market, it must produce competitive goods. During the country's 15 years of crisis, the deterioration of the infrastructure has hindered attempts to increase production and exports. Rice production, a major source of income, suffers from inadequate infrastructure to climatic effects of heavy rainfall and drought.

Seventy percent of the population was living under the poverty line in 1993.[29] The National Income per Capita (Sf) in 1990 was 7,093; in 1999, it was 1,402,160.[30]

D. Flooding and Flood Control

The majority of the Young Coastal Plain lies between 0.5 and 1.5 meters above national datum, about mean sea level (NSP) with the highest points (ridges) reaching 4.0 meters NSP. As a result, sea and river defenses are necessary in some regions to protect the land from inundation. When these defenses are breached or overtopped, as happens occasionally, tidal flooding by saline water causes damage to agricultural areas as well as to infrastructure such as roads and housing.[31] These defenses are very expensive to maintain.[32]

In the coastal area including Paramaribo, the drainage of storm water constitutes a serious problem during the wet seasons, as these areas are very flat, and low lying, resulting in frequent floods. Therefore, through the discharge of septic tank effluent, faecal waste is dispersed through the floodwater into the environment. In the wet season, the incidence of diarrhea increases in the marginal urban areas.

Flooding in Paramaribo and other places in the coastal plain are common. In relation to channels, there is a coordination problem since four ministries are in charge. A detailed investigation and program for restoration of the sewer system is badly needed. Greater Paramaribo has 25 sluices and pumping stations. Some of the pumping stations are in disrepair further reducing effective service. [33]

In past decades some measures in Paramaribo were taken to minimize the flooding, such as:

- The implementation of several projects to improve discharge capacity (pumping stations and open canals with large storage); and
- Improved mechanical equipment for the maintenance of open canals and ditches, and the cleaning up of sewer pipes.

However, the flooding conditions were aggraded due to:

- Growth and expansion in Paramaribo;
- Increased paved surfaces;
- Illegal occupation of the service roads alongside the open drainage channels;
- Illegally and inexpertly placed culverts;
- Replacement of ‘open water’ drainage with pipes having smaller cross section and storage capacity;
- Lack of maintenance in domestic ditches; and
- Deterioration of solid waste collection, prompting the population to dispose of their solid refuses in open channels.

E. Legislative Framework

The Ministry of Natural Resources controls the exploitation and management of all natural resources, including water. Within the ministry, the Water Supply Service (NH/DW) is responsible for the water supply in the remainder coastal area and the hinterland.

Three government entities presently share the responsibility for the water supply services:

1) The Suriname Water Company (SWM) which provides water supply services to the Paramaribo and part of Wanica, Nieuw Nickerie, and Albina;
2) The Water Supply Service of the Ministry of Natural Resources covers the rural population living in the coastal areas and the Interior; and
3) The Ministry of Regional Development, which provides logistic support.

The SWM has a management information system with several functioning database systems.

Five private entities provide drinking water to the communities of Patamaca, Yarikaba, Wageningen, Paranam, and Onverdacht. The responsibilities for sewage management and wastewater disposal are shared by: the Sewer and Drain Division of the Ministry of Public Works; the Environmental Control Division of the Bureau of Public Health of the Ministry of Health; and the Ministry of Regional Development.

Most of the institutions of the Water Supply and Sanitation Sector are weak. They are affected by lack financial means, lack of sufficient qualified personnel, and clear legislative direction. Most offer services that are not self-sustaining. At present, there is limited financing and limited financial resource allocation to the sector.

Responsibilities for the management of the sector are fragmented across several institutions and departments. Coordination and integration would lead to a more efficient use of personnel and materials, a more focused planning of necessary investment, and a uniform price level of water supply services. Although Suriname is striving for having the drinking water supply in the coastal area operated by only one drinking water supply company, the Water Supply Service has not been integrated into the SWM. Clearly, a politically acceptable integrated model for the water supply of the coastal area is required. The absence of a strong, coordinated rural sanitation program, coupled with limited health education and infrastructure weakness, represent a critical constraint for rural sanitation development in the country.

Institutional problems affect sanitation in greater Paramaribo. Various institutions share the actual management responsibility without coordination and without a common plan. The establishment of a Sanitation Master Plan for greater Paramaribo has been discussed and recommended in the Sector Analysis. [34]

Although studies undertaken in the past have represented a significant step forward, neither the National Water Authority nor the Drainage Authority for Paramaribo has been established.

At present, there is no law that comprehensively regulates the water supply and sanitation sector as a whole. However, there has been a draft water law since 1984. Most water supply systems use ground water as their source, which is a common property resource and should be protected by law. Legislation regarding the ground water procurement areas is drafted and should be adopted as soon as possible. The Water Supply Law regulating water supply services and protecting water resources was submitted to the Cabinet of Ministers in 1994. The status of this proposed law is unknown. A law protecting surface water is needed. This law should address, among other things, the technical standards for the discharge of wastewater. The existing legislation regarding health and environmental issues is vague and antiquated, being more than 50 years old. There is an urgent need to update the legal framework of the Water Supply and Sanitation Sector.[35]

The Hydraulic Research Division of the Ministry of Public Works promotes the optimum utilization, management and protection of water resources. It is the principal agency in the country that collects and publishes hydrologic, hydraulic, and water quality data and information, and conducts investigations and research. Activities regarding water resources are coordinated by this agency, which also provides advice to the government. This Division is in charge of the national hydrometric observation system, as well as the collection of basic hydraulic and water quality data. The main areas of concentration are water resources investigations and development, irrigation, drainage, erosion and sedimentation, water management, the environment, the protection of riverbanks and the coast, the navigability of the rivers and aquaculture.

The Ministry of Natural Resources is also responsible for the forestry sector and gives policy guidance. The Forest Service is in charge of the management and control of the public forests. In 1992, a new Forest Management Act was enacted for sustainable management of forest resources.[36]

The Ministry of Agriculture historically is responsible for irrigation water, infrastructure, and drainage.[37]

The Meteorological Service falls under the Ministry of Public Works. The Service maintains and manages all meteorological data of the country. They are responsible for all weather forecasts and meteorological data for Suriname.[38]

Other government institutes involved in the water supply and sanitation of the country are the Ministry of Planning and the National Institute for Environment and Development (NIMOS). International institutions involved include PAHO/WHO, UNICEF, IDB, Islamic Development Bank, and the Caribbean Development Bank (CDB). The Government of the Netherlands and Belgium, and the European Union (EU) also contribute. There are also a number of nongovernmental and private sectors that contribute.[39]

III. Current Uses of Water Resources

A. Water Supply and Distribution

Only 0.2 percent of the internal renewable water resources of the country are extracted per year for water supply. Water resources are abundant and can be found either as surface or ground water. Because of its superior quality, ground water is the primary source in the urban and coastal rural areas while in the Interior the population generally uses surface water. Surface water quality in urban, as well as rural areas, is under severe stress due to poor sanitary practices, and industrial and mining activities. Saltwater intrusion in the ground water is also becoming more of a problem in the coastal areas and in the water supply wells for Paramaribo.[40] To counteract this, some well fields that have higher chlorides are mixed with water of lower chlorides.[41]

In the 17th century, there were no water supply systems in Suriname. At the beginning of the 20th century, water was brought by train from Republiek, 40 kilometers south of Paramaribo. On 27 April 1933, Suriname was able to provide its population with potable water. A general government regulation, adopted on 22 February 1938, forbids private well construction and rainwater storage. The people were compelled to have their houses connected to the distribution system of the Suriname Water Company (SWM). In 1962, in order to provide more potable water, the government created a water supply section in the Ministry of Public Works. Later on, the water supply section was transferred to the Ministry of Natural Resources. In 1958, the SWM started a water supply system in Nickerie and, in 1960, the water supply of Albina. Nieuw Nickerie and Albina started as government-owned separate entities in which the government entrusted the management to the SWM.[42]

The SWM provides water supply services mainly to urban areas. The Water Supply Service of the Ministry of Natural Resources (NH/DW) covers the rural population. The Ministry of Regional Development provides logistic support.[43] Unlike other South American countries, Suriname has no plans for private participation in the water supply sector.[44]

A *Sector Analysis of Drinking Water Supply and Sanitation in Suriname* was prepared in the fall of 1998, and published in 1999. The Director of the Department of Energy, Mining, and Water Resources of the Ministry of Natural Resources was the National Coordinator of the Analysis. The Government of Suriname has adopted the Sector Analysis as the national strategy for the development of the water and sanitation sector.

At the end of 1998, about 90.6 percent of the people in the urban areas were connected to the public supply. In rural areas of the Coastal Plain and the Interior Precambrian Shield, only 34 percent have piped water supply in their home. In the Interior Precambrian Shield, 60 percent of the people use untreated river water for drinking purposes.

The distribution systems in all areas are compromised by poor maintenance, water theft, and leakages. This results in pump breakdowns, low pressure, intermittent supply, and high potential for contamination. In some cases, tanker trucks are in operation to provide services where the piped supply has broken down completely. Unaccounted for water has been estimated at more than 50 percent in the distribution systems. Furthermore, mercury pollution from gold mining activities in the Interior, as well as excessive pesticide use on agriculture lands in coastal areas, are a major threat to drinking water quality. In the absence of good monitoring data, and considering the fact that disinfection is not practiced, drinking water cannot be considered safe.

There are a total of 63 water supply systems - 58 are owned by the Government (NH/DW) and 5 are privately owned. Twenty-two systems use surface water and 41 use ground water. A total of

40 water treatment plants are in operation in the coastal areas excluding privately owned plants. They are supplied by 163 wells, except Moengo, which uses surface water. In the Interior, there are 27 small water treatment plants, which mainly treat surface water. Most of the population of the country is served by SWM systems.[45]

The water supply and sanitation problems are known; corrective measures are known, but problems are not corrected. Implementation of the known corrective measures is needed. Water supply services desperately need to be upgraded.[46]

1. Domestic Uses and Needs

In 1986, water quality monitoring virtually ceased. The Saramacca Kanaal, however, is monitored by the Department of Public Works because of the additional functions of the canal, such as drainage, irrigation, industrial waste discharge, etc. This canal is contaminated, but some of the water is used for domestic water supply.[47]

The services are sometimes inadequate due to operational and maintenance problems. Water is not generally disinfected. Treatment consists of iron and manganese removal by aeration followed by rapid or slow sand filtration and shell filtration. The pH of the raw water is generally acidic but after treatment is alkaline.[48]

a. Urban Areas

Paramaribo is the national capital and main urban center of the country. Roughly half of the country's population lives in Paramaribo. SWM provides water supply services to the urban areas including Paramaribo and part of Wanica, Nieuw Nickerie, and Albina.

Ground water is used for water supply. It is possible to expand the well field of the Zanderij aquifer to reach its optimum exploitation capacity of 1,300 cubic meters per hour and proceed with the exploitation of the Zanderij aquifer of Rijsdijk, which has a maximum capacity of 1,700 cubic meters per hour. In the Nickerie area, the Zanderij aquifer of Euro-Zuid polder could be used.

In Paramaribo, the SWM laboratory and the Environmental Control Division of the Bureau of Public Health conduct water quality monitoring.[49]

At the end of 1998, about 90.6 percent of the people in urban areas were connected to the public supply.

b. Rural Areas

Most of the land area is rural, most of which is the Interior of the country. However, the Interior is very sparsely inhabited, with only about 15 percent of the country's total population. The coastal areas are also considered rural, with about 15 percent of the country's total population.[50] There is no long-term planning for water supply and sanitation in the rural areas.[51]

Surface water is mostly used in rural areas and in the Interior.[52] However, in northern areas (mainly coastal areas), ground water is used.[53] Where piped water is scarce, domestic wells are sometimes used. The water is sometimes contaminated by seepage of septic tank effluent or pit latrines nearby. The NH/DW provides water supply coverage to the rural population, and manages 20 water plants in the Interior.[54,55] Also, many coastal aquifers are being over pumped, and thus many wells have had to be abandoned due to saltwater intrusion. A main concern is the contamination of surface water due to uncontrolled mercury contamination originating from gold mining processes. Little regulation exists and enforcement is limited due to a lack of resources.[56] There is also very little (if any) monitoring of mercury in the surface water in the Interior.[57] Water quality sampling is done on an ad hoc basis.[58]

The expansion of the gold mining industry has polluted many creeks and rivers, which the indigenous population uses for water supply. This additional health threat further expands the villages' need to be served with safe water from water supply systems. However, the active participation of the communities is necessary for this to be realized. Removal of mercury should be considered.[59]

In the rural areas, only 34 percent have piped water supply in their home. In the Interior, 60 percent of the people use untreated river water for drinking purposes. This is a major health concern because 25 percent of the population defecates in the country's rivers, mercury contamination from gold mining is widespread, and the water quality unmonitored. There are entire villages in the Interior without access to potable drinking water.

The structure of the Interior warrants the utilization of simple water supply schemes such as: sand filtration followed by storage tank and point distribution; tapping of springs in the mountainous areas followed by gravity transport and distribution at standpipes; and/or individual family filters or rainwater catchments.

Water treatment in coastal areas consists of aeration, rapid filtration (for heavy metals), and shell filtration (for pH) for ground water. There is no chemical treatment. In Moengo, however, much surface water is used, so chemicals are used in water treatment. In the future, Moengo will probably use ground water for their water supply. When treated, surface water is chlorinated. Brownsweg is an exception where slow sand filtration and chlorination is used for water from Lake Brokopondo.[60]

2. Industrial/Commercial Uses and Needs

Bauxite companies produce their own water. Many rice companies, particularly those in the western part of the country, produce their own irrigation water.[61]

3. Agricultural Uses and Needs

The Ministry of Agriculture historically is responsible for irrigation water, drainage, and infrastructure. Drainage is the main problem with irrigation, not irrigation water itself, particularly in the wet season. In the coastal areas, there are 2,500 millimeters of precipitation a year. The precipitation is unevenly distributed.

Rice, bananas, and vegetables are the main crops irrigated. Only surface water is used for irrigation water. There are four seasons; two main and two secondary. Vegetables are grown in the secondary season. Some farmers grow vegetables in the wet season.

The coastal areas, which are predominantly flat, are the main agricultural zones. Brackish water is used for aquaculture, for cultivating shrimp, fish, etc. Fresh water is used for all other crops. Freshwater is obtained from swamps and rivers.

There is no fee for irrigation, but there are proposals to start charging farmers for using surface water. Uncontrolled use of water by farmers, because the water is free from open systems, creates a lot of water waste. No measuring devices are installed on the irrigation systems now, but there are plans to measure the irrigation water in the future. Drip irrigation systems are used on a very small scale.

A new irrigation system is being tried in the banana fields. A total of 2,000 hectares of bananas are grown, with 1,100 hectares on sprinkler systems. The other 900 hectares uses surface systems. Irrigation for bananas varies, depending upon the weather. Much less irrigation is used in areas where rainfall is more evenly distributed. Except for bananas, fruit trees do not require irrigation.

Most rice is grown in the west in the Nickerie area, about 35,000 hectares. Water from the Corantijn Rivier is used to irrigate the rice. In the Coronie Distrikt, 5,000 hectares of rice are grown, irrigated from swamps. The rest of Suriname uses rivers for fresh water irrigation, mainly in the form of 'open' irrigation systems.

Rice irrigation is estimated at 1,500 millimeters/hectare, which is very high. It is estimated that the water usage for rice will drop to 1,000 millimeters/hectare when fees for irrigation are charged. It is believed that, presently, much irrigation water is wasted. Irrigation water is used for growing rice and also for weed control. Many of the weeds cannot live being inundated with water, but the rice can survive. There are two rice crops/year for a total of 60,000 hectares of rice annually.[62] Many rice companies produce their own irrigation water, particularly in the western part of the country.[63]

Government policies for the expansion of agriculture focus strongly on increased rice production. As a result, the multipurpose Corantijn project was initiated in 1976 to expand agricultural development in northwestern Suriname by supplying water from the Corantijn Rivier for irrigation. The major feature of the present project is the Corantijn Kanaal, which extends 66 kilometers. The Kanaal has been designed to transport water at a rate of 50 cubic meters per second; the pumping station at Wakay was designed for a capacity of 30 cubic meters per second.[64]

4. Sanitation and Wastewater Disposal

No wastewater treatment exists in the country. Septic tanks are used for treatment, with the sludge dumped directly into rivers. The first major wastewater treatment plant in the country was in Flora, but it is longer operational. Stabilization ponds are needed, and there is enough land available to support them. Solid waste is also improperly disposed of. It is collected and deposited into open pits. There is a new landfill, but it is not sanitary.

In Paramaribo, 70 to 80 percent of the population has septic tanks. The rest of the urban population uses pit latrines.[65] Nickerie has septic tanks and pit latrines. In the Interior, about 25 percent of the population defecates in the rivers, which are also used for water supply. Approximately 44 percent of the rural population has no access to sanitary facilities. This is mainly because of the lack of sanitary facilities in the Interior, where nearly 70 percent of the people use fields, bushes, or rivers.

The ground water table is very high in Paramaribo and in the coastal zone. The standard design of most septic tanks is very small and is inadequate to provide good removal of solids. These factors contribute to the fact that soak-aways often do not function properly and the effluent of the septic tanks is directly discharged into open storm drains, ditches, and canals. Sludge from septic tanks and the contents of latrines are removed using vacuum trucks, which discharge their loads in the canals and rivers. The other part of the domestic sewage, sullage, resulting from personal washing, laundry, and from the kitchen enters the storm and street drains untreated.

The uncontrolled extension of Paramaribo gives rise to severe financial and economical problems to maintain sanitation services. It is no longer acceptable for the tank trucks to empty septic tanks and latrines into the Suriname Rivier without treatment. Drainage via the Saramacca Kanaal is problematic because it serves as a water transport route and as an irrigation canal. Part of northern Paramaribo drains directly into the Atlantic Ocean. The building code for Paramaribo requires a septic tank and filter bed. However, due to lack of supervision and control, septic tanks are sometimes constructed without a bottom and without a filter bed. Due to the absence of a public sewer system, effluent flows into storm water drains. During heavy rain, the water may back up.[66]

5. Social Impacts

The incidence of infectious disease is associated with deficiencies in the supply of water and sanitation. This is a top priority health problem. Gastroenteritis is the fifth cause of death in the country. Considering the geo-hydrological conditions of the coastal areas, including Greater Paramaribo, with high ground water table and high risk of flooding, in combination with the inadequate disposal of septic tank effluent and sludge and deteriorating water supply infrastructure, serious concerns exist in respect of the outbreak of water related diseases. The Upper Suriname area is densely populated. The high incidence of childhood mortality is probably related to poor sanitary conditions, such as the lack of safe drinking water and the lack of sanitation.

Episodes of diarrheal diseases are more frequent during wet seasons than during the dry seasons. In the Interior, the situation is now aggravated by the presence of mercury in the rivers due to the rapid increase in small-scale gold mining operations. According to a recent Suriname study developed in 1997, mercury contamination in excess of permissible WHO limits of 0.001 milligrams per liter was found in the following rivers: Lawa (3.89 milligrams per liter), Marowijne (1.87 milligrams per liter), Tapanahoni (0.69 milligrams per liter), Saramacca (0.10 milligrams per liter) and the Suriname Rivier (2.97 milligrams per liter).[67]

There is no systematic health and environmental education on water and sanitation in the country. The existing health and environmental health surveillance systems also need to be improved.

B. Hydropower

In 1981, 30 percent of Suriname's total energy requirement (for Paramaribo) was met by hydroelectric power, provided by the Afobaka Dam. The energy is transported over 100 kilometers.[68]

Inexpensive power costs are Suriname's big advantage in the energy-intensive alumina and aluminum business.[69,70] Since 1965, the Afobaka central hydroelectric power generator has produced an annual average of 1,030 million kilowatt-hours. Aluminum Company of America (ALCOA) built this $150-million dam. The lake created, 1,550 square kilometers, is one of the largest artificial lakes in the world Of the 1,030 million kilowatt-hours, 70 to 80 million kilowatt-hours are for the public electrical supply of Paramaribo. The rest is consumed by the Paranam aluminum smelter, which produces 50,000 tons of aluminum a year..

Power generation must be adapted to the lake level. The lake level has been very erratic over the years. The flow and lake levels are regulated as much as possible. Low flow during some years has caused the smelter plant to shut down. The smelter was closed down in March 1999, and as of January 2001, was still closed. In 1987 and 1988, the smelter was closed for a year and a half.

The Tapahoni Rivier can be dammed to divert more water to Brokopondo Lake to increase the capacity. A series of dams to divert the water would cost U.S. $300 million.

Water quality monitoring is not conducted in the lake. Contamination from small gold mining operations is likely. Lake sedimentation is not monitored either.[71]

In 1981, a microhydroelectric generator was installed in Poketi to supply electricity for a number of small villages in that area. The border rivers - the Marowijne and the Corantijn - and their tributaries also have enormous potential and good locations for generating plants. Although the hydropower potential of the Surinamese Rivier amounts to approximately 2,400 megawatts, only one hydroelectric dam at Afobaka in the Brokopondo Distrikt, with an installed capacity of 189 megawatts, has been built. On average, it generates 117 megawatts. Some medium and large hydroelectric projects will be constructed in the medium to long-term future.[72,73]

C. Stream Gage Network

The stream gaging and rainfall network were destroyed in 1986 during the civil war. Today, only 5 to 10 stations are in operation. Most of the recent data is from the late 1970's, with a small amount of data from the early 1980's until 1986.[74] In 1986, water quality monitoring also virtually ceased.[75]

D. Waterway Transportation

Transport on the roughly 1,200 kilometers of inland rivers and canals are very important. Oceangoing vessels with drafts ranging up to 7 meters can navigate many of the principal waterways. Paramaribo and Nieuw Nickerie are the chief seaports. Moengo, Paranam, and Smalkalden are also important ports for shipping bauxite. All bauxite mined in Suriname is transported via navigable rivers and the Atlantic to Paranam. Most of the rural population of the country is situated along major rivers and is their source of transportation.[76,77,78]

In creeks and rivers unaffected by tides, there may still be a large fluctuation in level and discharge between the wet and dry seasons. Navigability of rivers and creeks with a variable water level is based on the average lowest water level, which is recorded regularly so that the navigability limits printed on the charts hold true even in the most unfavorable conditions. In the wet season, vessels may be able to penetrate much further upstream.

The bridge over the Nickerie Rivier near Henar has been designed to allow passage of ocean vessels that have to dock at Wageningen. There are lift locks at both ends of the Saramacca Kanaal at Uitkijk and in the Saramaccadoorsteek. There is also a lock in the Arawara Kreek, the connection between the Nickerie Rivier and the Wajambo Rivier. Near the polder pump of Wageningen, there is a lock so that ships may pass between the Nickerie Rivier and the polders. The locks are limited in their abilities: they allow passage, however, they also place restrictions on the size of vessels that can be accommodated and may cause considerable delay in passage.

Shore facilities for loading, discharging, and warehousing may be either ports or landings. The latter belong to industrial concerns and have been adapted for the loading and discharging of particular goods, for example, oil products or bananas. Ports are for multipurpose use. Ocean vessels can dock at the ports of Paramaribo, Paranam, Nieuw Nickerie, Apura, and Moengo. There are landing facilities for ocean vessels at Wageningen, Smalkalden, Slootwijk, Paramaribo and vicinity.[79]

E. Recreation

The first steps to develop the tourism industry were taken in 1951. Within the Government of Suriname, a tourism service was established, that is now the Bureau for the Coordination of the Tourism and Horeca sector. This Bureau operates under the Ministry of Transportation, Communication and Tourism. In 1970, the execution of nature tourism and nature education activities started within some nature reserves and in Brownsberg Nature Park.

Suriname is part of the Guianas, which is part of the Amazon Eco Region. Over 5 percent of Suriname's biodiversity is protected by the nature conservation legislation and the nature reservation system of the country. Although it seems the Interior is inaccessible, more than 25 airstrips, over 2,000 kilometers of accessible roads, and a good number of navigable waterways (rivers, creeks and canals) make travelling through the country possible.

By 1978, five nature reserves and the Brownsberg Nature Park were open to the general public. These six protected areas were chosen to facilitate the general public for nature tourism, education and research, due to their location, natural attractions, and unique ecosystems. Two of these five, Wia Wia and Galibi, are coastal reserves famous for the nesting population of four species of marine turtles. Wia Wia is immensely important to waterfowl, including migrating shorebirds and ciconiiform birds, such as herons and egrets, storks, scarlet ibises and spoonbills.[80] Seven of the nine major rivers start in the Central Suriname Reserve in the center of the country.[81]

The Marowijne Rivier, especially upstream, the Upper Suriname Rivier and the Upper Saramacca Rivier have interesting tourist resorts and cultural sites. The Marowijne adventure was the best-known and greatest river adventure of Suriname until the internal strife, which started in 1986. Many areas of the Upper Suriname Rivier and the Upper Saramacca Rivier have been transformed into eco-tourism resorts with nature and cultural attractions.

Several plans exist to exploit the Corantijn Rivier and its surroundings for eco-tourism purposes. Proposals to have large parts of the northern ecosystems protected within two nature reserves and two forest reserves have been submitted. The Upper Corantijn Rivier, its tributaries and the surrounding land is practically unknown.[82]

IV. Existing Water Resources

A. Surface Water Resources

The perennial rivers and streams supply water for mostly industrial and agricultural use. Surface water resources are not used as supplies for drinking water; the only exceptions are small communities in the remote Interior areas of the country. Climactic factors have a large impact on the country's streams, as evidenced by the dramatic seasonal and regional fluctuations in precipitation and stream flow. River discharges increase and decrease accordingly. Water quality for streams is fresh (less than 1,000 milligrams per liter total dissolved solids) and generally unpolluted from the headwaters in the south to roughly the northern quarter of the country, where the streams become estuaries and saline ocean water mixing occurs. However, mercury contamination from gold mining is a major environmental concern in the Interior of Suriname. A greater risk of pollutants entering the streams in the northern quarter also exists because of the population, agricultural, and industrial centers of the country.

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

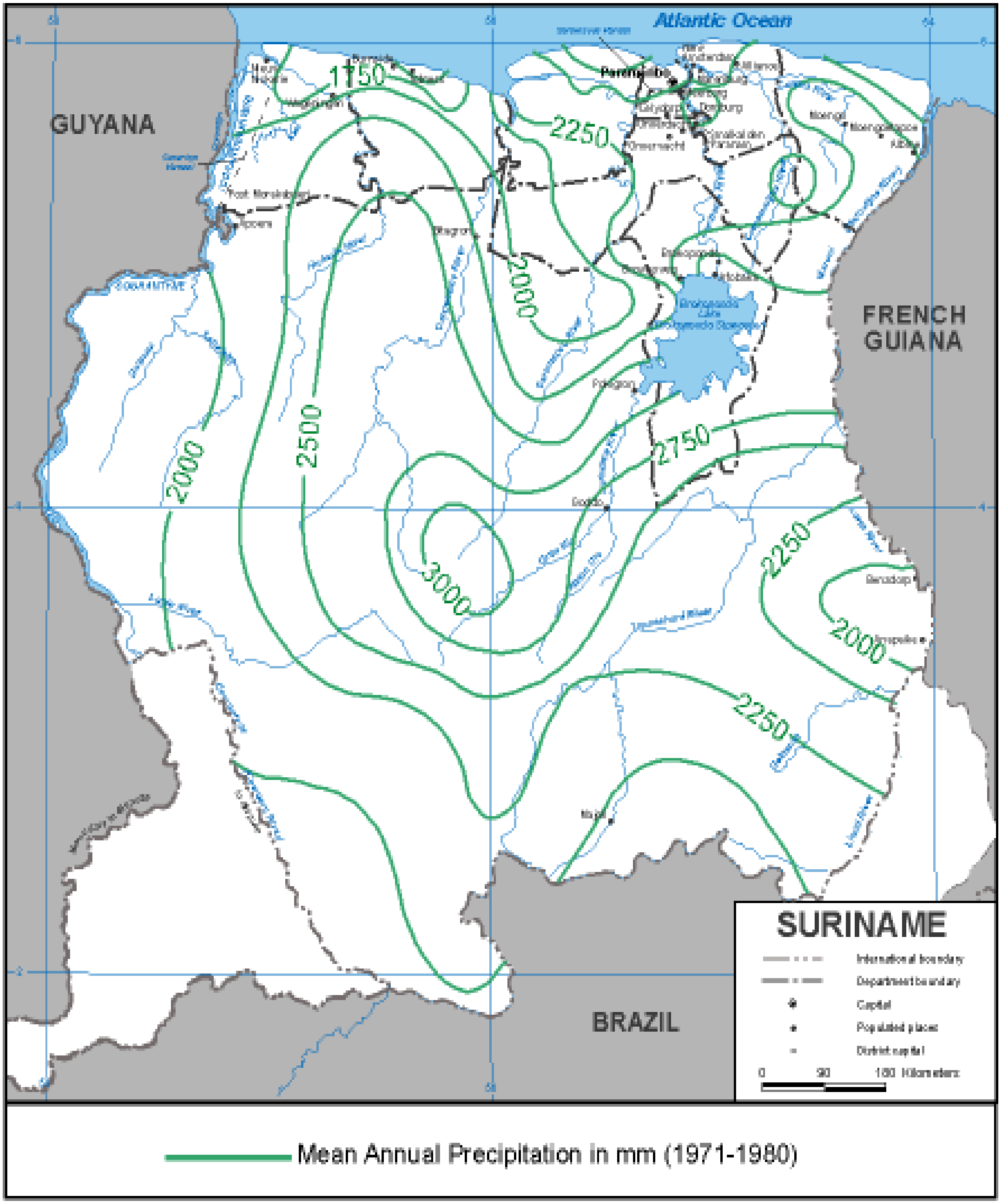
1. Precipitation and Climate

Suriname has a tropical climate with two wet seasons and two dry seasons per year. The long wet season is from late April to mid-August, and the short wet season is from early December to early February. The long dry season extends from mid-August to early December, and the short dry season is from early February to late April. The mean annual rainfall varies from about 1,450 millimeters at Coronie Distrikt to about 3,000 millimeters at Tafelberg (see figure 3). Average annual precipitation for the capital city of Paramaribo is 2,200 millimeters. About 50 percent of Suriname's annual rainfall occurs during the four months of the long wet season, while about 20 percent occurs during the long dry season.

Average annual precipitation rates in the Interior Precambrian Shield vary from 2,000 to 3,000 millimeters per year, with maximum daily rainfalls up to 100 to 200 millimeters once every 2 to 3 years. The infiltration and percolation of rainwater in this area is small compared to precipitation; therefore, surface runoff is relatively large. This leads to a rather high drainage density with numerous intermittent streams that flow only for short periods after rain events. About 67 percent of all rainfall in Suriname returns to the atmosphere by evapotranspiration, and about 33 percent is drained off into the Atlantic Ocean.

In the Savannah Belt, average annual precipitation rates vary from 1,900 to 2,600 millimeters. The infiltration and percolation of rainwater in this province is high, and the surface runoff is small. This indicates that most streams are gaining water from ground water primarily during the wet periods, with flow becoming nonexistent in small streams during the dry periods.

Average annual precipitation rates in the Coastal Plain vary from 1,500 to 2,500 millimeters.



Source: The National Planning Office of Suriname. *Suriname Planatlas*. Washington, DC, 1988, p.10.

Figure 3. – Precipitation Map

2. Drainage Basins

Suriname has seven major streams draining toward the Atlantic Ocean. The largest are the Marowijne and Corantijn (Courantyne) Riviers that form the country's borders, respectively, in the east and the west. These two rivers flow northward and drain almost 58 percent of the country. The Coppename and the Suriname Riviers also flow northward and together drain about 24 percent of the country. The smallest rivers are the Nickerie, Saramacca, and Commewijne Riviers, which drain 16 percent of the country. The final two percent of the country consists of coastal areas with direct drainage into the Atlantic Ocean. The three smallest streams flow northward parallel to the ocean before then they deflect westward and join with a larger river prior to reaching the Atlantic.

To the south, the border with Brazil coincides with the watershed boundary between the catchments of the Amazon and the catchments of the Surinamese Rivier. Country borders to the west and east also coincide with major rivers, and to the north is the Atlantic Ocean. This means that no rivers cross into or out of Suriname, and only minor tributaries from the bordering countries join the rivers to the west and east.

The character of each stream varies along its course, depending on which of three hydrologic zones it is passing through. These hydrologic zones correspond to the physiographic provinces shown on figure C-1. The provinces are from south to north, the Interior Precambrian Shield (Province III), the Savannah Belt (Province II), and the Coastal Plain (Province I). The largest is the Interior Precambrian Shield, covering about 80 percent of the country. The Savannah Belt is the smallest, covering 5 percent of the country, and the Coastal Plain covers the remaining 15 percent. Each province uniquely shapes the physical and chemical character of its surface waters through differences in geology, landscape, and climate. Therefore, the surface water resources description for the country is broken down by physiographic province. In addition, the predominant map units within each province are indicated, while the descriptions of each can be found in table C-1 and depicted on figure C-1.[83] Table 2 indicates the total catchment areas of each of the seven major streams and what percentage of each is contained in the three physiographic provinces.

Table 2. - Catchment Areas of Major Streams

Stream Name	Total Catchment Area (km^2)	Mean Discharge (m^3/s)	Interior Precambrian Shield (%)	Savannah Belt (%)	Coastal Plain (%)
Marowijne	68,700	1,791*	99.45	0.05	0.5
Corantijn	67,600	67,600*	90	4.6	5.4
Coppename	21,700	565	65.5	9.2	26.3
Suriname	16,500	422	84.8	4.5	10.7
Nickerie	10,100	174	42.3	23.6	34.1
Saramacca	9,000	257	74.1	3.1	22.8
Commewijne	6,600	169	36.4	11.5	52.1

*The total surface area of this river basin includes area in bordering countries. [84]

a. The Interior Precambrian Shield (Province III)

Precambrian rocks that are considered part of the Guiana Shield, a complex mixture of granites, gneisses, metasediments, and metavolcanics, form this province. Locally, this part of Suriname is often referred to as the Interior or Residual Uplands. It is characterized by a series of long terraces that are separated by pronounced scarps or cliffs. The remaining areas are mostly by low-lying plateaus, with only a few mountain groups rising over 250 meters above mean sea level. The border zone with Brazil is a bit higher with elevations ranging from 250 to 500 meters above mean sea level, and summits reaching up to 1,000 meters above mean sea level.[85]

Average annual precipitation rates vary from 2,000 to 3,000 millimeters for Province III, with maximum daily rainfalls reaching 100 to 200 millimeters once every 2 to 3 years. The infiltration and percolation of rainwater is small compared to precipitation; therefore, surface runoff is relatively large. This leads to a rather high drainage density, with numerous intermittent streams that flow only for short periods after rain events.

Province III is predominantly in Map Unit 5, indicating meager to very small quantities of fresh surface water available from seasonally intermittent streams and creeks. However, most major streams in this province are in Map Unit 3 with a few of the largest rivers having segments in Map Unit 1. The longitudinal profile of the major rivers does not show the usual smooth curve with increasing steepness toward the headwaters, but instead a more or less straight profile with steps. In the extreme headwaters sections, a steep increase is observed. In the middle sections, which comprise the most of the river reaches in this province, there are numerous rapids of up to meters in height. Some rivers contain a series of falls of up to 10's of meters in height, interspersed with quiet river reaches of a very low gradient.

b. The Savannah Belt (Province II)

The deposits throughout most of the Savannah Belt consist of the Pliocene age Coesewijne Formation, laid down by braided rivers flowing from the Interior Precambrian Shield (Province III), which created large amounts of sandy sediments as alluvial fans. This sand belt, also known as the Zanderij Belt, continues northward beneath the Coropina Formation that is at the surface in this province but occurs predominantly in the Coastal Plain (Province I). Erosion of the original Pliocene age alluvial fans has created a landscape that is flat to gently undulating, with broad plateaus alternated by creeks and rivers. The river valleys are deep, particularly in the western part of the country where the higher elevations allow for deeper dissection. Steep to very steep bank slopes occur with active erosion. The drainage network density is less in the Savannah Belt than in the Province III. About 93 percent of this province is covered with savannah forest, with the remaining 7 percent covered by deposits of bleached white sands.[86]

Average annual precipitation rates vary from 1,900 to 2,600 millimeters for Province II. The infiltration and percolation of rainwater is high, and the surface run-off is small. This indicates that most streams are gaining water from ground water primarily during wet periods, with flow becoming nonexistent in small streams during dry periods.

The step-like, longitudinal profile of the streams in the Interior Precambrian Shield continues northward into the Savannah Belt. Stream segments in the Savannah Belt show numerous rapids and falls interspersed with relatively quiet, low-gradient stretches. As they flow northward toward the Coastal Plain (Province I), some of the streams become estuarine, particularly in the eastern part of the country where the Savannah Belt is closer to the Atlantic Ocean. Major streams of the Savannah Belt are found in Map Units 1 and 3, while the most of the province is in Map Unit 4, consisting of seasonally intermittent streams, creeks, and swamps. During dry periods, both tidal and salinity effects from Atlantic waters can reach upstream into river segments in the Savannah Belt.

c. Coastal Plain (Province I)

The southern part of the Coastal Plain, often referred to as the Old Coastal Plain, consists of the Pleistocene age Coropina Formation of clays and sands which were deposited in a tidal flat-beach environment. The northern Coastal Plain, often referred to as the Young Coastal Plain, consists of the Holocene age, Demerara Formation of clays and ridges, which are made up of sands and shells. This part of Province I consists of extensive swamps and marshes, interspersed with roughly east-west trending ridges, which rise 1 to 3 meters above the neighboring clay flats. The longshore current moves along the coast from east to west carrying an abundance of clay-sized material from the outflow of the Amazon Rivier, located to the east in French Guiana. Only the larger rivers (Coppename, Corantijn, Marowijne, and Suriname) have enough flow to overcome the longshore current and associated Amazon Rivier derived clays, and flow directly northward to the Atlantic. The other major streams are forced to flow to the west and empty into one of the larger rivers that continue to the Atlantic.[87]

Average annual precipitation rates vary from 1,500 to 2,500 millimeters for the Province I. The perennial fresh water streams are in Map Units 1 and 3.

The major streams of the Coastal Plain are estuaries and are influenced by tides and saltwater surges from the Atlantic Ocean. In these estuaries, the water currents and levels are influenced by the tide and seasonal variations in fresh water discharge from the southern regions of the country. The Suriname tide is of the regular semidiurnal type, with two high waters and two low waters during a tidal day. Tidal and salt intrusions extend farther landward as the fresh water discharge decreases. Therefore, during dry periods with associated low flows, maximum salt intrusion occurs and during wet periods with peak flows, minimum salt intrusion occurs. Fresh water discharging from upstream is less dense and can occur above a deeper layer of brackish water from the sea.[88]

3. Lakes, Reservoirs, Swamps, and Lagoons

Suriname does not have many fresh water lakes. Brokopondo Lake (Brokopondo Meer) was created by damming of the Suriname Rivier. It covers an area of 1,560 square kilometers and is very low in dissolved oxygen as a consequence of vegetation drowned when the reservoir was constructed. Nani Lake (Nani Meer), located in the Nickerie Distrikt, is the only natural fresh water lake. Many exhausted bauxite mines have turned into small lakes. Topibo Lake (Topibo Meer) is a large red-mud lake complex at the old mining complex near Paranam.

Brackish lagoons in the coastal area, such as the Bigi Pan in the Nickerie Distrikt, are shallow depressions that are somewhat isolated from the ocean. In the dry season, when there is no source of fresh water, the salt content of the lagoons may increase enormously because of evaporation.

Swamps cover about 60 percent of the Coastal Plain and are characterized by stagnant water, dense tropical forest, and large amounts of decaying vegetation. In a 10-kilometer wide strip along the coast, the swamps contain brackish to saline water. The southern Coastal Plain contains swamps with fresh, soft water of low pH (less than 5.5). The northern Coastal Plain swamp waters become less acidic, pH of 6.1 to 7.5, and more brackish with soft-to-moderate hardness due to the proximity of and mixing with the Atlantic Ocean. The chemistry of the Coastal Plain water bodies changes significantly during the seasonal cycle, mainly due to the influences of rainwater and penetrating seawater. In many areas, water is fresh during the wet seasons from precipitation falling directly on the swamps. This fresh rainwater is less dense than the brackish swamp water and stays near the surface. During dry seasons, the swamps revert to brackish conditions. Swamp water is unaffected by the water flowing in the major streams which do not have extensive flood plains and basically flow without interaction to the Atlantic. In many of the swamps, a layer of peat (slightly decomposed organic material) has accumulated and the clay-rich deposits below prevent much infiltration and percolation. In the event of an extremely long dry period, which seems to occur about every 20 years, the water levels can fall below the peat layer and then there is a danger of the peat catching on fire. Swamp water does not generally mix with stream water but only very slowly drains into adjacent streams from small creeks. Instead, swamp water is transferred back to the atmosphere through evapotranspiration. Additionally, built-up agricultural areas of empoldered lands, containing primarily fresh water rice fields, cover 10 percent of the Coastal Plain. The fresh water swamps and agricultural areas are in Map Unit 2, while the brackish to saline swamps and the tidally influenced segments of the major streams are in Map Unit 6. The Nani and Coronie swamps, located in the Nickerie and Coronie Distrikts, provide fresh water for irrigation.[89]

4. Deforestation Effects

Suriname is densely forested and has suffered little from deforestation, but increased interest in large-scale commercial logging and mining in the Interior have raised environmental concerns. Suriname's rainforests have one of the most diverse eco-systems in the world. Sustainable development of the Interior and alternatives to deforestation, such as eco-tourism, is encouraged. Suriname is one of eight countries in the world that still have more than 70 percent of original forest cover. In most of Latin America and the Caribbean, an encroaching population is one of the major reasons for deforestation. This is not the case for Suriname; a fiscal crisis threatens the forests.

The Ministry of Natural Resources is responsible for the forestry sector and gives policy guidance. The Forest Service is in charge of the management and control of the public forests. In 1992 Suriname enacted a new Forest Management Act, which is directed to sustainable management of forest reserves. Forests are one of Suriname's most abundant natural resources with a high economic potential. It is reported by the United Nations Food and Agriculture Organization state that the annual deforestation rate is around 0.1 percent. The Suriname Forest Service suggests that the rate is 0.17 percent per year. The responsibility and authority regarding the state of forests is with the government.

Over 80 percent of the land surface is covered by tropical rainforests.[90] In 1993, Suriname invited Asian investors to explore possibilities for establishing logging concessions in the country's Interior. Five proposals were obtained by mid 1994.

Several thousand traditional people depend on Suriname's forests for their livelihoods. Subsistence use of the forest is the lifeline for most of the Amerindians and Maroons. These groups use a tremendous diversity of plant and animal products in daily life.[91]

The expansion of the agricultural frontier is another cause of deforestation. Traditional slash-and-burn practices have been the primary means of advancing the agricultural frontier in many countries. Two other factors are also becoming important threats: logging and fire caused by drought and human carelessness. In Suriname, as well as some other countries, a drive to exploit natural resources, brought about by an economic crisis, has accelerated the fragmentation of pristine forests over the past decade.[92]

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 streams, resulting in water levels that rise faster with larger peak discharges. The impact is dramatically increased immediately after logging, particularly in smaller watersheds. For the next 3 or 4 years, runoff and erosion are greatly increased, and less rainwater is able to infiltrate the soil to recharge the aquifers. This erosion increases the volume of sediment carried by the streams and degrades the water quality of the upland and downstream areas. Deforestation has also been associated with changes in rainfall patterns.

All streams have high sediment loads 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, 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.[93]

B. Ground Water Resources

The ground water resources of Suriname are used for public supply and to lesser extent industry. Ninety-five percent of the country's total supply of potable water comes from ground water.

See table C-2 and figure C-2 for further details on ground water resources.

Suriname contains two hydrologically distinct provinces, the Interior Precambrian Shield of crystalline rocks, comprising 80 percent of the country, and the Coastal Plain basin, comprising the remaining 20 percent.

The Coastal Plain basin contains an abundance of ground water confined under artesian conditions with water levels close to the ground surface. Very small to large quantities of fresh water are available from aquifers composed mainly of unconsolidated and consolidated clastic sediments of clay, sandy clay, and coarse-grained angular quartz sand that are more or less kaolinitic. Salinity generally increases toward the coast. Wells obtain ground water in the coastal hydrological province from three main aquifers: the Tertiary A Sand, the Tertiary Coesewijne, and the Tertiary Zanderij.

Ground water conditions in the northern Interior Precambrian Shield are generally unfavorable, because the geological formations in this province have little or no primary permeability. As a result, the aquifers, which consist of Precambrian age granite and gneiss, have low yields, except where fractures and weathering have enhanced the permeability and porosity.

Development of the ground water resources is variable. Siting and drilling for shallow artesian wells in the coastal area is easy. Problems include shallow ground water that is often contaminated near settlements. Locally high concentrations of iron make the water unsuitable for many purposes. Also, high acidic levels cause rapid corrosion of metals. Saltwater intrusion can be a problem in areas along the coast. The shallow aquifers are subject to mercury contamination from illegal gold mining activities. Accessibility to drilling sites is difficult in many areas due to dense forests and seasonal coastal inundations. Wells in all areas should be cased and screened.

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 followed by specific country attributes.

Ground water supplies are developed from aquifers, which are saturated beds or formations (individual or groups) that yield water in sufficient quantities to be economically useful. To be 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. On the other hand, 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 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, which 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 potentially, the difference between producing some water versus no water at all. Onsite 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 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 Suriname are: Tertiary age Coesewijne and A Sand aquifers consisting of unconsolidated and consolidated clastic sediments of clay, sandy clay, and coarse-grained sandstone (Map Unit 1); and Tertiary age Zanderij aquifers consisting of unconsolidated to consolidated sediments of sandstone, siltstone, and gravel (Map Unit 2). Other aquifers are Precambrian age fractured and weathered sedimentary, metaclastic, and carbonate rocks (Map Unit 3); and Precambrian age metamorphic and igneous rocks (Map Unit 4). These aquifer systems are described in table C-2 and are depicted on figure C-2. Descriptions are based upon interpretation of the most current hydrogeological information available.[94]

a. Unconsolidated and Consolidated Sedimentary Aquifers (Map Units 1 and 2)

Fresh water is generally plentiful in very small to large quantities from the productive Tertiary age Coesewijne and A Sand aquifers consisting of unconsolidated and consolidated clastic sediments of clay, sandy, clay, and coarse-grained sandstone (Map Unit 1). The thickness of the Coesewijne aquifer decreases from north to south. The thickness varies from 17 meters at

Republiek to 100 meters at Paramaribo. Along the coastline, the thickness increases from 90 meters near the Marowijne Rivier to 150 meters at Nieuw Nickerie. Depth to the Coesewijne aquifer ranges from 10 meters in the Old Coastal Plain to 70 meters at Paramaribo, and up to 230 meters at Nieuw Nickerie. The formation consists of alternating sand and clay layers with the thickness of the individual sand layers not exceeding 10 meters. Sand layers constitute 30 to 50 percent of the total formation. South of Lelydorp, the Coesewijne sands are in hydraulic contact with the overlying Zanderij Formation. North of Paramaribo, the aquifer becomes brackish.

The Tertiary age A Sand (Burnside Formation) aquifer contains fresh water in many places, including the capital city of Paramaribo. The sands are found north of Lelydorp village at depths of 120 to 160 meters; at Nieuw Nickerie, the aquifer is encountered at a depth of 340 meters. Lateral aquifer boundaries are the crystalline rocks to the south, which pinch-out just east of the Suriname Rivier and westward in the vicinity of the Saramacca Rivier. The aquifer thickness varies from 2 to 60 meters and becomes brackish north of Paramaribo. The A Sand aquifer receives no recharge and is therefore being mined for ground water. However, the underlying Paleocene to middle Eocene age Onverdacht aquifer system, consisting of multiple sand lenses, is hydrologically important as a potential source of upward leakage to the A Sand aquifer. Wells completed in this aquifer typically yield about 11.5 liters per second.[95]

Small to large quantities of fresh water are generally plentiful from the Tertiary age Zanderij aquifer consisting of unconsolidated to consolidated sediments of sandstone, siltstone, and gravel (Map Unit 2). The Zanderij aquifer outcrops in the Savannah Belt bordering the crystalline basement. Depth to aquifer in the northern part of the coastal zone is about 30 to 50 meters. The aquifer thickness varies near Paramaribo from 10 meters, in the Savannah Belt, to 40 meters near the coast, and 230 meters in Nieuw Nickerie. The aquifer mainly contains brackish water in the Young Coastal Plain. This aquifer is primarily located in the coastal plain hydrological province and along the courses of the Corantijn and Marowijne Riviers.

<u>b. Fractured and Weathered Sedimentary, Metaclastic, and Carbonate Aquifers (Map Unit 3)</u>
Fresh water is generally plentiful in meager to large quantities from fractured and weathered zones in Precambrian age sedimentary, metaclastic, and carbonate rocks. Fracturing and weathering may extend up to 70 meters. The deepest weathering occurs in the metasediments (15 to 30 meters) and the least in the granites (up to 16 meters): these aquifer areas primarily located in the Interior Precambrian Shield (Province III).

<u>c. Other Aquifers (Map Unit 4)</u>
Fresh water is scarce or lacking in areas with fractured and weathered zones in Precambrian age granite and gneiss. These aquifers are located in the northern Interior Precambrian Shield hydrological province. Meager to moderate quantities of brackish to saline water is found in the fractured and weathered zones from 15 to 30 meters. Locally, weathering may extend up to 70 meters deep.[96]

C. Water Quality

The quality of drinking water delivered to the population is generally good. However, it should be monitored regularly on the coastal areas as well as the Interior. Determination of the concentration of heavy metals, such as mercury and cyanide in drinking water, should be considered particularly in the Interior.[97]

1. Surface Water

Surface water quality in urban as well as rural areas is under severe stress due to poor sanitary practices and industrial and mining activities.[98]

Water quality for streams is fresh from the headwaters in the south to roughly the northern quarter of the country where the streams become estuaries and saline ocean water mixing occurs. A greater risk also exists of pollutants entering the streams in the northern quarter because this region has the major population, agricultural, and industrial centers of the country. The Coastal Plain province is the population and industrial center of the country. The bauxite mining and aluminum refinery near Paranam has created areas contaminated by heavy metals and alkaline rich effluent from the use of caustic soda in the refinement process. Topibo Meer is a large red-mud lake complex at the old mining complex near Paranam.[99] In areas of empoldered agricultural fields, swamp forest may have been removed by poisoning or by raising the water level to drown the trees. The Saramacca Kanaal carries soft and very turbid water from the Saramacca Rivier to Paramaribo to the Suriname Rivier. It is situated in an area with a lot of industrial activities (paints, wood, rice, and washing powder), and is consequently strongly polluted. The Kaanal is also used for some domestic water supply. The Corantijn Kanaal carries fresh water from the Corantijn Rivier to coastal areas for rice irrigation.

Biological contamination is widespread near and downriver from populated places and industrial activities. Rivers and creeks of the Savannah Belt have low pH of usually less than 5.0. This acidity is derived from humic acids, which are released in the water from decaying plant material or through the soils. Often these streams are referred to as Black Water Riviers due to the tea-brown color imparted by the high amount of humic acids. The stream water also has low hardness, low salinity, low turbidity, and low dissolved oxygen levels (less than 35 percent saturated). Large concessions to forestry have been made in the Savannah Belt; the logging industry uses some of the larger rivers to float fallen trees down stream. Overall, the surface water resources of the Savannah Belt are fresh. The only exception is during dry periods. The saline water of the Atlantic can encroach upstream into the most northerly areas where the eastern streams of the Savannah Belt are most susceptible. Biological contamination is possible near and downriver from populated places.[100]

Rivers and creeks of the Interior Precambrian Shield have medium pH levels from 6.5 to 7.3 and low electrical conductivity. They contain water that is soft to moderately hard, with low to very low salinity and low turbidity. However, this water is high in dissolved oxygen (66 to 131 percent saturated) because of the numerous falls and rapids. Some streams have locally high levels of hardness because these flow through areas containing rocks, which contribute large amounts of total dissolved solids such as gneisses and amphibolites. Many of the rivers have high mercury levels due to illegal gold mining activities. Sara Creek, which flows into Brokopondo Lake, has a large concentration of sediment and is highly contaminated by mercury. Brokopondo Lake (Map Unit 1), a lake created by the damming of the Suriname Rivier, is very low in dissolved oxygen as a consequence of vegetation drowned when the reservoir was constructed. Overall, the surface water resources of the Interior Precambrian Shield can be considered fresh, yet some biological contamination is possible near and downriver from populated places.

2. Ground Water

The ground water resources of Suriname are suitable for most uses. Fresh to brackish ground water is available from the aquifers of the Coastal plain (Province I). Brackish to saline ground water is available from the aquifers in the Interior Precambrian Shield. 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 contamination occurs in shallow aquifers near population centers. Chemical contamination of shallow aquifers by pesticides occurs in agricultural areas. Ground water from the igneous and metamorphic aquifers may be distasteful and discolored due to high iron and manganese content. A major water quality concern is the mercury contamination of the shallow aquifers from illegal gold mining activities. Treatments of fresh ground water by a simple sand and shell filtration method and of saline ground water by reverse-osmosis desalination is necessary to insure the water is suitable for human consumption.[101]

V. Water Resources Distrikt Summary

A. Introduction

This chapter summarizes the water resources information of Suriname, 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 6. 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 4. 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 distrikts.

B. Water Conditions by Map Unit

Figure C-1, Surface Water Resources, divides the country into six map units based on water quantity, water quality, and seasonality. Map Units 1 through 3 depict areas where fresh surface water is perennially available in small to enormous quantities. Map Units 4 and 5 depict areas where fresh surface water is seasonally available in meager to moderate quantities during high flows. Map Unit 6 depicts areas where fresh surface water is scarce or lacking and moderate to enormous quantities of brackish to saline water are perennially available. Figure C-1 also divides the country into three drainage regions, the Coastal Plain (Province I) drainage region, the Savannah Belt (Province II) drainage region, and the Interior Precambrian Shield (Province III) 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 four map unit categories based on hydrogeological characteristics. Map Units 1 and 2 depict areas where ground water development appears to be most favorable and fresh water is generally available in very small to large quantities. Map Unit 3 depicts areas where meager to large quantities of fresh water is locally plentiful. Map Unit 4 depicts areas where fresh water is scarce or lacking and areas where the ground water is brackish to saline.

In the text, surface and ground water quantity and quality for each province 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	= ≤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 Distrikt

The following information was compiled for each distrikt from figures C-1 and C-2 and tables C-1 and C-2. The write-up for each distrikt 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 distrikt 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 distrikt. Specific well information is 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.

Brokopondo

Area and Relative Size:	7,364 square kilometers (4.0 percent of the country)
Estimated Population (1980):	6,622 (0.8 percent of the population)
Population Density:	0.9 people per square kilometer
Distrikt Capital:	Brokopondo
Location:	The distrikt is located in the east-central part of the country and contains Brokopondo Lake. The distrikt is bounded on the north by Para Distrikt and on the south, east, and west by the Sipaliwini Distrikt.

Surface Water:

Fresh surface water is perennially available in large to enormous quantities in the part of the distrikt that lies along the Suriname Rivier and its tributaries. Large to enormous quantities are available from Lake Brokopondo; Map Unit 1 depicts these areas. The distrikt capital of Brokopondo lies in Map Unit 1.

Fresh surface water is seasonally available from intermittent streams and creeks in the rest of the distrikt as depicted by Map Unit 5. Meager to very small quantities are available during the high flow season from April through mid-August. The low flow season is from mid-August to December, when unsuitable to meager quantities are available. Within Map Unit 5, all but the largest streams go dry for extended periods of time during the low flow season.

Access to and the development of water sources are hindered by the lack of all-weather roads, rough terrain, and seasonally marshy ground. Toward the Interior of the country, access is difficult because of dense vegetation and steep rugged terrain.

Ground Water:

The best areas for ground water exploration are from the Tertiary age Zanderij aquifer present at the northern extent of Brokopondo Lake, as depicted by Map Unit 2. Small to large quantities of fresh water are available from the Zanderij aquifer at depths less than 80 meters. The aquifer consists of unconsolidated sediments of sandstone, siltstone, and gravel. About 20 percent of the distrikt lies within Map Unit 2. 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. Shallow ground water is often biologically contaminated near settlements. The distrikt capital of Brokopondo lies within Map Unit 2.

Map Unit 3 covers about 40 percent of the distrikt and is in the northwest, northeast, and southeast parts. Meager to large quantities of fresh water are available locally from fractured and weathered zones in Precambrian age sedimentary, metaclastic, and carbonate rock at depths of less than 70 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. Shallow ground water is often biologically contaminated near settlements.

About 40 percent of the distrikt lies in Map Unit 4 where ground water exploration is not recommended during military exercises. Fresh water is scarce or lacking along the eastern boundary of Brokopondo Lake and in the southern part of the distrikt.

Commewijne

Area and Relative Size:	2,353 square kilometers (1.0 percent of the country)
Estimated Population (1980):	20,063 (5.7 percent of the population)
Population Density:	8.5 people per square kilometer
Distrikt Capital:	Nieuw Amsterdam
Location:	The distrikt is located in the northeastern part of the country along the Atlantic Ocean. It is bound on the east by Marowijne Distrikt, on the south Para Distrikt, and on the west by Wanica Distrikt.

Surface Water:

Fresh surface water is perennially available in large to enormous quantities in the part of the distrikt that lies along the Suriname Rivier and its tributaries. Fresh surface water is perennially available in moderate to very large quantities from streams, canals, marshes, swamps, lakes and empoldered agricultural fields located in the coastal plain depicted by Map Unit 2. Small to moderate quantities of fresh water are perennially available from reaches of the Commewijne Rivier and its tributaries unaffected by saltwater incursion from tidal surges depicted by Map Unit 3. Flows are highly variable, with peak flow generally occurring during the long wet season from April to mid-August. Low flow periods generally occur during the long dry season from mid-August to December.

Moderate to enormous quantities of brackish to saline water are perennially available from streams, swamps, coastal lagoons, small ponds, and tidal marshes located along the coastal area depicted by Map Unit 6. The distrikt capital, Nieuw Amsterdam, lies within Map Unit 6.

Access to and the development of water sources are difficult due to dense vegetation, soft ground, saturated terrain, and the general lack of all-weather roads along much of the northern coast. Many areas are at roughly sea level, and tidal surges can inundate low-lying areas with saline water.

Ground Water:

The best areas for ground water exploration are the Tertiary age Coesewijne and A Sand aquifers found in the northern two-thirds of the district, as depicted by Map Unit 1. About 80 percent of the distrikt lies within Map Unit 1. The aquifers consist of unconsolidated and consolidated clastic sediments of clay, sandy clay, and coarse-grained sandstone. Depth to the Coesewijne aquifer may range up to 110 meters in the coastal area. Depth to the A Sand aquifer ranges from 186 meters in the coastal area at Nieuw Amsterdam to 350 meters inland. Very small to large quantities are available from these aquifers. Saline water zones underlie the fresh water zones in coastal areas and caution should be exercised in pumping to prevent saline water intrusion. Saline water wells would require reverse-osmosis and desalination equipment. Shallow aquifers may be biologically contaminated near settlements. Accessibility is generally easy, but may be locally difficult in areas along the coast subject to seasonal inundation. Alluvial aquifers, when properly developed, are suitable for municipal or irrigation wells. The distrikt capital, Nieuw Amsterdam, lies within Map Unit 1.

Map Unit 2 covers about 20 percent of the distrikt and is located along the southern boundary. Small to large quantities of fresh water are available from the Tertiary age

Zanderij aquifer, at depths of less than 80 meters. The aquifer consists of nonconsolidated sediments of sandstone, siltstone, and gravel. 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. Shallow ground water is often biologically contaminated near settlements.

Coronie

Area and Relative Size:	3,902 square kilometers (2.0 percent of the country)
Estimated Population (1980):	2,777 (0.8 percent of the population)
Population Density:	0.7 people per square kilometer
Distrikt Capital:	Totness
Location:	The distrikt is located in the northern part of the country along the Atlantic Ocean. It is bound on the west by Nickerie Distrikt and on the east by Saramacca Distrikt; Sipaliwini Distrikt forms the southern boundary.

Surface Water:

Fresh surface water is perennially available in moderate to very large quantities from streams, canals, marshes, swamps, lakes, and empoldered agricultural fields located in the coastal plain depicted by Map Unit 2. Small to moderate quantities of fresh water are perennially available from reaches of the Nickerie and Coppename Riviers and their tributaries, which are unaffected by saltwater incursion from tidal surges, and are depicted by Map Unit 3. Flows are highly variable with peak flow generally occurring during the long wet season from April to mid-August. Low flow periods generally occur during the long dry season from mid-August to December.

Meager to moderate quantities of fresh water are seasonally available in the southern part from intermittent streams, creeks, and swamps located in the coastal plain and savannah region as depicted by Map Unit 4. Peak flows generally occur during the long wet season from April to mid-August. During dry periods, minor streams and creeks may go dry and the water level in the swamps drop below the ground surface.

Moderate to enormous quantities of brackish to saline water are perennially available from streams, swamps, coastal lagoons, small ponds, and tidal marshes located along the coastal area depicted by Map Unit 6. The distrikt capital of Totness lies within Map Unit 6.

Access to and the development of water sources are difficult due to dense vegetation, soft ground, saturated terrain, and the general lack of all-weather roads along much of the northern coast. Many areas are at roughly sea level, and tidal surges can inundate low-lying areas with saline water.

Ground Water:

The best areas for ground water exploration are the Tertiary age Coesewijne and A Sand aquifers found in the northern two-thirds of the distrikt as depicted by Map Unit 1. About 80 percent of the distrikt lies within Map Unit 1. These aquifers consist of unconsolidated and consolidated clastic sediments of clay, sandy clay, and coarse-grained sandstone. Depth to the Coesewijne aquifer ranges from 140 to 180 meters at Totness and may range up to 280 meters inland. Depth to the A Sand aquifer ranges from 120 meters in coastal areas to 350 meters inland. Very small to large quantities of water are available from these aquifers. 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 along the coast subject to seasonal inundation. Alluvial aquifers, when properly developed, are suitable for municipal or irrigation wells. The distrikt capital of Totness lies within Map Unit 1.

Map Unit 2 covers about 20 percent of the distrikt and is found along the southern boundary and part of the eastern boundary. Small to large quantities of fresh water are available from the Tertiary age Zanderij aquifer at depths 80 meters or less. The aquifer consists of unconsolidated sediments of sandstone, siltstone, and gravel. 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. Shallow ground water is often biologically contaminated near settlements.

Marowijne

Area and Relative Size:	4,627 square kilometers (3.0 percent of the country)
Estimated Population (1980):	16,125 (4.5 percent of the population)
Population Density:	3.5 people per square kilometer
Distrikt Capital:	Albina
Location:	The distrikt is located in the northeastern-central part of the country along the border with French Guiana. The Atlantic Ocean lies to the north. It is bound on the west by Para and Commewijne Distrikts and on the southwest by Sipaliwini Distrikt.

Surface Water:

Large to enormous quantities of fresh surface water are perennially available from a small reach of the Marowijne Rivier depicted by Map Unit 1.

Fresh surface water is perennially available in moderate to very large quantities from streams, canals, marshes, swamps, lakes, and empoldered agricultural fields located in the coastal plain depicted by Map Unit 2.

Meager to moderate quantities of fresh water are seasonally available in one-third of the distrikt from intermittent streams, creeks, and swamps located in the coastal plain and savannah region as depicted by Map Unit 4. Peak flows generally occur during the long wet season from April to mid-August. During dry periods, minor streams and creeks may go dry and the water level in the swamps drop below the ground surface.

Fresh surface water is seasonally available from intermittent streams and creeks located in the savannah and Interior regions of the distrikt as depicted by Map Unit 5. One third of the distrikt is in Map Unit 5. Meager to very small quantities are available during the high flow season from April through mid-August. The low flow season is from mid-August to December, when unsuitable to meager quantities are available. Within Map Unit 5, all but the largest streams go dry for extended periods of time during the low flow season. The distrikt capital, Albina, lies within Map Unit 5.

Moderate to enormous quantities of brackish to saline water are perennially available from the Marowijne (Mareni) Rivier and other streams, swamps, coastal lagoons, small ponds, and tidal marshes located along the coastal area depicted by Map Unit 6.

Access to and the development of water sources are difficult due to dense vegetation, soft ground, saturated terrain, and the general lack of all-weather roads along much of the northern coast. Many areas are at roughly sea level, and tidal surges can inundate low-lying areas with saline water.

Ground Water:

The best areas for ground water exploration are the Tertiary age Coesewijne and A Sand aquifers found in the northern part of the distrikt as depicted by Map Unit 1. About 30 percent of the distrikt lies within Map Unit 1. These aquifers consist of unconsolidated and consolidated clastic sediments of clay, sandy clay, and coarse-grained sandstone. Depth to the Coesewijne aquifer may range up to 110 meters in the coastal area and depth to the A Sand aquifer may range up to 180 meters in the coastal area. Very small to large quantities of water are available from these aquifers. Saline water zones underlie the fresh water zones in the coastal area and caution should be exercised while 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 along the coast, subject to seasonal inundation and along the Marowijne Rivier. Alluvial aquifers, when properly developed, are suitable for municipal or irrigation wells.

Map Unit 2 covers about 40 percent of the distrikt and is found in the center and along the Marowijne Rivier. Small to large quantities of fresh water are available from the Tertiary age Zanderij aquifer consisting of unconsolidated to consolidated sediments of sandstone, siltstone, and gravel: depth to the aquifer is less than 80 meters. The distrikt capital of Albina lies within Map Unit 1.

Map Unit 3 covers about 30 percent of the distrikt and is found in the southwest. Meager to large quantities of fresh water are available locally from fracture and weathered zones in Precambrian age sedimentary, metaclastic, and carbonate rock at depths of 70 meters maximum. 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. Shallow ground water is often biologically contaminated near settlements.

Nickerie

Area and Relative Size:	5,353 square kilometers (3.0 percent of the country)
Estimated Population (1980):	32,690 (9.2 percent of the population)
Population Density:	6.1 people per square kilometer
Distrikt Capital:	Nieuw Nickerie
Location:	The distrikt is located in the northwestern part of the country along the border with Guyana. The Atlantic Ocean lies to the north. It is bounded to the east by Coronie Distrikt and to the south by Sipaliwini Distrikt.

Surface Water:

Large to enormous quantities of fresh surface water are perennially available from a small reach of the Corantijn Rivier as depicted by Map Unit 1. Throughout most of the distrikt, fresh surface water is perennially available in moderate to very large quantities from streams, canals, marshes, swamps, lakes, and empoldered agricultural fields located in the coastal plain as depicted by Map Unit 2.

Small to moderate quantities of fresh water are perennially available from reaches of the Nickerie Rivier and its tributaries, which are unaffected by saltwater incursion from tidal surges as depicted by Map Unit 3. Flows are highly variable, with peak flow generally occurring during the long wet season from April to mid-August. Low flow periods generally occur during the long dry season from mid-August to December.

Meager to moderate quantities of fresh water are seasonally available in the southern part of the distrikt from intermittent streams, creeks, and swamps located in the savannah region as depicted by Map Unit 4. Peak flows generally occur during the long wet season from April to mid-August. During dry periods, minor streams and creeks may go dry and the water level in the swamps drop below the ground surface.

Moderate to enormous quantities of brackish to saline water are perennially available from the Corantijn Rivier and other streams, swamps, coastal lagoons, small ponds, and tidal marshes located along the coastal area as depicted by Map Unit 6. The distrikt capital, Nieuw Nickerie, is in Map Unit 6.

Access to and the development of water sources is difficult due to dense vegetation, soft ground, saturated terrain, and the general lack of all-weather roads along much of the northern coast. Many areas are at roughly sea level, and tidal surges can inundate low-lying areas with saline water. The Corantijn Kanaal provides fresh water from the Corantijn Rivier to irrigate rice patties in the coastal area.

Ground Water:

The best areas for ground water exploration are the Tertiary age Coesewijne and A Sand aquifers as depicted by Map Unit 1. About 80 percent of the distrikt lies within Map Unit 1. These aquifers consist of unconsolidated and consolidated clastic sediments of clay, sandy clay, and coarse-grained sandstone. Depth to the Coesewijne aquifer at Nieuw Nickerie is 230 meters, and depth to the A Sand aquifer at Nieuw Nickerie is 340 meters. Very small to large quantities are available from these aquifers. Saline water zones underlie the fresh water zones in the coastal area, and pumping should be done with caution 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 along the coast subject to seasonal inundation. Alluvial aquifers, when properly developed, are suitable for municipal or irrigation wells. The distrikt capital, Nieuw Nickerie, lies within Map Unit 1.

Map Unit 2 covers about 20 percent of the distrikt and is found along the southern boundary. Small to large quantities of fresh water are available from the Tertiary age Zanderij aquifer at depths of up to 50 meters. The aquifer consists of unconsolidated sediments of sandstone, siltstone, and gravel. 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 may be difficult due to dense vegetation. Shallow ground water is often biologically contaminated near settlements.

Para

Area and Relative Size:	5,393 square kilometers (3.0 percent of the country)
Estimated Population (1980):	12,027 (3.4 percent of the population)
Population Density:	2.2 people per square kilometer
Distrikt Capital:	Onverwacht
Location:	The distrikt is located in the north-central part of the country. Saramacca Distrikt lies to the north, Sipaliwini Distrikt to the south and east, Brokopondo Distrikt to the south-southwest, and Coronie Distrikt lies to the west.

Surface Water:

Fresh water is perennially available from the Suriname Rivier and its tributaries as depicted by Map Unit 1. In the northern part of the distrikt, fresh surface water is perennially available in moderate to very large quantities from streams, canals, marshes, swamps, lakes, and empoldered agricultural fields located in the coastal plain as depicted by Map Unit 2. The distrikt capital, Onverwacht, is in Map Unit 2.

Small to moderate quantities of fresh water are perennially available from reaches of the Commewijne and Saramacca Riviers, which are unaffected by saltwater incursion from tidal surges as depicted by Map Unit 3. Flows are highly variable, with peak flow generally occurring during the long wet season from April to mid-August. Low-flow periods generally occur during the long dry season from mid-August to December.

Meager to moderate quantities of fresh water are seasonally available throughout the distrikt from intermittent streams, creeks, and swamps located in the coastal plain and savannah region as depicted by Map Unit 4. Peak flows generally occur during the long wet season from April to mid-August. During dry periods, minor streams and creeks may go dry and the water level in the swamps drop below the ground surface.

Fresh surface water is seasonally available from intermittent streams and creeks located in the southern part of the distrikt as depicted by Map Unit 5. Meager to very small quantities are available during the high flow season from April through mid-August. The low flow season is from mid-August to December, when unsuitable to meager quantities are available. Within Map Unit 5, all but the largest streams go dry for extended periods of time during the low flow season.

Access to and development of water sources is difficult due to dense vegetation, soft ground, saturated terrain, and the general lack of all-weather roads along much of the northern part of the country. Many areas are close to sea level, and tidal surges can inundate low-lying areas with saline water.

Ground Water:

The best areas for ground water exploration are the Tertiary age Coesewijne and A Sand aquifers found in the northern part of the distrikt as depicted by Map Unit 1. About 20 percent of the distrikt lies within Map Unit 1. These aquifers consist of unconsolidated and consolidated clastic sediments of clay, sandy clay, and coarse-grained sandstone. Depth to the Coesewijne aquifer may range up to 110 meters in the coastal area, and depth to the A Sand aquifer can be up to 180 meters in the coastal area. Very small to large quantities are available from these aquifers. Saline water zones underlie the fresh water zones in the coastal area. Caution should be exercised while pumping to prevent saline water intrusion. Saline water wells would require reverse osmosis/desalination equipment. Accessibility is generally easy. Alluvial aquifers, when properly developed, are suitable for municipal or irrigation wells.

Map Unit 2 covers about 35 percent of the distrikt and is found in the west and east. Small to large quantities of fresh water are available from the Tertiary age Zanderij aquifer at depths of less than 80 meters. The aquifer consists of unconsolidated sediments of sandstone, siltstone, and gravel. 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 may be difficult due to dense vegetation. Shallow ground water is often biologically contaminated near settlements, in all Map Units.

Map Unit 3 covers about 35 percent of the distrikt and is found in the southern and eastern parts of the distrikt. Meager to large quantities of fresh water are available locally from fracture and weathered zones in Precambrian age sedimentary, metaclastic, and carbonate rock at depths of less than 70 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. The shallow ground water is often biologically contaminated near settlements.

Ten percent of the distrikt lies in Map Unit 4, where ground water exploration is not recommended during military exercises.

Paramaribo (City)

Area and Relative Size:	183 square kilometers (<1.0 percent of the country)
Estimated Population (1980):	169,798 (47.8 percent of the population)
Population Density:	927.9 people per square kilometer
Capital of Suriname:	Paramaribo
Location:	The city is located in the northern part of the country within the Wanica Distrikt and is the capital of Suriname.

Surface Water:

The city of Paramaribo, the capital of Suriname, lies entirely within Map Unit 2. Fresh surface water is perennially available in moderate to very large quantities from streams, canals, marshes, swamps, lakes, and empoldered agricultural fields.

Access is easy due to an established road network.

Ground Water:

The capital city of Suriname, Paramaribo, lies entirely within Map Unit 1. The Tertiary age Coesewijne and A Sand aquifers consist of unconsolidated and consolidated clastic sediments of clay, sandy clay, and coarse-grained sandstone. Depth to the Coesewijne aquifer in the Paramaribo metropolitan area ranges from 70 to 110 meters, and depth to the A Sand aquifer ranges up to 180 meters in the coastal area. Very small to large quantities of fresh water are available from these aquifers. Saline water zones underlie the fresh water zones in the coastal area, and caution should be exercised while 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 along the coast subject to seasonal inundation. Alluvial aquifers, when properly developed, are suitable for municipal or irrigation wells.

Saramacca

Area and Relative Size:	3,636 square kilometers (2.0 percent of the country)
Estimated Population (1980):	10,808 (3.1 percent of the population)
Population Density:	3 people per square kilometer
Distrikt Capital:	Groningen
Location:	The distrikt is located in the north-central part of the country along the Atlantic Ocean, with Coronie Distrikt to the west, Para Distrikt to the south, and Wanica Distrikt to the east.

Surface Water:

Throughout the majority of the distrikt, fresh surface water is perennially available in moderate to very large quantities from streams, canals, marshes, swamps, lakes, and empoldered agricultural fields located in the coastal plain as depicted by Map Unit 2. Small to moderate quantities of fresh water are perennially available from the Saramacca Rivier, a small reach of the Coppename Rivier and their tributaries as depicted by Map Unit 3. These sources are unaffected by saltwater incursion from tidal surges. Flows are highly variable, with peak flow generally occurring during the long wet season from April to mid-August. Low flow periods generally occur during the long dry season from mid-August to December.

Meager to moderate quantities of fresh water are seasonally available in the southern and southeastern parts of the distrikt from intermittent streams, creeks, and swamps located in the coastal plain region as depicted by Map Unit 4. Peak flows generally occur during the long wet season from April to mid-August. During dry periods, minor streams and creeks may go dry and the water level in the swamps may drop below the ground surface.

Moderate to enormous quantities of brackish to saline water are perennially available from the Coppename and Saramacca Riviers and other streams, swamps, coastal lagoons, small ponds, and tidal marshes located along the coastal area as depicted by Map Unit 6.

Access to and the development of water sources are difficult due to dense vegetation, soft ground, saturated terrain, and the general lack of all-weather roads along much of the northern part of the country. Many areas are close to sea level and tidal surges can inundate low-lying areas with saline water.

Ground Water:

The best areas for ground water exploration are the Tertiary age Coesewijne and A Sand aquifers found in the northern part of the distrikt as depicted by Map Unit 1. About 60 percent of the distrikt lies within Map Unit 1. These aquifers consist of unconsolidated and consolidated clastic sediments of clay, sandy clay, and coarse-grained sandstone. Depth to the Coesewijne aquifer ranges up to 110 meters in the coastal area; depth to the A Sand aquifer may range up to 180 meters in the coastal area. Very small to large quantities are available from these aquifers. 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 difficult in areas along the coast subject to seasonal inundation. Alluvial aquifers, when properly developed, are suitable for municipal or irrigation wells. The distrikt capital, Groningen, lies within Map Unit 1.

Map Unit 2 covers about 40 percent of the distrikt and is found along the southern boundary. Small to large quantities of fresh water are available from the Tertiary age Zanderij aquifer at depths of less than 80 meters. The aquifer consists of unconsolidated sediments of sandstone, siltstone, and gravel. 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. Shallow ground water is often biologically contaminated near settlements, in Map Units 1 and 2.

Sipaliwini

Area and Relative Size:	130,566 square kilometers (80.0 percent of the country)
Estimated Population (1980):	23,225 (6.5 percent of the population)
Population Density:	0.2 people per square kilometer
Distrikt Capital:	Not determined.
Location:	Sipaliwini Distrikt is the largest distrikt, covers the southern three-fourths of the country, and is bordered by every distrikt except Wanica and Paramaribo. It is bounded on the south by Brazil, French Guiana on the east, and Guyana on the west.

Surface Water:

Fresh water is perennially available in large to enormous quantities from the Corantijn Rivier and a part of Brokopondo Lake. Small to moderate quantities of fresh water are available from streams with highly variable flows as depicted by Map Unit 3. Peak flows generally occur during the long wet season from April to mid-August. Low flow periods generally occur during the long dry season from mid-August to December.

Meager to moderate quantities of fresh water are seasonally available in the northwestern part of the distrikt from intermittent streams, creeks, and swamps located in the savannah region as depicted by Map Unit 4. Peak flows generally occur during the long wet season from April to mid-August. During dry periods, minor streams and creeks may go dry and the water level in the swamps can drop below the ground surface.

Ninety percent of the distrikt is in Map Unit 5. Fresh surface water is seasonally available from intermittent streams and creeks located in the southern part of the distrikt as depicted by Map Unit 5. Meager to very small quantities are available during the high flow season from April through mid-August. The low flow season is from mid-August to December, when unsuitable to meager quantities are available. Within Map Unit 5, all but the largest streams go dry for extended periods of time during the low flow season.

Access to and the development of water sources are difficult due to dense vegetation, soft ground, saturated terrain, steep rugged terrain, and the general lack of all-weather roads. Access is extremely difficult in the Interior of the country due to the steep terrain, dense vegetation, and lack of an established road network.

Ground Water:

The best areas for ground water exploration are from the Tertiary age Zanderij aquifer found along the Corantijn and Marowijne Riviers and along the distrikt’s northeastern and northwestern boundaries as depicted by Map Unit 2. Small to large quantities of fresh water are available from the Zanderij aquifer at depths of up to 80 meters. The aquifer consists of unconsolidated sediments of sandstone, siltstone, and gravel. About 20 percent of the distrikt lies within Map Unit 2. 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.

Map Unit 3 covers about 20 percent of the distrikt and is found in the northeast and scattered areas throughout the distrikt. Meager to large quantities of fresh water are available locally from fractured and weathered zones in Precambrian age sedimentary, metaclastic, and carbonate rock at depths of less than 70 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. Shallow ground water is often biologically contaminated near settlements, in Map Units 2 and 3.

Sixty percent of the distrikt lies in Map Unit 4 where ground water exploration is not recommended during military exercises.

Wanica

Area and relative size:	433 square kilometers (<1.0 percent of the country)
Estimated Population (1980):	60,725 (17.1 percent of the population)
Population Density:	140.2 people per square kilometer
Distrikt Capital:	Lelydorp
Location:	The distrikt is located in the northern part of the country bordered by Saramacca Distrikt on the west, Commewijne Distrikt to the east, and Para Distrikt to the south.

Surface Water:

Large to enormous quantities of fresh surface water are perennially available from a small reach of the Suriname Rivier as depicted by Map Unit 1. Throughout the majority of the distrikt, fresh surface water is perennially available in moderate to very large quantities from streams, canals, marshes, swamps, lakes, and empoldered agricultural fields located in the coastal plain as depicted by Map Unit 2. Small to moderate quantities of fresh water are perennially available from a small reach of the Saramacca Rivier and its tributaries unaffected by saltwater incursion from tidal surges, as depicted by Map Unit 3. Flows are highly variable with peak flow generally occurring during the long wet season from April to mid-August. Low flow periods generally occur during the long dry season from mid-August to December.

Moderate to enormous quantities of brackish to saline water are perennially available from the Saramacca and Suriname Riviers and other streams, swamps, coastal lagoons, small ponds, and tidal marshes located along the coastal area as depicted by Map Unit 6.

Access to and development of water sources is difficult due to dense vegetation, soft ground, saturated, and the general lack of all-weather roads along much of the northern part of the country. Many areas are at roughly sea level and tidal surges can inundate low-lying areas with saline water.

Ground Water:

The distrikt of Wanica lies entirely within Map Unit 1. The Tertiary age Coesewijne and A Sand aquifers consist of nonconsolidated and consolidated clastic sediments of clay, sandy clay, and coarse-grained sandstone. Depth to the Coesewijne aquifer ranges from 70 to 110 meters and depth to the A Sand aquifer at Lelydorp ranges from 120 to 160 meters and up to 180 meters in the coastal area. Very small to large quantities are available from these aquifers. Saline water zones underlie the fresh water zones in the coastal area and caution should be exercised while 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 along the coast subject to seasonal inundation. Alluvial aquifers, when properly developed, are suitable for municipal or irrigation wells.

VI. Recommendations

Many of the agencies and individuals that were interviewed during the country visit expressed concern with the lack of proper sewage treatment and disposal, the lack of proper solid waste disposal, saltwater intrusion affecting coastal water supply wells, and the uncontrolled use of mercury from gold-mining processes in the Interior. Another major concern is the lack of a national water authority and a national water law. Interest was also expressed in technical assistance and training.

A. General

In the *Assessment of Drinking Water and Sanitation 2000 in the America's*, it is recommended a water tariff system be designed. The rehabilitation of the water supply systems and the modernization of the treatment plant facilities will require a profound enlargement in the number and distribution of personnel working in the sub-sector. More qualified upper and middle management staffs are necessary; inclusion of professionals such as engineers, geologists, analysts, economists, sociologists, and technicians will be needed. Extensive local and overseas training programs, to develop the types of skills necessary, will be needed.

In order to realize a sustainable water supply, it is important to create a feeling of 'ownership' for water supply systems in the communities in the Interior. It is recommended to require the local communities to cover the operation and maintenance costs of water supply themselves, by raising basic water fees. Investment, maintenance, and major overhaul costs can be subsidized by the central government, to be implemented by either NH/DW or the SWM. Funds should be allocated for this purpose to allow either of these organizations to provide adequate assistance to local communities.

It is recommended to finance rehabilitation of NH/DW installation by means of grants or subsidies from the government. After rehabilitation and upgrading of service levels, adequate water fees must to be introduced in these areas. The establishment of a revolving fund for the Water Supply and Sanitation Sector should be considered in order to ensure the availability of sufficient funds for future investments.

Ultimately, Suriname should organize under a National Water Authority.[102] Other actions that need to be taken to improve the sector are:

- Adoption of a national water law;
- Drafting and execution of a master plan;
- Establishing the Drainage Authority for Greater Paramaribo;
- Design and construction of anaerobic and stabilization ponds for the treatment of septic tank sludge and pit latrine content;
- Re-establish the hydrological monitoring network;
- Update and execution of the WHO/UNDP plans on the sanitation of Nieuw Nickerie and start the execution of this plan.

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 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 in the different sectors. This creates duplication of effort and little exchange of technical knowledge and data.

The potential benefits of an improved water resources management and policy is 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 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; and
- 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 for potable water and sanitation, the water users 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

Meetings and discussions with managers have indicated a good, practical water law is needed. This law must be uncomplicated and enforceable. A national water law has been in draft since 1984.

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 could be heads of national offices and development corporation presidents. At the international level, candidate members could 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 Suriname and act as a policy advisor to Suriname’s President. It is conceivable that member nations or other entities could contribute to a fund that would finance common water resources development or common 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 more cost-effective operations. 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 national 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 difficulty with this alternative would be the high expenses for staffing. Another difficulty would be obtaining uniform cooperation from all those involved. The only known examples of success with clearinghouses are in countries where 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 could 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 Paramaribo. 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 of widespread interest to entities operating in Suriname. 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 Suriname. 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 Suriname) 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 Suriname. 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. Technical Training and Assistance

Government officials recognize the need to further develop their technical capabilities in many areas. These areas include updating methods from hydrological data collecting, monitoring and analysis, wastewater treatment plant operations, sewage treatment and disposal, and water treatment methods and applications.

D. Troop Exercise Opportunities

U.S. Southern Command currently provides assistance to Latin American and Caribbean countries through its Humanitarian Civic Assistance exercises, which can include water well drilling. Wells are sometimes drilled and used as water supply for troops during these exercises. Upon completion of an exercise, any successful wells are appropriately fitted and turned over to the local communities for use as a water supply. Small surface impoundments could also be constructed by U.S. troops during troop engineering exercises, if conditions warrant. However, small surface impoundments should be constructed only in areas where no surface water contamination exists.

1. Well Exercises

The population of Suriname depends heavily on ground water for water supply. Overall, the quality of ground water is good. Small hand pumps are in 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 benefit. These wells could be a source of safe water for populations without access to safe water. The NH/DW would be an excellent source of information to determine rural areas with the greatest need for water. Installing water wells in the urban areas would require very selective sites, working closely with SWM, to avoid siting wells where saltwater intrusion may occur.

2. Small Surface Impoundments

In certain areas of the country, the construction of small impoundments to capture water for a water supply may be considered. In Interior areas, access may be challenging or prohibitive. Other areas where small impoundments could be considered are areas where ground water exploration may be too difficult for troop exercises or potential well depths too great. Surface impoundments may also be beneficial for decreasing surface runoff and erosion and may aid aquifer recharge. Extreme caution should be exercised in site selection because of the potential for water contamination. Most of the water quality problems in the country are associated with surface water as opposed to ground water. These impoundments should be considered only in areas where the surface water is not heavily polluted, such as upstream from populated places, away from untreated domestic wastewater discharge, and away from gold mining sites and major cities. The impoundments should be sited where water contamination would not be a problem. This may be extremely difficult to accomplish due to the uncontrolled mercury contamination by the gold mining industry. 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

Overall, the water quality of the water supply is good. Ground water quality problems are often associated with saltwater intrusion in the coastal areas, due to overpumping. Surface water quality problems are due to biological, pesticide, and mercury contamination. Non-existent sewage treatment and improper disposal is a problem throughout the country. A result has been the discharge of poor-quality effluent into the nation's waterways. Proper sewage treatment and disposal with a decrease in the use of septic tanks and soak-away pits should improve water quality. The improvement of water resources management is fundamental to the future control of water pollution.

Most urban residents have access to safe, piped water. A much smaller percentage of rural households have piped water, and the quality is lower than in urban areas. A lack of access to safe water and sanitation services directly affects the quality of life. The distribution system in the urban areas is very old and in great disrepair. It is estimated that about half the water is ‘lost’ in the distribution system. The Paramaribo distribution system is in dire need of repair to save the water supply it is currently using.

VII. Summary

Water resources and water supplies are the responsibilities of many agencies. The uneven distribution of the population causes water supply and sanitation service hardships. Biological, mercury, and pesticide contamination, as well as excessive chlorides, compromise water quality in many areas of the country. Saltwater intrusion is affecting some of the water supply wells in the urban areas due to overuse. Some factors contributing to the problems associated with water resources and supply are as follows:

- No national water authority or water law;
- Uneven population distribution;
- Improper sewage solid waste disposal and non-existent wastewater treatment;
- Pollution of surface water from gold-mining processes in the Interior;
- Inadequate and insufficient water and sanitation services in rural areas;
- Poorly maintained and old distribution network in Paramaribo;
- Inadequate drainage and structures to control flooding in the urban areas; and
- A lack of trained personnel in the water agencies.

Critical issues are the lack of access to safe water and sanitation, particularly in the rural areas, 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.

The lack of a water policy and the lack of a water law constitute one of the largest weaknesses in managing water resources. This results in uncontrolled exploitation and use of water. Another major critical issue is the uncontrolled use of mercury in the gold-mining processes, which is threatening the health of the nation's waterways.

The recommendations offered in this report present some of the 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. Water is critical, a main source of life and socio-economic development of a country. Water and its use should be protected, managed responsibly, in a sustainable way. Proper management of the abundant water resources can provide adequately for the needs of the country.

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APPENDIX A

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

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APPENDIX B

Glossary

Glossary

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.
amphibolites	Crystalline rocks consisting mainly of amphibole and plagioclase with little or no quartz.
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.
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 the 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.
carbonate rock	A rock, such as limestone or dolomite, that consists chiefly of carbonate minerals.
chemical contamination	The presence in water of a significant quality 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	As a soil separate, the individual particles less than 0.002 millimeter in diameter.
confined aquifer	An aquifer bounded above and below by impermeable beds or by beds of distinctly lower permeability than the aquifer itself.
conglomerate	Gravel-size or larger, consolidated, rounded to semi-rounded rock fragments in a finer grained material. Depending upon the degree of cementation, the drillability and ground water potential can vary significantly.

consolidated	Where loosely aggregated, soft, or liquid earth materials have become firm and coherent rock.
contaminant or pollutant	Any dredged spoil, solid waste, incinerator residue, sewage, garbage, sludge, munitions, chemical wastes; biological or radioactive material; heat; wrecked or discarded equipment; rock, sand, or dirt; industrial, municipal, and agricultural wastes discharged into water.
deforestation	Clear the land or forest of trees.
desalination	A water purification process which removes dissolved salts from brackish or saline water to improve water quality.
dike/dyke dischage	A protective embankment or dam made to prevent flooding by the sea or by a river.
discharge	Quantity of flow.
dry season	The period of the year when there is little to no rainfall or when rainfall is at a minimum.
empoldered agricultural fields	An area of low-lying land reclaimed from a sea, lake or river by building dikes.
estuaries	Portions of a stream influenced by the tide of the body of water into which it flows.
fault	A fracture or fracture zone of the Earth along which there has been displacement of one side with respect to the other.
formation	Strata or series of strata of rock or sediment showing distinct and unifying lithologic properties or characteristics and large enough to be mappable. Usually tabular in shape.
fracture	A break in a rock with no significant displacement across the break.
fresh water	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.
gneiss	A medium- to coarse-grained, hard, metamorphic rock composed of alternating bands of light- and dark-colored minerals. Gneiss is considered to have some engineering uses.
granite	A coarsely crystalline, hard, massive, light-colored igneous rock. Granite is generally good for construction purposes. If not highly fractured or weathered, it is difficult to drill through and normally yields little ground water.
ground water	Water beneath the Earth's surface, often between saturated soil and rock, that supplies wells and springs.
hand pump well	A well, designed to supply water for domestic use, that is powered by a hand-drawn piston pump.
high flow season	The period of time when a stream's discharge is greater than average.

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. If not fractured or weathered it will normally yield only small amounts of ground water.
impermeable	Bed or stratum of material through which water will not move.
interbedded	Occurring between or lying in with other sediments or rock units; interstratified.
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.
joint	A fracture in a rock where there has been no movement of the two sides.
kaolinitic	Refers to a mineral, the essential constituent of kaolin, which is a fine clay.
lense	A geologic deposit or water bearing zone bounded by converging surfaces, thick in the middle and thinning out toward the edges, resembling a convex lens.
low flow season	The period of time when a stream's discharge is less than average.
medium-grained	Rocks or soil including sand made up of separate particles that are less than 0.5 millimeter but greater than 0.075 millimeter in diameter.
metaclastic (rock)	Rocks composed principally of fragments derived from pre-existing rocks or minerals.
metamorphic	Rocks formed in the solid state from previously existing rocks in response to pronounced changes in temperature, pressure, and chemical environment.
mineralization	The process of replacing the organic constituents of a body by inorganic fossils.
perennial	Pertaining to water that is available throughout the year.
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.
pH	Hydrogen-ion concentration: a measure of the acidity or basicity of a solution.
polder	An area of lowlying land reclaimed from a sea, lake or river by building dikes.
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.
Precambrian	An informal geologic time term referring to all rocks older than 570 million years. Generally includes the pre-Archean, Archean, and Proterozoic.
primary porosity	The porosity that developed during the final stages of sedimentation or that was present within the sedimentary particles at the time of deposition.
recharge	Addition of water to the zone of saturation from precipitation, infiltration from surface streams, and other sources.
reverse osmosis	An advanced method used in desalination which relies upon a semipermeable membrane to separate the water from its impurities. An external force is used to reverse the normal osmotic flow, resulting in movement of the water from a solution of higher solute concentration to one of lower concentration. Sometimes called hyperfiltration.
saline water	Water containing greater than 15,000 milligrams per liter of total dissolved solids. Saline water is undrinkable without treatment.
salinity	A measure of the concentration of dissolved mineral substances in water.
saline or saltwater 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 fresh water wells.
sand	As a soil separate, 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 composed of sandstone.
savannah	A treeless plain or a grassland characterized by scattered trees.
schist	A fine- to coarse-grained, foliated, metamorphic rock composed of discontinuous thin layers of parallel minerals. Because of a tendency to split along these layers into thin slabs or flakes, schist is avoided by construction engineers.
sedimentary (rocks)	A class of rocks formed from the accumulation and solidification of a variety of sediments.
shale	A soft to moderately hard sedimentary rock of very fine-grained quartz particles. Shale often weathers or breaks into very thin platy pieces or flakes. In most places it can be excavated without drilling and blasting. Due to weakness and lack of durability, it makes very poor construction material. Shale is a confining bed to many aquifers in sedimentary rock.
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.
soft water	Water containing 0 to 60 mg/L of $CaCO_3$.
specific capacity	The yield of a well per unit of drawdown in cubic meters per hour per meter.
specific yield	The ratio of the volume of water that will drain under the influence of gravity to the volume of saturated rock.
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.
Tertiary Period	A division of geologic time from 1.6 to 66 million years ago, during which certain rocks were formed. Falls chronologically after the Cretaceous and before the Quaternary. Includes the Paleocene, Eocene, Miocene, and Pliocene. Is the oldest division of the Cenozoic. Outside the United States is sometimes divided into the Paleogene and Neogene.
total dissolved solids (TDS)	The sum of all dissolved solids in water or waste water.
tributary	Stream or other body of water, surface or underground, which contributes its water to another and larger stream or body of water.
transmissivity	The rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of an aquifer under a unit hydraulic gradient; the rate at which water passes through a unit width of an aquifer.
unconfined aquifer	An aquifer where the water table is exposed to the atmosphere through openings in the overlaying material.
unconsolidated	Loose, soft, or liquid earth materials that are not firm or compacted.
yield or well yield	The volume of water produced from a well. Typically reported as liters per second (L/s) or gallons per minute.
wastewater	A community or industry's spent or used water which contains dissolved and suspended matter.
water table	The depth or level below which the ground is saturated with water.
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.
well	Artificial excavation that derives water from the interstices of the rocks or soil which it penetrates.
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

Prepared by: U.S. Army Corps of Engineers
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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 and lakes in northern Suriname. Corantijn Rivier (0557N05706W), Marowijne Rivier (0545N05358W), Brokopondo Lake (Brokopondo Stuwmeer) (0445N05500W), and Suriname Rivier (0555N05510W).[3]	Large to enormous quantities of fresh water are perennially available. Peak flows generally occur during the long wet season from April to August. Low flow periods generally occur during the long dry season from August to December. Selected stream gaging stations with characteristic maximum, minimum and/or average annual discharges if known are listed below.[4] Discharges are compiled from measurements taken between 1952 and 1996. Also listed is the surface areas of a major stream and a lake. **1** Corantijn Rivier at Cow Vallen (0500N05739W): Max 2,900 m^3/s; Min 320 m^3/s; Avg 1,350 m^3/s. **2** Corantijn Rivier at Belumo (0341N05750W approximate): Avg 1,160 m^3/s. **14** Suriname Rivier at Afobaka (0459N05500W): Max 700 m^3/s; Min 214 m^3/s; Avg 324 m^3/s. Brokopondo Lake (0445N05500W) has a surface area of 1,560 km^2.	Sections of the rivers below the falls are fresh with very low sediment levels and soft to moderate hardness. Hardness and salinity increase downstream toward the coast because of mixing with oceanic waters. Sediment loads and turbidity increase during high flow periods though not significantly. Salinity is highly variable seasonally, and decreases noticeably during high flow periods. Stream sections above the first falls and above the savannahs contain fresh, soft water nearly saturated with oxygen and an extensive sediment load. Stream sections located in the savannahs contain fresh, soft water depleted of oxygen and with low turbidity. Water quality data from points along selected streams and any associated major pollution problems are listed below. **21** Corantijn Rivier at MacClemen Eiland (0536N05710W): DO 5.8 mg/L. Some contamination because of the discharge of agrochemicals from polders near the stream is likely. Large forestry concessions along the stream may contribute	Streams in the Coastal Plain (0550N05600W) are surrounded by swamps, marshes, and polder-type agricultural fields making accessibility difficult except at roads and constructed crossings. Roads generally extend east-west, and in many places act as dykes raising the water level on the south side and lowering the waters to the north. At some places, deep water conditions and stagnated drainage have resulted in the formation of thick peat layers. Perennial swamps give way to seasonal swamps in the upstream direction (south), making accessibility highly variable depending on season and vegetation density. Farther to the south are sand savannahs, a flat to gently undulating landscape with broad plateaus alternated with creeks and rivers. River valleys are deep with steep to very steep erosion makes	Characteristics of the Afobaka Dam (0459N05500W): Total length over crest is 1,913 m; height from spillway foundation to deck is 54 m; total quantities of sand, clay, rock, and concrete is 8 Mm^3; number of auxiliary dikes is 16; construction began in 1960, and power generation started in 1965.

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			contaminates from wood preservatives and/or fertilizers associated with reforestation. **22** Suriname Rivier at Paranam (0537N05506W): TDS* 27.7 mg/L, pH 7.5, hardness 8.95 mg/L $CaCO_3$, Cl 10 mg/L, DO 5.36 mg/L. Some biological contamination from domestic waste water occurs near and down river from populated places. A bauxite processing plant is near Paranam, and the refinement process involves the use of caustic soda. Open manmade reservoirs of high-alkalinity waters contaminate adjacent natural waters during large precipitation events, when overflowing of dykes occurs. The alkaline pollution is present in fresh water swamps near the refinery, and it may extend to nearby streams. **23** Suriname Rivier at Berg en Dal (0509N05504W): TDS* 14.2 mg/L, pH 6.6, hardness 8.05 mg/L $CaCO_3$, Cl 6 mg/L, DO 4.71 mg/L. Brokopondo Lake (Brokopondo Stuwmeer) (0445N05500W): DO is very low because of vegetation drowned when the reservoir was constructed. At	accessibility difficult. In the western part of the country, the Savannah Belt (0520N05540W) is found at a higher elevation, and dissection is deeper. The Interior Precambrian Shield (0400N05600W) has dense rain, forest-type vegetation, few roads, and is mostly uninhabited. Vegetation is the major hindrance to access to streams and water bodies. The drainage network of streams is slightly more dense than in the Savannah Belt (0520N05540W), and the landscape is predominantly low lying with few mountain groups reaching over 250 m above mean sea level. The border zone towards Brazil is somewhat higher with elevations generally 250 to 500 m above mean sea level. Rock outcrops are rare and are usually covered by dense vegetation. Streams have numerous falls and rapids.	

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			the dam, water is tapped from an aerobic layer caused by the decomposition of vegetation near the bottom of the lake.		
2 Fresh water perennially available	Perennial streams, canals, marshes, swamps, lakes, and empoldered agricultural fields located in the Coastal Plain of northern Suriname. Nani Meer (0524N05701W), Cottica Rivier (0552N05452W), Nani Kreek (0553N05705W), Saramacca Kanaal (0549N05511W), Corantijn Kanaal (0530N05715W), and Coronie Swamp (0536N05614W approximate).	Moderate to very large quantities of fresh water are perennially available. Extensive swamps and marshes dominate, having a poorly developed drainage network of primarily stagnated water with little flow to streams via short creeks. The major component of water flow is vertical in nature via rainfall and evapotranspira-tion. Peak flows for streams and peak water depths for swamps occur during the long wet season from April to August. Low flow periods generally occur during the long dry season from August to December. In some swamp areas, dykes were built creating polders mainly for rice agriculture. In 1996 approximately 2,000 km^2 of polderland had been created. Dykes also serve to dry out areas, making mining possible and preventing floods. Also listed are the surface areas of a major swamp, canal and lake. Coronie Swamp (0536N05614W) has a surface area of 1,600 km^2. Water	Water found in swamps and associated marshes and lakes is fresh with low turbidity and low hardness. Salinity may increase with depth and with proximity to the more saline lagoons along the coast. The stagnant nature of the swamp water and decaying vegetation contributes to a low pH (<5.5) and low DO (<35 percent saturated). Small streams and creeks draining these swamps have similar chemistry. Agricultural lands, consisting predominately of rice fields, contain fresh water. Irrigation waters for these empoldered lands come from either adjacent swamps or from canals with sources in upstream fresh water river reaches. Water quality data from points along selected streams, canals and/or swamps, and any associated major pollution problems are listed below.	Streams in the Coastal Plain (0550N05600W) are surrounded by swamps, marshes, and polder-type agricultural fields making accessibility difficult except at roads and constructed crossings. Roads generally extend east-west and in many places act as dykes raising the water level on the south side and lowering the level on the north. At some places, deep water conditions and stagnated drainage have resulted in the formation of thick peat layers. Perennial swamps give way to seasonal swamps in the upstream direction (south) making accessibility highly variable depending on season and vegetation density.	

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)		movement is very slow and shows a radial drainage pattern. Corantijn Kanaal (0530N05715W): Avg 50 m^3/s. Nani Meer (0524N05701W) has surface area of 5 km^2.	**24** Hooi Kreek (0536N05510W approximate), a tributary of the Para Rivier (0545N05508W): TDS* 24.2 mg/L, pH 6.2, hardness 5.37 mg/L $CaCO_3$, Cl 11 mg/L, DO 4.10 mg/L. A bauxite processing plant near Paranam (0537N05506W) has a refinement process that involves the use of caustic soda. Open manmade reservoirs of high alkalinity water contaminate adjacent natural waters during large precipitation events when overflowing of dykes occurs. The alkaline pollution is present in fresh water swamps near the refinery and probably extend to nearby streams.		
3 Fresh water perennially available	Major perennial streams located in the Coastal Plain (0550N05600W), Savannah Belt (0520N05540W), and Interior Precambrian Shield (0400N05600W). Commewijne Rivier (0554N05505W), Coppename Rivier (0548N05555W), Corantijn Rivier (0557N05706W), Dalbana Kreek (0448N05727W), Jai Kreek (0358N05449W),	Small to moderate quantities of fresh water are perennially available. Peak flows generally occur during the long wet season from April to August. Low flow periods generally occur during the long dry season from August to December. Selected stream gaging stations with characteristic maximum, minimum, and/or average annual discharges if known are listed below.[4] Discharges	Sections of the rivers below the falls are fresh with very low sediment levels and soft to moderate hardness. Hardness and salinity increase downstream toward the coast because of mixing with oceanic waters. Sediment loads and turbidity increases during high flow periods though not significantly. Salinity is highly variable seasonally and decreases noticeably during high flow periods. Stream sections	Streams in the Coastal Plain (0550N05600W) are surrounded by swamps, marshes, and polder-type agricultural fields making accessibility difficult except at roads and constructed crossings. Roads generally extend east-west and in many places act as dykes raising the water level on the south side and lowering the waters to the	

Table C-1. Surface Water Resources (Continued)

Map Unit (See Fig C-1)	Sources	Quantity[1]	Quality[2]	Accessibility	Remarks
3 Fresh water perennially available	Kabalebo Rivier (0502N05721W), Kleine Saramacca Rivier (0458N05533W), Lawa Rivier (0422N05426W), Litani Rivier (0318N05406W), Lucie Rivier (0335N05740W), Marowijne Rivier (0545N05358W), Nickerie Rivier (0559N05700W), Oelemari Rivier (0313N05409W), Saramacca Rivier (0551N05553W), Suriname Rivier (0555N05510W), and Tapanahoni Rivier (0422N05427W).	are compiled from measurements taken between 1952 and 1996. **3** Corantijn Rivier at Meeteiland (0324N05739W approximate): Avg 910 m^3/s. **4** Corantijn Rivier at Coeroenie Airfield (0322N05721W): Avg 324 m^3/s. **5** Kabalebo Rivier at Avanavero Vallen (0449N05724W): Max 390 m^3/s; Min 43 m^3/s; Avg 142 m^3/s. **6** Lucie Rivier at (0328N05718W approximate): Avg 198 m^3/s. **7** Nickerie Rivier at Blanche Marie Vallen (0444N05653W): Avg 28 m^3/s. **8** Nickerie Rivier at Stondansie Val (0509N05629W): Max 450 m^3/s; Min 4 m^3/s; Avg 91 m^3/s. **9** Coppename Rivier at Maksita Kreek (0455N05607W): Max 1420 m^3/s; Min 16 m^3/s; Avg 319 m^3/s. **10** Saramacca Rivier at Dramhosso Soela (0454N05534W): Max 493 m^3/s; Min 4 m^3/s; Avg 100 m^3/s. **11** Kleine Saramacca Rivier at Anoemafoetoe (0456N05530W approximate): Avg 16.8 m^3/s.	upstream from the first falls and south of the savannahs contain fresh, soft water nearly saturated with oxygen and with an extensive sediment load. Stream sections located in the savannahs contain fresh, soft water depleted of oxygen and with low turbidity. Water quality data from points along selected streams, and any associated major pollution problems are listed below. **25** Saramacca Rivier at Uitkijk (0546N05520W): TDS* 6.5 mg/L, pH 6.1, hardness 14.32 mg/L $CaCO_3$, Cl 11 mg/L, DO 4.71 mg/L. TDS, hardness, and chloride values vary with tide. The above values were measured at low tide and would be greater at high tide. **26** Saramacca Rivier near Kwakoegron (0515N05520W): TDS* 16.5 mg/L, pH 6.2, hardness 9.84 mg/L $CaCO_3$, Cl 10 mg/L, DO 6.63 mg/L. **27** Corantijn Rivier at confluence with Lucie Rivier (0335N05741W approximate): TDS* 12.4 mg/L, pH 7.3, Cl 2.0 mg/L, DO 7.0 mg/L.	north. At some places, deep water conditions and a stagnated drainage have resulted in the formation of thick peat layers. Perennial swamps give way to seasonal swamps in the upstream direction (south) making accessibility highly variable depending on season and vegetation density. Beyond these areas to the south are the sand savannahs; a flat to gently undulating landscape with broad plateaus alternated with creeks and rivers. River valleys are deep with steep to very steep slopes. Active erosion makes accessibility difficult. In the western part of the country, the Savannah Belt (0520N05540W) is found at a higher elevation and dissection is deeper. The interior of the country contains dense rain, forest type vegetation, few roads, and is	

Table C-1. Surface Water Resources (Continued)

Map Unit (See Fig C-1)	Sources	Quantity[1]	Quality[2]	Accessibility	Remarks
3 Fresh water perennially available (continued)		**12** Suriname Rivier at Pokigron (0430N05522W): Max 378 m^3/s; Min 86 m^3/s; Avg 224 m^3/s. **13** Jai Kreek at (0404N05501W approximate): Avg 60 m^3/s. **15** Tapanahoni Rivier at Drietabbetje (0407N05440W): Avg 616 m^3/s. **16** Commewijne Rivier at Destombesburg (0542N05443W): Max 97 m^3/s; Min 28 m^3/s; Avg 51 m^3/s. **17** Marowijne River at Langatabbetje (0500N05431W): Max 2,261 m^3/s; Min 167 m^3/s; Avg 1,638 m^3/s. **18** Marowijne Rivier at Gransanti Val (0419N05424W): Avg 929 m^3/s. **19** Oelemari Rivier at (0314N05409W approximate): Avg 159 m^3/s. **20** Litani Rivier at (0318N05405W approximate): Avg 351 m^3/s.	**28** Kabalebo Rivier near Avanavero Vallen (0449N05724W): pH 6.7, Cl 9.0 mg/L, DO 6.6 mg/L. **29** Nickerie Rivier near Blanche Marie Vallen (0444N05653W): pH 6.5, Cl 4.7 mg/L, DO 7.85 mg/L. **30** Coeroeni Rivier (0255N05710W approximate): pH 6.5, hardness 15.0 mg/L $CaCO_3$, Cl 2.9 mg/L, DO 11.12 mg/L (supersaturated). **31** Tapanahoni Rivier near Tepoe Airfield (0310N05543W): pH 6.5, hardness 1.2 mg/L $CaCO_3$, Cl 1.5 mg/L.	mostly uninhabited.The vegetation is the major hindrance the accessibility of streams and water bodies. The drainage network of streams is slightly more dense than in the Savannah Belt (0520N05540W) and the landscape is predominantly low-lying with few mountain groups reaching over 250 m above mean sea level. The border zone towards Brazil is somewhat higher with elevations generally 250 to 500 m above mean sea level. Rock outcrops are rare and are usually covered by dense vegetation. Streams have numerous falls and rapids.	
4 Fresh water seasonally available	Seasonally intermittent streams, creeks, and swamps located in the southern Coastal Plain (0550N05600W) and Savannah Belt (0520N05540W). Coesewijne Rivier (0546N05552W),	Meager to moderate quantities of fresh water are seasonally available. Peak flows generally occur during the long wet season from April to August. Low flow periods generally occur during the long dry season from August to December. During the drier seasons,	Stream sections in the Savannah Belt (0520N05540W) contain fresh, soft water depleted of oxygen and with low turbidity. Rivers draining the savannah region contain water colored tea brown by the high amount of humic acids occurring in the soil.	Seasonal swamps in the southern Coastal Plain (0550N05600W) make accessibility highly variable depending on season and vegetation density. Even during relatively dry conditions,	

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)	Coropina Kreek (0532N05510W), Maratakka Rivier (0546N05641W), and Para Rivier (0545N05508W).	flow within the minor streams and creeks can be nonexistent and the water level in the swamps will drop below the ground surface.	The highest concentration of humic acids is measured at the beginning of the long wet season. Water quality data from points along selected streams and any associated major pollution problems are listed below. **32** Maratakka Rivier at (0516N05648W approximate) a tributary of the Nickerie Rivier: pH 4.5, hardness 2.7 mg/L $CaCO_3$, Cl 6.8 mg/L, DO 2.85 mg/L. **33** Coesewijne Rivier at (0527N05536W approximate): pH 5.2, hardness 9.74 mg/L $CaCO_3$, Cl 7.78 mg/L, DO 2.65 mg/L. **34** Coropina Kreek at (0532N05510W approximate), a tributary of the Para Rivier (0545N05508W): TDS* 20 mg/L, pH 4.5, hardness 3.27 mg/L $CaCO_3$, Cl 5.73 mg/L, DO 1.26 mg/L. **35** Para Rivier at (0534N05508W approximate): TDS* 22.4 mg/L, pH 4.3, hardness 4.54 mg/L, $CaCO_3$Cl 6.32 mg/L, DO 1.0 mg/L. Much of the savannah region of Suriname is used for logging. Forestry concessions along	the water level may be very shallow keeping the accessibility in such areas very difficult. The roads and constructed crossings are the only reliable locations with adequate accessibility. Beyond these areas to the south are the sand savannahs; a flat to gently undulating landscape with broad plateaus alternated with creeks and rivers. River valleys are deep with steep to very steep slopes and active erosion making accessibility difficult. In the western part of the country, the Savannah Belt (0520N05540W) is found at a higher elevation and dissection is deeper.	

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)			the streams indicate probable chemical contamination from wood preservatives and/or fertilizers associated with re-forestation.		
5 Fresh water seasonally available	Seasonally intermittent streams and creeks located in the Interior Precambrian Shield (0400N05600W). Fallawatra Rivier (0506N05631W), Brons Kreek (0458N05514W), Compagnie Kreek (0507N05459W), Sara Kreek (0430N05457W), Sipaliwini Rivier (0221N05652W), and Peluli Kreek (0235N05558W).	Meager to very small quantities of fresh water are seasonally available. Peak flows generally occur during the long wet season from April to August. Low flow periods generally occur during the long dry season from August to December. During the drier seasons, flow within the minor streams and creeks can be nonexistent.	Streams contain fresh, soft water nearly saturated with oxygen because of numerous rapids and with a more extensive sediment load. Water quality data from points along selected streams are listed below as well as any associated major pollution problems. **36** Maskita Kreek at (0300N05707W approximate): TDS* 14.8 mg/L, pH 7.1, Cl 4.0 mg/L, DO 7.8 mg/L. **37** Sisa Kreek at (0352N05745W approximate): TDS* 16.5 mg/L, pH 7.2, Cl 10.0 mg/L, DO 8.0 mg/L. **38** Fallawatra Rivier at (0450N05641W approximate): pH 6.3, hardness 16 mg/L $CaCO_3$, Cl 7.9 mg/L, DO 9.67 mg/L. **39** Brons Kreek at (0458N05514W approximate): TDS* 13.6 mg/L, pH 6.5, hardness 2.68 mg/L $CaCO_3$, Cl 9.0 mg/L, DO 6.76 mg/L. **40** Mama Kreek at (0507N05524W approximate): TDS* 16.5 mg/L, pH 6.6, hardness	The Interior Precambrian Shield (0400N05600W) contains dense rain, forest-type vegetation, few roads, and is mostly uninhabited. Vegetation is the major hindrance to the accessibility of streams and water bodies. The drainage network of streams is slightly more dense than in the Savannah Belt (0520N05540W) and the landscape is predominantly low lying with few mountain groups reaching over 250 m above mean seal level. The border zone towards Brazil is somewhat higher with elevations generally 250 to 500 m above mean sea level. Rock outcrops are rare and are usually covered by dense vegetation. Streams have numerous falls and rapids.	

Table C-1. Surface Water Resources (Continued)

Map Unit (See Fig C-1)	Sources	Quantity[1]	Quality[2]	Accessibility	Remarks
5 Fresh water seasonally available			11.46 mg/L $CaCO_3$, Cl 8.0 mg/L, DO 6.53 mg/L. **41** Compagnie Kreek at (0504N05504W approximate): TDS* 14.8 mg/L, pH 6.6, hardness 9.49 mg/L $CaCO_3$, Cl 7.0 mg/L, DO 6.34 mg/L. **42** Vier Gebroeders Kreek at (0155N05602W approximate): pH 6.5, hardness 8.5 mg/L $CaCO_3$, Cl 1.5 mg/L, DO 10.0 mg/L. **43** Sipaliwini Rivier at (0206N05622W approximate): pH 6.5, hardness >1 mg/L $CaCO_3$, Cl 1.0 mg/L, DO 7.8 mg/L. **44** Peluli Kreek at (0235N05558W approximate): pH 6.8, hardness 0.8 mg/L $CaCO_3$, Cl 1.1 mg/L. Sara Kreek (0430N05457W) is highly contaminated by mercury from gold mining activity.		
6 Fresh water scarce or lacking	Mouths of streams and the tidally influenced sections of streams, estuaries, coastal lagoons, small ponds, tidal marshes, and saline swamps are located along the northern coastal region of Suriname.	Moderate to enormous quantities of brackish to saline water are perennially available. Peak flows generally occur during the long wet season from April to August. Low flow periods generally occur during the long dry season from August to December. Estimates of maximum, minimum,	Water is brackish to saline because of the influence of sea water. During intense rains, the salinity decreases near the surface of water bodies but salinity remains high at depth. The estuaries of the large rivers show varying amounts of salinity, depending on the precedent precipitation and the tide. Saline water	Access is difficult because of soft ground, saturated terrain, and the general lack of roads along much of the northern coast. Many areas are at roughly sea level. Tidal surges can inundate low-lying areas with saline sea water. Dense	

Table C-1. Surface Water Resources (Continued)

Map Unit (See Fig C-1)	Sources	Quantity[1]	Quality[2]	Accessibility	Remarks
6 Fresh water scarce or lacking		and/or average annual discharge at the mouths of major streams are listed below if known.[4] Estimates are derived from discharge measurements at gaging stations located south of the tidally influenced zone and the size of the stream's catchment area within the coastal region. Discharge cannot be measured directly in the tidally influenced estuaries of rivers because of the oscillating direction of flow associated with tidal fluctuations. Corantijn Rivier at the outfall (0324N05739W): Max 10,000 m^3/s; Min 200 m^3/s; Avg 1,572 m^3/s. Nickerie Rivier at the outfall (0509N05629W): Max 1,200 m^3/s; Min 20 m^3/s; Avg 178 m^3/s. Coppename Rivier at the outfall (0455N05607W): Max 2,700 m^3/s; Min 50 m^3/s; Avg 500 m^3/s. Suriname Rivier at the outfall (0430N05522W): Max 1,800 m^3/s; Min 220 m^3/s; Avg 426 m^3/s. Commewijne Rivier at the outfall (0542N05443W): Max 800 m^3/s; Min 10 m^3/s; Avg 120 m^3/s.	surges up river during low flows and high tide.	vegetation is a hindrance to the development of water points throughout many of the areas containing brackish to saline swamps and marshes.	

Table C-1. Surface Water Resources (Continued)

Map Unit (See Fig C-1)	Sources	Quantity[1]	Quality[2]	Accessibility	Remarks
6 Fresh water scarce or lacking (continued)		Marowijne Rivier at the outfall (0419N05424W):Max 10,000 m^3/s; Min 200 m^3/s; Avg 1,785 m^3/s.			

[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

The quantitative terms given above were derived from global stream distribution data. Streams may be more significant on a local or regional scale than the terms imply.

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 $CaCO_3$

Table C-1. Surface Water Resources (Continued)

[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:

Corantijn Rivier 0557N05706W

Geographic coordinates for the Corantijn Rivier drainage region that are given as 0557N05706W equal 5º57' N, 57º6' W and can be written as a latitude of 5 degrees and 57 minutes north and a longitude of 57 degrees and 6 minutes west. Geographic coordinates are approximate but are sufficiently accurate for locating features on the country-scale map. Geographic coordinates for rivers are generally at the river mouth.

[4]Maximum discharge values correspond to the monthly average discharge during the wettest month. Minimum discharge values correspond to the monthly average discharge during the driest month

Note:

Ca	= calcium	m^3/h/m	= cubic meters per hour per meter
$CaCO_3$	= calcium carbonate	m	= meters
Cl	= chloride	m/d	= meters per day
DO	= dissolved oxygen	Mg	= magnesium
gal/min	= gallons per minute	mg/L	= milligrams per liter
K	= potassium	Mm^3	= million cubic meters
km^2	= square kilometers	Na	= sodium
L/min	= liters per minute	pH	= potential of hydrogen
L/s	= liters per second	SO_4	= sulfate
m^2/d	= square meters per day	TDS*	= total dissolved solids, calculated from conductivity
m^3/s	= cubic meters per second		

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

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	Tertiary age Coesewijne and A Sand (Burnside) artesian aquifers in the Coastal Plain hydrological province(0550N05600W).[3] Aquifers are continuous with regional to limited regional extent. They are confined in most places, but locally unconfined in the extreme southern areas. Aquifers consist of unconsolidated and consolidated clastic sediments of clay and sandy clay interbedded with sandstone. Sand layers constitute 30 to 50 percent of the total formation. **Coesewijne Aquifer:** Permeability ranges from medium to high. The aquifer is up to 100 m thick in the Savannah Belt (0520N05540W) and Suriname Rivier (0555N05510W) areas and up to 120 m thick in the Nieuw Nickerie (0557N05659W) area. The thickness varies from 17 m at Republiek (0550N05510W) to 100 m at Paramaribo (0550N05510W). Porosity ranges from 8 to 13 percent. The Coesewijne	Very small to large quantities of ground water are available. **Coesewijne Aquifer:** Specific capacity >4 m^3/h/m. Average flow per well at Totness (0553N05619W): 3.0 L/s; Apoera/Wakai (0512N05710W): 3.0 L/s; Nani Kreek (0553N05705W): 3.0 L/s; Tambaredjo (0550N05533W): 2.0 L/s; Morico Kreek (0546N05446W): 2.9 L/s; Paranam/Vigilantia (0537N05506W): 10 L/s; Kwattabari Soela (0435N05610W): 2.0 L/s; and Livorno (0548N05511W): 2.6 L/s. Total yield for 12 wells in the Coesewijne aquifer is 440 L/s (37 L/s per well). Hydrologic conductivities range from 10 to 130 m/d. The lower values are for aquifer areas with a substantial clay content. Average hydrologic conductivities at specific locations are listed below. Nieuw Amsterdam (0553N05505W): 10 to 12 m/d; Uitkijk (0546N05520W):	Fresh ground water is available from the Coesewijne and A Sand aquifers. **Coesewijne Aquifer:** TDS concentrations in the Coesewijne aquifer are generally <800 mg/L and tend to decrease as depth increases. Locally in some eastern coastal areas, TDS concentrations are higher than average. Shallow ground water tends to be brackish north of Paramaribo (0550N05510W). TDS concentrations at specific locations are listed below. Uitkijk (0546N05520W): 366 to 596 mg/L; Koewarasan (0547N05519W): 435 to 749 mg/L; Landsboerderij (0549N05513W): 370 mg/L; Alliance (0554N05454W): 940 mg/L; Totness (0553N05619W): 311 mg/L; Santo Boma (0547N05557W): 292 mg/L; and Kampong Baroe (0545N05524W): 442 mg/L. Chemical concentrations at specific locations: Nieuw Amsterdam (0553N05505W): Cl 907 to 1,400 mg/L;	**Coesewijne Aquifer:** Depth to aquifer ranges from 70 to 110 m in the Paramaribo (0550N05510W) metropolitian area and to 230 m in the Nieuw Nickerie (0557N05659W) area. In the western part of the country, depth to aquifer ranges from 240 to 280 m. Depths to aquifer at specific locations are listed below. Totness (0553N05619W): 140 to 180 m; Apoera/Wakai (0512N05710W): 15 to 85 m; Nani Kreek (0553N05705W): 40 to 120 m; Tambaredjo (0550N05533W): 120 to 160 m; and Morico Kreek (0546N05446W): 80 to 110 m. Static water levels range from 0.85 to 1.85 m. **A Sand Aquifer:** Depth to aquifer ranges from 120 m in the coastal area to 340 m in the western part of the country.	Ground water is primarily used for domestic purposes and to a smaller degree industrial. The Zorg en Hoop (0549N05512W) and Leysweg (0550N05510W) well fields produce water from the A Sand aquifer at depths of 150 to 170 m. These well fields supply water to the capital city of Paramaribo (0550N05510W). The A Sand aquifer is being mined with no recharge. In the District of Commewijne, studies suggest that the A Sand aquifer has only about 20 more years of production. Leakage from the overlying Zanderijj aquifer recharges the Coesewijne aquifer. Suitable for irrigation, municipal water supply wells, tactical wells, and small submersible pump wells. Also, suitable for hand pump wells where the depth to water is <100 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
1 Fresh water generally plentiful (continued)	aquifer is overlain by the Zanderij aquifer. **A Sand Aquifer:** The A Sand aquifer underlies the Coesewijne aquifer and is everywhere confined. The sand is mainly graded, coarse grained, angular, and kaolinitic. Lateral boundaries are the crystalline rocks in the south and pinchouts just east of the Suriname Rivier (0555N05510W) and westward in the vicinity of the Saramacca Rivier (0551N05553W). In the western coastal area, the A Sand is about 80 m thick beginning at a depth of about 350 m. To the north of Paramaribo (0550N05510W), it is about 50 m thick at a depth of 180 m. It is up to 80 m thick in the Nieuw Nickerie (0557N05659W) area. The aquifer thins inland towards the basement rock. The aquifer has not been found in the Tambaredjo oil field west of Paramaribo. In the undisturbed state, effective porosity ranges from 7 to 15 percent.	27 to 261 m/d; Koewarasan (0547N05519W): 9 to 153 m/d; Landsboerderij (0549N05513W): 41 m/d; Paramaribo (0550N05510W): 64 m/d; Alliance (0554N05454W): 31 m/d; Totness (0553N05619W): 62 m/d; Santo Boma (0547N05557W): 40 m/d; and Kampong Baroe (0545N05524W): 120 m/d. Average discharges at specific locations are listed below. Nieuw Amsterdam (0553N05505W): 0.5 L/s; Uitkijk (0546N05520W): 06 to 2.8 L/s; Koewarasan (0547N05519W): 9 to 153 L/s; Landsboerderij (0549N05513W): 2 L/s; Paramaribo (0550N05510W): 3.1 L/s; Alliance (0554N05454W): 1.1 L/s; Totness (0553N05619W): 2.9 L/s; Santo Boma (0547N05557W): 1.9 L/s; and	Uitkijk (0546N05520W): 63 to 143 mg/L; Koewarasan (0547N05519W): 45 to 154 mg/L; Landsboerderij (0549N05513W): 59 mg/L; Paramaribo (0550N05510W): 148 mg/L; Alliance (0554N05454W): 196 mg/L; Totness (0553N05619W): 77 mg/L; Santo Boma, (0547N05557W): 69 mg/L; and Kampong Baroe (0545N05524W): 91 mg/L. Chemical characteristics of ground water from the Coesewijne aquifer for specific wells are listed below. Well 9/70 at Morico Kreek (0546N05446W): Cl 205 mg/L, SO_4 119 mg/L, TDS 725 mg/L. Well 0-5 at Zorg en Hoop (0549N05512W): Na 81 mg/L, K 7 mg/L Ca 10 mg/L Mg 21 mg/L, SO_4 88 mg/L, TDS 253 mg/L. Well GMD 37 at Santo Boma Project (0547N05557W): Cl 70 mg/L, SO_4 70 mg/L, TDS 310 mg/L.	Depths to aquifer at specific locations are listed below. North of Lelydorp (0542N05514W): 120 to 160 m; Zorg en Hoop (0549N05512W): 163 m; Nieum Amsterdam (0553N05505W): 186 m; Meerzorg (0549N05509W): 148 m; Nieuw Nickerie (0557N05659W: 340 m; and Koewarasan (0547N05519W): 155 m. Caution should be exercised in pumping to prevent saltwater intrusion. Saline water wells require reverse osmosis/ desalination equipment. Wells should be screened because of 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. Accessibility is easy in agricultural areas. The	

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)	Permeability ranges from medium to high.	Kampong Baroe (0545N05524W): 1.1 L/s. Average transmissivities at specific locations are listed below. Nieuw Amsterdam (0553N05505W): 48 to 58 m^2/d; Uitkijk (0546N05520W): 6 to 290 m^2/d; Koewarasan (0547N05519W): 9 to 153 m^2/d; Landsboerderij (0549N05513W): 207 m^2/d; Paramaribo (0550N05510W): 320 m^2/d; Alliance (0554N05454W): 120 to 155 m^2/d; Totness (0553N05619W): 308 m^2/d; Santo Boma (0547N05557W): 198 m^2/d; and Kampong Baroe (0545N05524W): 120 m^2/d. Storage coefficient ranges from 10^{-4} to 10^{-5} m^2/d. **A Sand Aquifer:** Hydrologic conductivities for the A Sand, Koewarasan (0547N05519W) range mainly from 30 to 80 m/d with a high of 374 m/d. Average hydrologic conductivities at specific locations are listed below.	Well 3/71 at Rijsdijkweg (0537N05514W), sample depth 84 to 87 m, Na 133 m, K 8.2 m, Ca 2.5 m, Mg 11.3 m, Cl 121 m, SO_4 104 m, TDS 433. Well 21/71 at Welgedacht B (0545N05514W), sample depth 68 to 74 m, Na 47 m, K 4 m, Ca 16 m, Mg 22 m, Cl 45 m, SO_4 93 m, TDS 250 m. **A Sand Aquifer:** North of Paramaribo (0550N05510W), the water becomes brackish. The water quality of the A Sand is only known in the area of the lower Saramacca (0551N05553W) and Suriname (0555N05510W) Riviers. Ground water contains mainly sodium chloride in solution with TDS ranging from 340 to 2,100 mg/L. TDS concentrations at specific locations are listed below. Zorg en Hoop (0549N05512W): 150 to 446 mg/L; Nieuw Amsterdam (0553N05505W): 2,100 mg/L; Uitkijk (0546N05520W):	shallow ground water is often biologically contaminated near settlements. Siting and drilling for shallow artesian wells are easy. High iron concentrations may make the water unsuitable for many purposes.	

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)		Zorg en Hoop (0549N05512W): 37 to 132 m/d; Nieuw Amsterdam (0553N05505W): 7 m/d; Uitkijk (0546N05520W): 79 m/d; Koewarasan (0547N05519W): 36 to 374 m/d; and Meerzorg (0549N05509W): 33 m/d. Transmissivity ranges from 180 m^2/d at the southern aquifer boundary, where the aquifer is 2 m thick to 4,500 m^2/d along the north coastal area, where the thickness is 50 m. Average transmissivities at specific locations are listed below. Zorg en Hoop (0549N05512W): 185 to 660 m^2/d; Nieuw Amsterdam (0553N05505W): 34 m^2/d; Uitkijk (0546N05520W): 397 m^2/d; Koewarasan (0547N05519W): 179 to 1,870 m^2/d; and Meerzorg (0549N05509W): 167 m^2/d. Storage coefficients at Paramaribo (0550N05510W) range from 10^{-4} to 10^{-5} m^2/d.	482 mg/L; Koewarasan (0547N05519W): 468 to 504 mg/L; and Meerzorg (0549N05509W): 190 to 450 mg/L. Cl concentrations at specific locations are listed below. Zorg en Hoop (0549N05512W): 136 to 270 mg/L; Meerzorg (0549N05509W): 177 mg/L; Uitkijk (0546N05520W): 153 mg/L; and Koewarasan (0547N05519W): 158 to 215 mg/L. Chemical characteristics of ground water from the A Sand aquifer for specific wells are listed below. Houttuin (0545N05509W): 2/69 mg/L sample depth 125 to 148 m, Na 101 mg/L, K 6 mg/L, Ca 7 mg/L, Mg 19 mg/L, Cl 141 mg/L, SO_4 45 mg/L, TDS 367. Well GMD 7 at Meerzorg (0549N05509W): Na 119 mg/L, K 7.8 mg/L, Ca 10 mg/L Mg 14 mg/L, Cl 184 mg/L, SO_4 14 mg/L, TDS 387 mg/L.		

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)		Average discharges at specific locations are listed below. Zorg en Hoop (0549N05512W): 1.8 to 6.3 L/s; Nieuw Amsterdam (0553N05505W): 1.5 L/s; Meerzorg (0549N05509W): 1.5 L/s; Uitkijk (0546N05520W): 3.8 L/s; Koewarasan (0547N05519W): 1.7 to 17.8 L/s; and Meerzorg (0549N05509W): 1.6 L/s. Wells completed in the A Sand aquifer typically yield about 11.5 L/s. Average flow per well at Kwattabari Soela (0435N05610W): 2.0 L/s; and Livorno (0548N05511W): 2.6 L/s. The average daily withdrawals from the A Sand well fields from 1958 to 1987 in are listed below. Zorg en Hoop (0549N05512W): 144 L/s; Livorno (0548N05511W): 23 L/s; Meerzorg (0549N05509W): 14 L/s; and Koewarasan (0547N05519W): 7 L/s. About 227 Mm^3 were withdrawn from			

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)		the A Sand aquifer from 1958 to 1987.			
2 Fresh water generally plentiful	Tertiary age Zanderij aquifers are located in the Coastal Plain hydrological province (0550N05600W) and along the courses of the Corantijn (0557N05706W) and Marowijne (0545N05358W) Riviers. Aquifers are continuous with regional to restricted extent; in places unconfined or locally confined in unconsolidated and consolidated clastic sediments (sandstone, siltstone, and gravel). Permeability ranges from low to medium. Thickness of the aquifers in the Nieuw Nickerie (0557N05659W) area is about 230 m, but may include some overlying Coropina sands. In the coastal area of eastern Suriname, thickness reaches 40 to 50 m in the valley areas, which approximate the locations of present-day	Small to large quantities of ground water are available. Specific capacity is <0.5 m^3/h/m. Average flow per well at Rijsdijk/ Lelydorp (0542N05514W) ranges from 4.4 to 10 L/s; and at Wonoredjo (0538N05424W) 4.0 L/s. Total yield for 11 wells in the Savannah Belt is 528 L/s (48 L/s per well). Specific yield of 13 percent is estimated at Republiek (0530N05512W). Average hydrologic conductivities at specific locations are listed below. Republiek (0530N05512W): 83 m^2/d; Domburg (0542N05505W): 2 to 16 m^2/d; Livorno (0548N05511W): 34 to 116 m^2/d; Nieuw Amsterdam (0553N05505W): 13 to 83 m^2/d; Nieuw Nickerie (0557N05659W): 29 to 128 m^2/d; Jagtlust (0549N05506W):	Ground water is generally fresh, but salinity increases toward the coast. The ground water is low in TDS in the Savannah Belt. TDS concentrations of 46 and 86 mg/L are reported in the Zanderij-Matta (0527N05512W) area and to the east near Powakka (0527N05505W). The northern limit of fresh water varies considerably and the transition to brackish water may be sharp. Between the Suriname (0555N5510W) and Saramacca (0551N05553W) Riviers, water with low TDS is present. North of Sidodadi (0549N05530W), TDS of 222 mg/L are from well TW 44/71. One km west of Lelydorp (0542N05514W), TDS of 311 mg/L are from well TW 35/71. Suralco wells yield water up to 150 mg/L of TDS, whereas only 4 km to the north. The TDS of the water from well TW 6/72 at La Vigilantia	Depth to aquifer in the Savannah Belt ranges from 15 to 60 m. Depth to aquifer at Rijsdijk/ Lelydorp (0542N05514W) ranges from 30 to 80 m, 15 to 25 m at Vierkinderen/ Republiek (0530N05512W), and 6 to 15 m at Wonoredjo (0538N05424W). In the coastal area of eastern Suriname, the aquifer depth ranges from 30 to 40 m. Depth to aquifer in the Nieuw Nickerie (0557N05659W) area is 50 m. Ground water is available from poorly graded sand and silty sand lenses at depths <6 m along the course of the Courantyne (0323N05736W) and Maroni (0545N05358W) Riviers. Caution should be exercised in pumping to prevent saltwater intrusion. Saline water wells require reverse osmosis/	Ground water is primarily used for domestic purposes and to a smaller degree industrial. The Republiek well field established in 1933, produces from the Zanderij aquifer at depths up to 30 m. This well field supplies water to the capital city of Paramaribo (0550N05510W). The present withdrawal rate is 9,400 m^3/d. The Zanderij aquifer receives recharge directly by infiltration of rainfall. Since there is no clay layer present, contamination of the aquifer may occur. Supports irrigation and municipal water supply wells. Suitable for tactical wells, small submersible pump wells. Also, suitable for hand pump wells where the depth to water is <100 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
2 Fresh water generally plentiful (continued)	streams. Near Paramaribo (0550N05510W), thickness varies from 10 m in the Savannah Belt (0520N05540W) to 40 m near the coast. The formation outcrops in the Savannah Belt (0520N05540W) bordering the crystalline basement.	35 m^2/d; Tamanredjo (0550N05533W): 45 m^2/d; Uitkijk (0546N05520W): 4 m^2/d; Koewarasan (0547N05519W): 4 to 90 m^2/d; Boxel (0543N05506W): 100 to 138 m^2/d; and Alliance (0554N05454W): 9 to 50 m^2/d. Average transmissivities at specific locations are listed below. Livorno (0548N05511W): 171 to 580 m^2/d; Nieuw Amsterdam (0553N05505W): 63 to 415 m^2/d; Nieuw Nickerie (0557N05659W): 178 to 580 m^2/d; Tamanredjo (0550N05533W): 223 m^2/d; Uitkijk (0546N05520W): 22 m^2/d; and Koewarasan (0547N05519W): 19 to 463 m^2/d; Boxel (0543N05506W): 498 to 688 m^2/d; and Alliance (0554N05454W): 105 to 150 m^2/d.	(0527N05512W) is 1,564 mg/L. Brackish water is found farthest inland immediately north of the bauxite area of Onverdacht (0536N05509W). The salinity of the water is caused mainly by sodium chloride. TDS concentrations are highest in the thickest parts of the aquifer, and range from 2,000 to 5,000 mg/L. TDS concentrations at specific locations are listed below. Republiek (0530N05512W): 66 mg/L; Domburg (0542N05505W): 7,987 to 16,800 mg/L; Livorno (0548N05511W): 2,034 to 4,130 mg/L; Nieuw Nickerie (0557N05659W): 586 mg/L; Uitkijk (0546N05520W): 1,174 mg/L; Koewarasan (0547N05519W): 1,265 to 1,843 mg/L; Boxel (0543N05506W): 5,410 to 5,820 mg/L; and Alliance (0554N05454W): 323 to 1,736 mg/L. Chemical characteristics of ground water from specific wells are	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. Accessibility is easy in agricultural areas. High iron concentrations make the water unsuitable for many purposes. The shallow ground water is often biologically contaminated near settlements. Siting and drilling for shallow artesian wells are easy. Treatment of the ground water is by a simple sand and shell filtration designed by the Suriname Water Supply Company.	

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)			listed below. Well 3/71 at Rijsdijk (0537N05514W): sample depth 30.9 to 40.2 m, Na 13 mg/L, K 4 mg/L , Ca 35 mg/L, Mg 12 mg/L, Cl 28 mg/L, SO_4 5 mg/L, TDS 148 mg/L. Well 4/71 at Commetewane Kreek (0552N05452W): sample depth 95.2 to 100 m, Na 221 mg/L, K 14 mg/L, Ca 21 mg/L, Mg 35 mg/L, Cl 276 mg/L, SO_4 147 mg/L, TDS 819 mg/L. Well 35/71 at Tawajariweg (0542N05514W): Na 35 mg/L, K 4 mg/L, Ca 15 mg/L, Mg 18 mg/L, Cl 73 mg/L, SO_4 50 mg/L, TDS 228 mg/L. Well 42/71 at Carolina (0524N05504W): sample depth 18.3 m, Na 4.5 mg/L, K <4 mg/L, Ca <3 mg/L, Cl 9 mg/L, $S0_4$ 4 mg/L, TDS 35.5 mg/L. Nani Polder at (0553N05703W): Na 121 mg/L, K 6.6 mg/L, Ca 19 mg/L, Mg 47 mg/L, Cl 343 mg/L, SO_4 37 mg/L,		

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)			TDS 577 mg/L. Well 32/71 at Craneweg (0542N05515W): Na 34 mg/L, K <4 mg/L, Ca 11 mg/L, Mg <3 mg/L, Cl 27 mg/L, SO_4 67 mg/L, TDS 184 mg/L.		
3 Fresh water locally plentiful	Local aquifers consisting of Precambrian age granite, gneiss, sandstone, and conglomerate. Location is in the northern part of the Interior Precambrian Shield hydrological province (0400N05600W). Ground water is found in fracture, karstic dissolution and weathered zones, Weathering to depths of 70 m is reported. The deepest weathering occurs in basic rocks and metasediments (15 to 30 m) and least in granites (up to 16 m). Permeability ranges from low to medium.	Meager to large quantities of ground water are available locally. Highest yields are available from large fracture zones. Meager to moderate quantities of ground water are available from fractured sandstone and conglomerate at the head of the Saramacca Rivier (0551N05553W).	Ground water is generally fresh. Shallow aquifers tend to be of poor quality ranging from brackish to saline. Fresh water is available at the head of the Saramacca Rivier (0551N05553W).	Siting is difficult. Ground water occurs at varying depths but generally <70 m. 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. The shallow ground water is often biologically contaminated near settlements.	Suitable for hand pump wells where depth to water is <100 m. Some areas are suitable for tactical wells and submersible pump wells. Successful wells may depend upon encountering water-bearing fractures and/or weathered zones.
4 Fresh water scarce or lacking	Local aquifers consisting of Precambrian age granite and gneiss. Located in the northern Interior Precambrian Shield hydrological province (0400N05600W). Ground water is	Meager to moderate quantities of ground water are available. Highest yields are available from large fracture zones.	Shallow aquifers tend to be of poor quality ranging from brackish to saline.	Siting is difficult. Ground water occurs at varying depths but generally <70 m. Extensive reconnaissance or exploratory drilling may be necessary to locate zones of best quality and maximum yield.	Suitable for hand pump wells where depth to water is <100 m. Some areas are suitable for tactical wells and submersible pump wells. Successful wells depend upon encountering water-bearing fractures or

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)	found in fracture and weathered zones. Generally weathering ranges from 15 to 30 m in metamorphic rocks and up to 16 m in granites. In some extreme cases, weathering may extend up to 70 m. Permeability is generally low.			Hard-rock drilling techniques are required. Wells should be cased and screened. The shallow ground water is often biologically contaminated near settlements.	weathered zones. Brackish to saline water wells require reverse osmosis/ desalination equipment.

[1]Quantitative Terms:

Enormous = >100 L/s (1,600 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 to160 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 = $\leq$0.25 L/s (4 gal/min)

[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 the Eastern (E) or Western (W) Hemisphere. For example:

Coastal Plain hydrological province 0550N05600W

Geographic coordinates for the Caribbean Coast drainage region that are given as 0550N05600W equal 5º50' N, 56º0' W and can be written as a latitude of 5 degrees and 50 minutes north and a longitude of 56 degrees and 0 minutes west. Geographic coordinates are approximate but sufficiently accurate for locating features on the country-scale map.

Table C-2. Ground Water Resources (Continued)

Note:

Ca	= calcium	$m^3/h/m$	= cubic meters per hour per meter
$CaCO_3$	= calcium carbonate	m	= meters
Cl	= chloride	m/d	= meters per day
DO	= dissolved oxygen	Mg	= magnesium
gal/min	= gallons per minute	mg/L	= milligrams per liter
K	= potassium	Mm^3	= million cubic meters
km^2	= square kilometers	Na	= sodium
L/min	= liters per minute	pH	= potential of hydrogen
L/s	= liters per second	SO_4	= sulfate
m^2/d	= square meters per day	TDS*	= total dissolved solids, calculated from conductivity
m^3/s	= cubic meters per second		

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

SURINAME

- International boundary
- District boundary
- National Capital
- Populated places
- District capital

Scale 1:2,000,000

0 25 50 75 Statute Miles

0 25 50 75 Kilometers

SURFACE WATER RESOURCES

Physiographic Provinces

- I Coastal Plain
- II Savannah Belt
- III Interior Precambrian Shield
- Province Boundary

Drainage Features

- 20 Stream gaging station (most stations inoperative)
- 44 Water quality point

Map Unit

FRESH WATER PERENNIALLY AVAILABLE

1 Large to enormous quantities are available from major streams and lakes.

2 Moderate to very large quantities are available from streams, canals, marshes, swamps, lakes, and impoldered agricultural fields mostly in the northern coastal plain.

3 Small to moderate quantities are available from streams with highly variable flows. Peak flows generally occur during the wet season, April to August. Low flow periods generally occur during the dry season, August to December.

FRESH WATER SEASONALLY AVAILABLE

4 Meager to moderate quantities are available from seasonally intermittent streams, creeks, and swamps in the southern coastal plain and savannah region. Peak flows generally occur during the wet season, April to August. Low flow periods generally occur during the dry season, August to December. During dry periods, minor streams and creeks can go dry, and the water level in the swamps drops below the ground surface.

5 Meager to very small quantities are available from seasonally intermittent streams and creeks in the interior regiion. Peak flows generally occur during the wet season, April to August. Low flow periods generally occur during the dry season, August to December. During dry periods, minor streams and creeks usually go dry.

FRESH WATER SCARCE OR LACKING

6 Moderate to enormous quantities of brackish to saline water are perennially available from streams, swamps, coastal lagoons, small ponds, and tidal marshes along the northern coastal region. Salinity varies both on a seasonal and tidal basis with the lowest levels occurring during wet periods and low tides. Water in the stream estuaries can become stratified, with fresher water occurring above more saline water at depth.

District Boundaries

1 Paramaribo (city)
2 Wanica
3 Para
4 Brokopondo
5 Commewijne
6 Saramacca
7 Coronie
8 Nickerie
9 Marowijne
10 Sipaliwini

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	= ≤0.01 m^3/s (0.35 ft^3/s)

QUALITATIVE TERMS:

Fresh water	= maximum total dissolved solids (TDS) ≤1,000 milligrams per liter (mg/L); maximum chlorides ≤600 mg/L; 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

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

Note: Map unit numbers and map feature numbers refer to entries in table C-1.

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 $CaCO_3$

Note: Features have been obtained from various sources of differing scales. Alignment and geospatial accuracy are approximate.

Figure C-1. Surface Water Resources

SURINAME

- International boundary
- District boundary
- National Capital
- Populated places
- District capital

Scale 1:2,000,000

0 25 50 75 Statute Miles

0 25 50 75 Kilometers

GROUND WATER RESOURCES

District Boundaries

1	Paramaribo (city)	6	Saramacca
2	Wanica	7	Coronie
3	Para	8	Nickerie
4	Brokopondo	9	Marowijne
5	Commewijne	10	Sipaliwini

Map Unit

FRESH WATER GENERALLY PLENTIFUL

1 — Very small to large quantities of fresh water available from the Teritary age Coesewijne and A Sand artesian aquifers consisting of nonconsolidated and consolidated clastic sediments of clay and sandy clay, and coarse-grained sandstone. Depth to the Coesewijne aquifer ranges from 70 to 110 m in the Paramaribo area and up to 280 m in the western part of the country. Depth to the A Sand aquifer ranges from 120 m in the coastal area to 340 m in the western part of the country.

2 — Small to large quantities of freshwater available primarily from the Tertiary age Zanderij aquifer consisting of non-consolidated to consolidated sediments of sandstone, siltstone, and gravel. Depth to aquifer is less than 80 m.

FRESH WATER LOCALLY PLENTIFUL

3 — Meager to large quantities of fresh water available locally from fractured and weathered zones in Precambrian age sedimentary, metaclastic and carbonate rocks. Depth to aquifer is less than 70 m.

FRESH WATER SCARCE OR LACKING

4 — Meager to moderate quantities of brackish to saline water available from fractured and weathered zones in Precambrian age granite and gneiss. Depth to aquifer is less than 70 m.

Note: Map unit numbers refer to entries in table C-2.

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; 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 $CaCO_3$

CONVERSION CHART:

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

Note: Features have been obtained from various sources of differing scales. Alignment and geospatial accuracy are approximate.

Figure C-2. Ground Water Resources