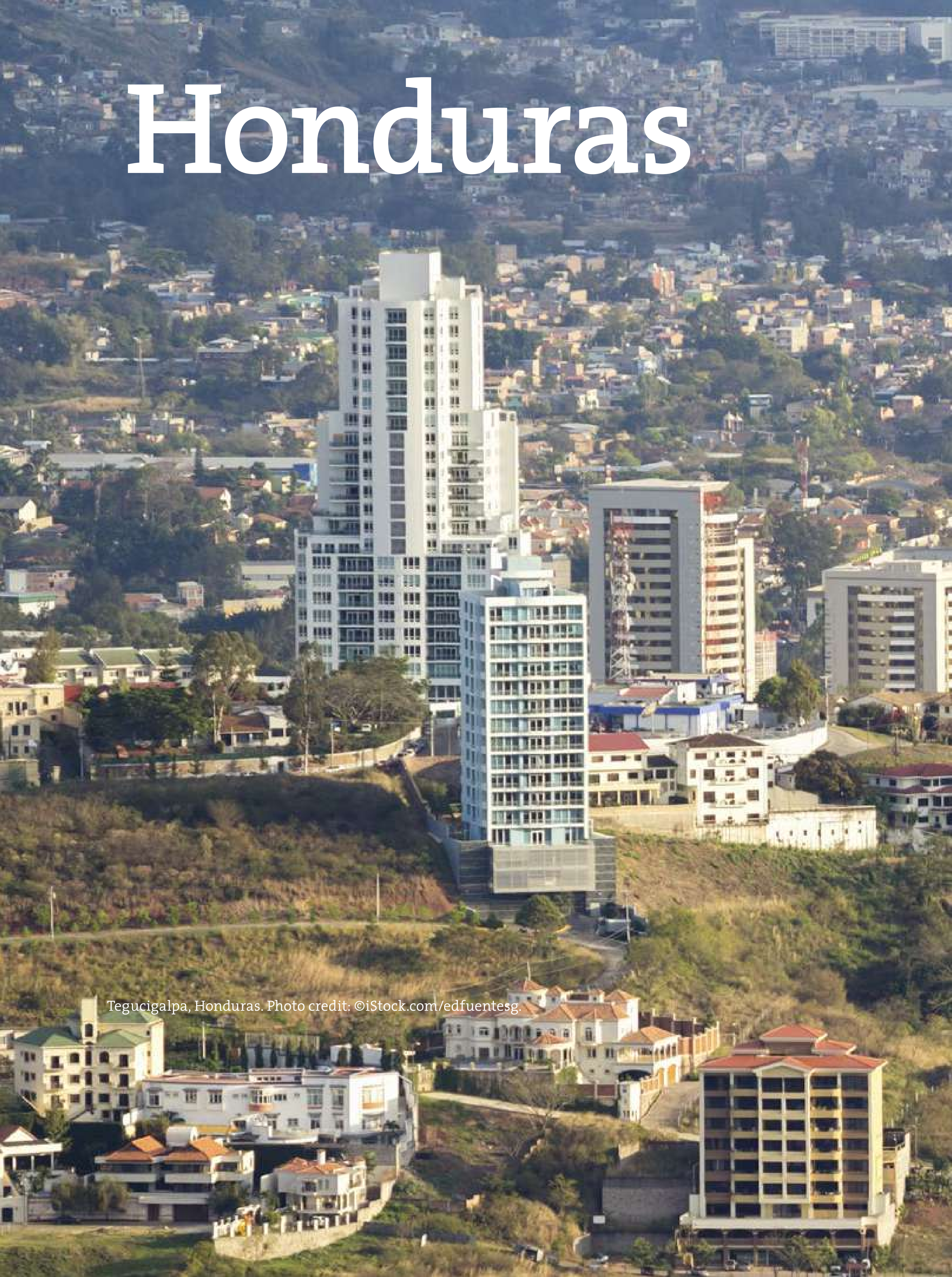
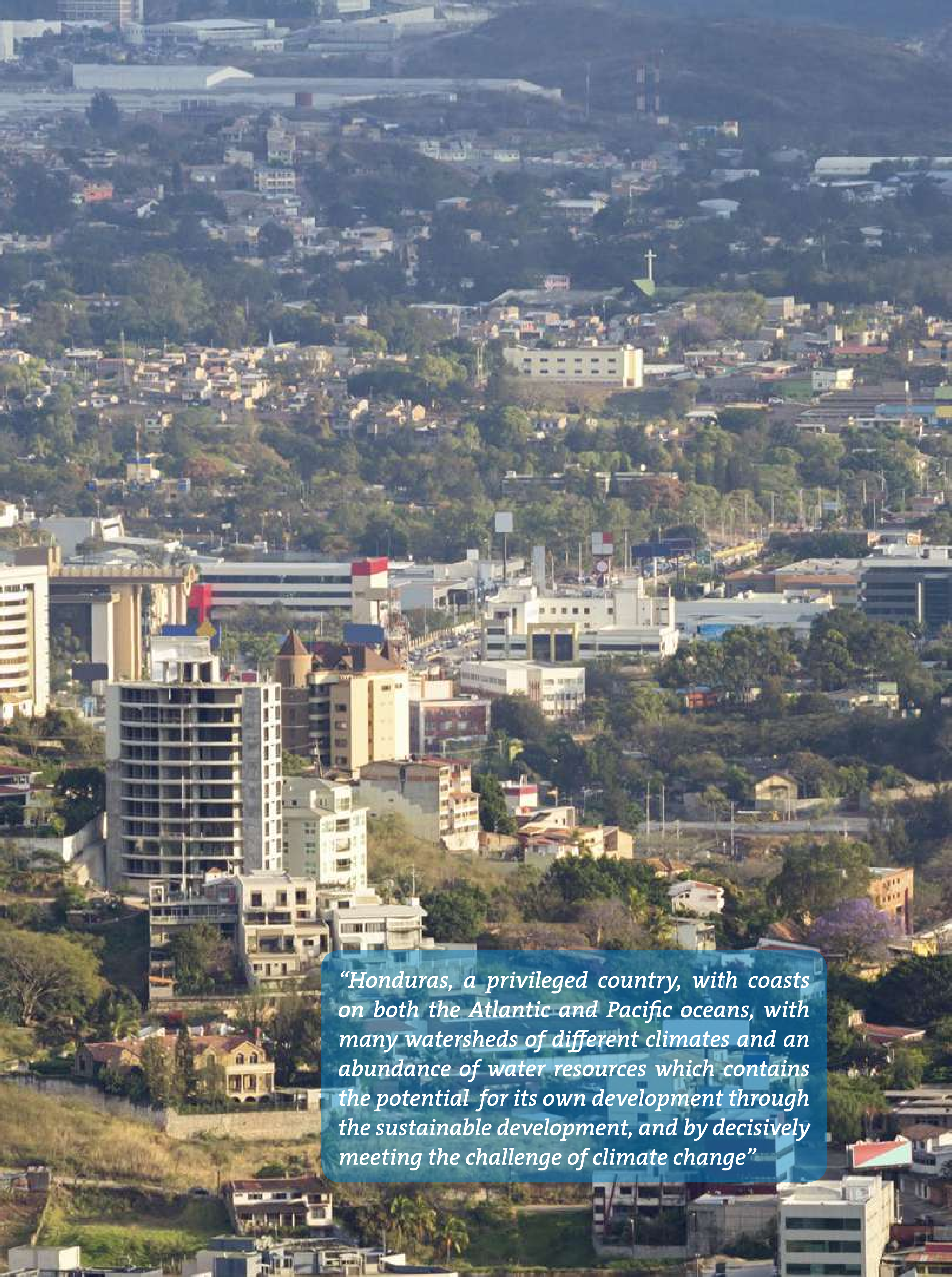
Honduras



Tegucigalpa, Honduras. Photo credit: ©iStock.com/edfuentesg.



“Honduras, a privileged country, with coasts on both the Atlantic and Pacific oceans, with many watersheds of different climates and an abundance of water resources which contains the potential for its own development through the sustainable development, and by decisively meeting the challenge of climate change”

Urban Water Management in Honduras. The Case of Tegucigalpa*

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Summary

Honduras is a privileged country with coastlines on the Atlantic and Pacific oceans, a varied climate ranging from tropical, hot and humid on the Atlantic coast to dry, temperate and tropical in the central-western area, and tropical savannah on the Pacific coast, with abundant, unevenly distributed water resources, since the Atlantic slope basin has a greater number of rivers, lakes and lagoons.

Despite this abundance of water resources, the country faces serious problems of water supply to the population, which has three salient characteristics: 1) a very young population (55% under 25 years); 2) the population in rural areas is greater, and 3) the female population is larger.

The problem of water supply in the capital of Honduras is replicated in other cities in the country, with the exception of the city of San Pedro Sula, where the drinking water supply has positive indicators of quality of service and quality of product, reflected in the good level of overall public health and individual health of the population in particular.

The influence of climate change is noticeable, which, added to man's actions through frequent forest fires and deforestation, has caused variability in natural resources such as modifications in rainfall patterns, extreme temperature changes, siltation of waterways by erodible material and frequent floods.

The government has taken action by defining strategies and policies for the rational use of resources, giving priority to water by declaring it a social good and an important factor in the alleviation of poverty.

*A Chapter developed with support from the Global Water Partnership GWP

1. Introduction

Honduras has a surface area of 112,492 km^2 and is hydrological divided into 22 watersheds that drain into two slopes: the Atlantic slope with 16 major watersheds and the Pacific slope with 6 river basins. It has a population of 8.5 million, with approximately 50% living in urban areas. Until 1950, the population of Honduras' major cities accounted for a mere 10% of the current population. Population growth has led to rapid, disorganized urbanization, especially in Tegucigalpa, where it has had substantial impacts on water availability for human use.

Although water resources are abundant, water infrastructure is extremely limited, since the implementation of new works for incorporating more water supply sources has failed to keep pace with population growth, resulting in a severe water shortage during the dry season, causing strict rationing of the water service system, whereas during the rainy season, the city is affected by frequent floods and landslides. Moreover, deforestation and uncontrolled urban encroachment in watersheds near the metropolitan area threaten the quality of surface and groundwater, which is compounded by the lack of treatment for most of the wastewater in the capital. This is also associated with weaknesses in water governance related to the lack of enforcement of the legislation related to the issue, especially as regards institutional reforms.

The water supply problem is particularly acute in the outlying neighborhoods around the Central District, located in unstable, rugged terrain without access to the conventional piping system for water supply. This issue negatively impacts the quality of life of disadvantaged populations, reflected in diseases, economic and social costs and environmental degradation.

Despite significant advances in the Water and Sanitation Sector, current water management practices for the main urban area of Honduras have proved unable to solve existing problems. The country is currently striving to enforce the Framework Law on the Drinking Water and Sanitation Sector, enacted in 2003, which provides for the decentralization of services to the national firm SANAA and the General Water Law, which envisages the creation of a National Water Authority.

This paper presents a diagnosis of the state of water resources in urban areas, focusing on the metropolitan area of the Central District. Its contents are divided into five chapters addressing urbanization, the state of drinking water service, water treatment, impact on human health and climate variability and change. The information contained in each of the chapters was gathered through the analysis and consultation of various national and regional studies as well as data provided by the relevant government institutions.

The preparation of this document was made possible by the collaboration between the Academy of Sciences in Honduras and GWP Central America, in an effort to contribute to generating useful information for determining the status of urban water management, and making decisions on the actions required for its use and sustainable management.

2. Water Sources in Urban Areas and the Impacts of Urbanization

This chapter contains a diagnostic summary of Tegucigalpa, the capital of Honduras, on the various water sources as well as information on the quality and quantity of the water used in the urban area corresponding to the Metropolitan District. It also studies problems that arise when population distribution does not correspond to the availability of water sources and critical problems in specific zones, such as informal settlements and periurban areas.

The physical characteristics of the Central District where Tegucigalpa is located are shown in the Table 1 (INE, May 2013; Wikipedia, May 2013).

On the basis of the description by the Administrative Division, the Central District Metropolitan Area is a conurbation (INE, 2001), since it meets the characteristics of this definition: "Region comprising cities, large towns, urban villages, which, through population growth and spatial expansion, may be integrated into a single system."

2.1 Drinking Water Service in the Municipality of Distrito Central

Tegucigalpa and Comayagüela, like most Latin American capitals, have a rapidly growing population in their metropolitan area, which requires an increase in basic service coverage, including water and sanitation services.

According to the Population and Housing Census 2001 and the Permanent Multiple Purpose Household Survey (EPHPM) 2013, both conducted by the National Statistics Institute (INE), until 2013, the population of the urban area of the city capital was 1.11 million, corresponding to 13% of the national population, estimated at 8.5 million, characterized by being a young population, since 55% are under the age of 25, as shown in the accompanying figure.

According to records from the National Autonomous Service of Aqueducts and Sewers (SANAA, 2014) in the urban area of the Central District, the institution provides water service to 120,204 users, representing almost 50% of the urban population, distributed among 424 districts and neighborhoods. SANAA rations service, with constant interruptions due to network failures and pressure constraints, which must be controlled by special operating tasks. This is also linked to restrictions on water availability.

A large section of the population, mainly in the periurban areas, equivalent to approximately 38% of households, self-supplies water by purchasing it from tanker trucks that sell it in barrels, equivalent to 42 gallons.

Figure 1. Population by Age Ranges and Sex

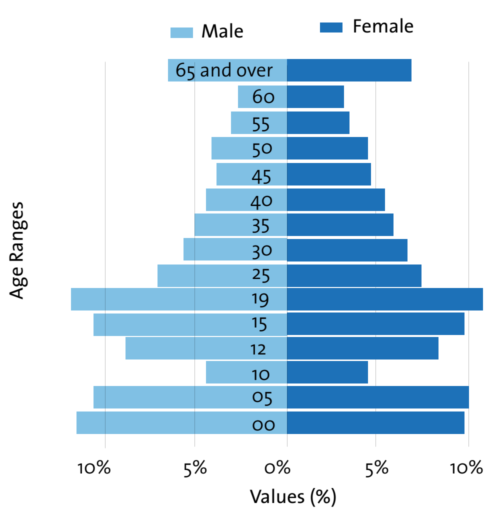


Table 1. Municipality of Distrito Central

1. Administrative division	2 Cities: Tegucigalpa y Comayagüela 44 Villages 291 Hamlets
2. Territorial size	1.514.6 km²
3. Urban area	150 km²
4. Mean altitude	1,100 masl
5. Population	Urban: 1,101,900 Rural 100,900
6. Housing	Urban: 249,945 Rural: 22,422

Source: Prepared by the authors, based on INE, May 2013 and Wikipedia, the free encyclopedia, May 2013.

Given the current population, current water demand (2014) for the Central District is 3.66 m³/s. This means a theoretical water deficit of 0.37 m³/s in winter time and of 1.92 m³/s in the summer. However, considering unaccounted water, estimated at 45%, the actual deficit is 1.58 m³/s and 2.54 m³/s for the two seasons respectively (SANAA, 1986).

Figure 2.2 shows the projected water demand until 2040, which will require the incorporation of new sources to provide over 600,000 m³/d.

2.2 Type of Supply Sources

The water supply system in the capital city comprises surface and groundwater sources, with surface water accounting for 96% of the total. The systems are therefore gravity-based.

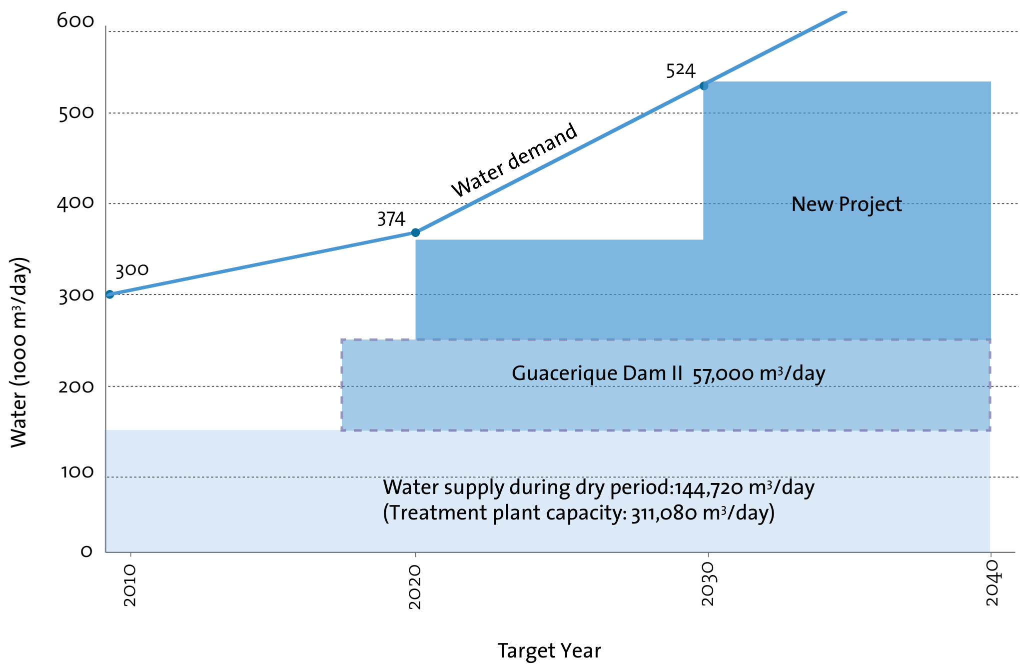
Existing water supply sources constituting the supply of water by SANAA are shown in the following table (SANAA, 2014 and 1986).

2.3 Impact of Urbanization

Urban development is one of the main factors affecting water quantity and quality. Some of the impacts of urbanization include erosion and sedimentation, urban runoff, contaminant refuse, and sewage spills, which have a direct impact on water quality.

The main problem of the capital is that it went from being a small town to a large city, with a consequent increase in population due to urbanization

Figure 2. Water demand for the Municipality of Distrito Central



Source: SANAA/KOICA, Tegucigalpa, 2012. Estudio de Factibilidad para la Construcción de Presa Guacerique II.

and industrialization. Water in the outskirts of the city has been affected by the development of industrial and commercial activities, so that nearby available water resources are reduced or degraded due, inter alia, to deforestation, forest fires and wastewater discharges.

Deforestation is caused by logging, which is largely illegal. It is practiced for the commercial exploitation of timber, firewood use or for converting forests to farmland, affecting vast amounts of forest with a deforestation rate of 62 thousand hectares/year (Suazo Bulnes, July 2010), and in the specific case of the Central District Municipality, it is carried out prior to the construction of new urban areas. Forest fires, most of which are thought to be intentional, average between 400 and 650 a year (*La Tribuna*, 2014) across the country, and of these, at least 50 fires occur in the Central District Municipality *(El Heraldo*, 2014).

As a result, the capital's water supply basins are being degraded, causing an increase in the cost of developing new water supplies, since the sources available for exploitation are increasingly distant, and require more treatment for their purification due to poor water quality.

2.4 Pollution of Water Sources

The open discharge or improper disposal of urban and industrial wastewater and the lack of treatment thereof, contributes to the deterioration of water quality in potential drinking water sources. This is the case of the Central District Municipality, where the wastewater load is approximately 260,000 m³/d, of which only 22.7% is treated, equivalent to 59,000 m³/d. The remaining wastewater is freely discharged into the Choluteca River through its various tributaries: rivers, streams and winter creeks that cross the city. The problem becomes more severe because of the constant expansion of the urban area due to continued urbanization, the opening of large malls and new industrial zones, which discharge into the existing sewerage network, which has yet to be expanded. Once its capacity is exceeded, the system necessarily discharges its surplus into the environment at the lowest, most fragile points.

Waterproofing urbanized areas by paving streets and parking lots in addition to roof areas considerably modifies urban hydrology, causing runoff volumes with higher peaks that cause waterlogging in the streets and frequent floods.

Table 2. SANAA Water sources for the Capital

Source	Production (m^3/d)	
	Winter	Summer
1. Surface sources	**286,244**	**151,340**
1.1 San Juancito-El Picacho	78,624	30,240
1.2 Concepción Reservoir	129,600	95,040
1.3 Los Laureles Reservoir	64,800	21,600
1.4 Tatumbla-Sabacuante-Miraflores	6,480	2,160
1.5 El Lindero	6,740	2,300
2. Underground sources	**12,960**	**8,986**
2.1 Various wells	12,960	8,986
Total	**299,204**	**160,326**

Source: Prepared by the authors based on SANAA, Department of the Metropolitan District, May 2014.

This instant runoff with short periods of concentration constitutes one of main sources of nonpoint pollution, since it carries polluting matter into riverbeds. The improper, illegal practice of connecting sewage systems to rainwater systems means that the systems are overloaded in the rainy season, causing sewage overflows into the streets. This wastewater is carried along with garbage and other surface contaminants, creating a highly polluted mix that damages natural receiving bodies comprising rivers, streams and winter riverbeds located within the urban area.

Street cleaning, where inlets are used as rubbish deposits is another of the specific problems exacerbating the problem of pollution, since the waste deposited in inlets produces obstructions, pushing out the trash that has been dragged along, together with soil and granular material. Due to the irregular geomorphology of the capital, floods occur in the lower parts of the city with highly polluted water. This bad practice leads to public health problems associated with environmental pollution, as well as reducing opportunities for recreation and domestic and international tourism.

2.5 Supply System Features

In addition to the National Autonomous Aqueduct and Sewer Service (SANAA), water supply service in the Central District Municipality is provided through Water Management Boards and tanker trucks.

The SANAA Metropolitan Division is responsible for the metropolitan aqueduct as well as the sewerage system. Within the Central District Municipality, there are 245 Administrative Boards registered to operate legally, and it is estimated that there are approximately 50 unregistered Boards. As for water trucks, SANAA has units that provide water service at affordable prices to users who, for whatever reason, have a shortage of water, whether temporarily or systemically. There are approximately 60 private tank trucks engaged in the sale of water purchased at SANAA's facilities for this purpose, while a similar number obtain their water from other private providers. These tanker trucks meet water demand in developing neighborhoods, particularly those which lack a SANAA supply network.

SANAA has three water treatment plants, meaning that the water distributed is of good quality and suitable for domestic use. Due to the characteristics of the water, the unitary processes in the three plants include coagulation, flocculation, sedimentation, filtration and chlorination for final disinfection, which makes it suitable for human consumption.

It is worth mentioning the case of the El Picacho system, which consists of 24 mountain intakes, originally with good quality water. However, population growth in the vicinity of the intakes has created pressure on land where agricultural, livestock and poultry operations have expanded, leading to the degradation of watersheds and affecting water quality. Thus, the old water treatment plant, which consisted of a chlorination system, was replaced by a conventional rapid filtration treatment plant.

In order meet the water demand of the population of the Central District Municipality, in 1980 SANAA established the Master Water Plan for Tegucigalpa with a 2020 horizon (SANAA, Nov. 1980a), which envisages the construction of four new dams. However, the Master Plan has not been implemented according to schedule. Only one reservoir has been built, which was incorporated into the system in 1992, and since then, the water supply has not increased. The existing system is therefore subject to constant rationing to meet demand partially, with supplies by area and set times.

2.6 Available Water Sources

The sub-basins near Tegucigalpa have a combined production capacity of 225.4 million m^3/year. The largest and those with the highest capacity are the sub-basins of Río del Hombre and Guacerique, located to the west and southwest of the Central District, accounting for 77.2% of the city's water supply.

The following table provides a summary of SANAA's water supply from the main sources it currently exploits.

Water produced in the sub-basins is stored in four major subsystems, equipped with: two reservoirs with storage capacity of 48 million cubic meters of water called Los Laureles and Concepción, the El Picacho subsystem, which captures 24 surface sources within the La Tigra National Park on the San Juancito mountain and the Miraflores aqueduct, comprising the sources of the Sabacuante and Tatumbla rivers.

The total water supply of the Central District basin system located south-east and west of the capital is estimated at 7.14 m^3/s, of which SANAA currently operates approximately 3.31 m^3/s during the rainy season and 1.74 m^3/s in the dry season.

2.7 Protection of Water Sources

SANAA has a Watershed Department, responsible for watershed management. Actions include monitoring pollutant discharges into headwaters to permit the rapid intervention of the competent authority to solve the problems; prevention and fighting fires and illegal logging within the basin, particularly in the reserve areas. The point is also to control the spread of urbanization, which should not even reach the basin's buffer zones.

SANAA's Master Plan for Tegucigalpa also established the corresponding Master Sewer Plan for Tegucigalpa, which includes the development and expansion of the collection system and 100% wastewater treatment in order to minimize pollution of water sources by direct discharges of raw sewage into rivers, streams and natural winter waterways.

3. Drinking Water Service in the Distrito Central Urban Zone

The Central District, where the capital of Honduras is located, has a complex geomorphology with extremely irregular topography and steep natural slopes, as shown in the figure comprising the isometric view and profile of the central area of Tegucigalpa.

As shown in the profile, the city has variations in altitudes from 910 masl in the center of the city to 1,300 masl at Cerro Picacho, located 1.7 km northeast of the city.

This situation requires finding solutions adapted to the context of the city, and in the particular case of the drinking water system, its infrastructure has been designed to adapt to this extreme variation in altitudes. Thus, the Metropolitan District water distribution system comprises eight networks: seven being pressure networks and one a network outside them. Each network, designed to withstand pressures of up to 40 mca, is described below:

Evaluation of the service, administration and regulation that determines the water supply and availability of water for the capital of Honduras, which has a higher average density of population with a high demand for water, is undertaken in the following sections.

Table 3. Water supply of the main water sources near the Distrito Central

Name of the Watershed	Area	Production (LPS)
(Km²)	Production	2.66
(LPS)	140.0	0.99
Sabacuante	80.0	0.27
Tatumbla	64.0	0.35
Río del Hombre	343.0	2.85
Totals	837.0	7.14

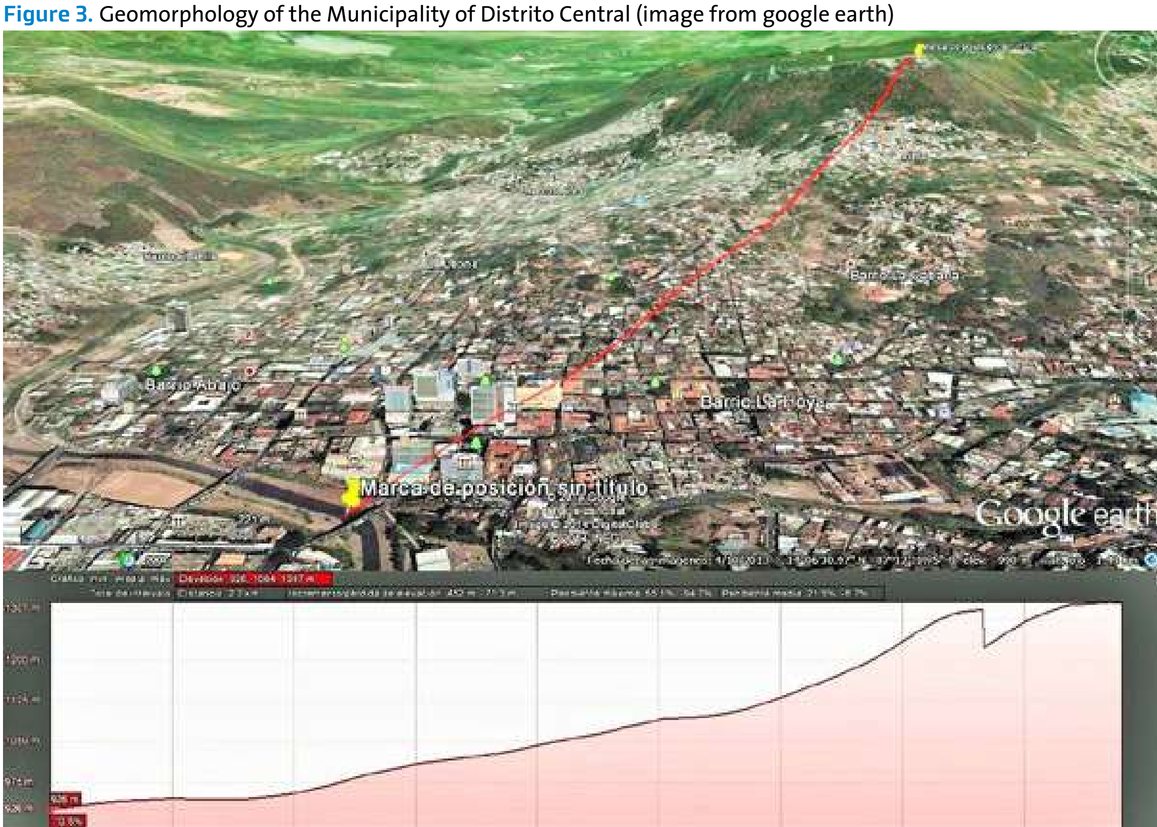
Source: Prepared by the authors based on the Funding Request for the Expansion and Improvement of the Tegucigalpa Water System, Tegucigalpa Master Plan, 1986.

Table 4. Water network distribution in the Distrito Central

Pressure Network	Pressure Range (Masl)	
1. Low Network	910	950
2. Intermediate Network	950	990
3. High Network	990	1030
4. Upper Network I	1030	1070
5. Upper Network II	1070	1110
6. Upper Network III	1110	1150
7. Upper Network IV	1150	1190
8. Network Outside Upper Network IV	1190	and above

Source: Prepared by the authors based on the Funding Request for the Expansion and Improvement of the Tegucigalpa Water System, Tegucigalpa Master Plan, 1986.

Figure 3. Geomorphology of the Municipality of Distrito Central (image from google earth)



3.1 Systems Administration

Administration of water supply systems for the population in the Metropolitan District urban area poses a number of problems due to its unequal population density, sharp socioeconomic contrasts, and developing neighborhoods with a high density population with a corresponding high water demand.

The National Autonomous Aqueducts and Sewer Service (SANAA) is the official decentralized institution of the Central Government, established by Legislative Decree No. 91 on April 26, 1961, to construct and administer potable water and sewage services throughout Honduras (National Congress of Honduras, 1961).

The population growth and urban expansion of the Central District Metropolitan Area has caused a serious problem, since water project development has failed to keep pace with urban expansion or population growth. Therefore, in the 1980s and 1990s, these services began to be delivered through Water Administration Boards (JAA) as a means of meeting the demand for water services and sanitation of the city's newly urbanized areas.

Since SANAA found a good ally in the communities, especially in the Developing Neighborhoods, through these JAA, it supported the community participation model by providing technical and administrative assistance. These JAA succeeded the Neighborhood and District Board of Trustees in the management of such services, having created an institutional structure governed by Water Boards Regulations promoted by SANAA (ERSAPS, July 2006).

Water demand is so high and supply so low that there has been a proliferation of Water Boards and water trucks selling water. However, many Water Administration Boards have a proper institutional structure, together with support from national and international NGOs to develop their own supply sources, which are mostly groundwater through boreholes, a supply network and storage tanks.

In the Central District Metropolitan Area, SANAA remains the institution responsible for water and sanitation service management, involving a total of 183 water boards, operating mostly in Developing Neighborhoods. In remote, in accessible zones and periurban areas, water trucks owned by SANAA and the Central District Municipal Town Hall (CDMA) provide water for residents, while approximately 150 private water trucks sell water indiscriminately to any neighborhoods, districts or dwellings that so request.

3.1.1 Modernization of the sector

Legislative Decree No. 118-2003 created the Framework Law for the Drinking Water Sector and its Regulations (National Congress of Honduras, January 2004) to promote the provision of water and sanitation services under the principles of quality, equity, solidarity, sustainability, generality, environmental respect and citizen participation. The overall objective of the Framework Law is to establish "the rules applicable to the drinking water and sanitation in the country as a basic instrument for promoting the quality of life among the population and strengthening sustainable development as a generational legacy."

The Framework Law establishes the National Water and Sanitation Council (CONASA) as the official representative of the Government of Honduras with regard to drinking water and sanitation both nationally and internationally, and sets the policies, strategies and plans for the sector. It also creates the Drinking Water and Sanitation Service Regulator (ERSAPS) as a decentralized institution with functional technical and administrative independence, responsible for the regulation and control of potable water and sanitation provision within the country.

Within CONASA, it hierarchizes responsibility for water and sanitation system management, recognizing the Municipal Authority as the leading authority, followed by the Water Administration Boards.

The Framework Law and the Municipal Law provide that the Municipal Authority may administer services directly, or through a Drinking Water and Sanitation Service Provider (EPS-APS), a decentralized municipal entity. Both cases involve Municipalization of Services. It may also delegate administration to a private firm through Service Concession. In the latter type of administration, assets and infrastructure remain the property of the Municipality. Lastly, there is the Administrative Board, which may assume responsibility for the administration directly as a municipal agency or as a decentralized unit of the municipality.

The Framework Law does not in any way permit or contemplate the provision of drinking water and sanitation services within the concept of "privatization".

As part of the implementation of the Framework Law, a maximum of five years was proposed from the time of the implementation of the law, so that SANAA would transfer all the systems under its administration to municipal governments, with the commitment to support them in their technical and administrative organization under the management model chosen by the municipality in question. To date, 27% of the systems have yet to be transferred and are therefore still managed by that organization. The remainder are administered by municipalities, decentralized units of the municipality and municipal companies.

The Framework Law therefore regulates the strengthening of the planning and governance of the water and sanitation sector, given the existence of a large number of national and foreign institutions involved in the development of projects with local or external funding.

In 2009, the General Water Act was passed, which regards the basin as a water management unit and provides for the establishment of River Basin Councils as regional bodies tasked with the coordination of actions between public and private stakeholders who live in and administer a basin. These organizations are tasked with proposing and implementing programs and activities to improve water management, water infrastructure, and the protection, conservation and preservation of water resources in the basin.

3.1.2 Regulation of institutions

The Framework Law establishes the need to readjust the legal and institutional framework for the water and sanitation sector in order to improve service planning, regulation, control and delivery as part of the state's decentralization policy. It also forms part of the modernization of its institutions, assigning a key role to municipal governments and the need for the broad participation of social sectors, which involves establishing mechanisms to promote joint participation by the municipal authorities and citizens (ERSAPS, May 2013). This vision is achieved through the creation of the Municipal Water and Sanitation Commission (COMAS) with jurisdiction throughout the municipality.

The Framework Law also clearly states that for the performance of its control functions, ERSAPS must have the support of regional and municipal bodies and citizen participation in a clear acknowledgement of the role that the law grants municipal governments in the provision of water and sanitation services, and of the limitations that a centralized body may have regarding the delivery of fully decentralized services. ERSAPS has therefore adopted a decentralized control model, yet one that is oriented and directed from the central level, resulting in regulatory instruments with sufficient latitude for municipalities to adopt and adapt the models commonly used in the country to the specific conditions of each (ERSAPS, September 2009). This vision is achieved through the creation of Local Supervision and Control Unit (LSCU) with jurisdiction over the entire municipality.

a. COMAS, comprising city councilors and representatives of users, is a body that ensures genuine participation by the Municipal Government and sectors of society in the dissemination and ongoing dialogue regarding the contents of the sectorial analyses, municipal water and sanitation policies, investment programs and other issues of national importance that must be based on the local analysis of each community. COMAS also serves as a coordination mechanism between municipal authorities and citizens, to provide advice to the municipal corporation and assist citizens in decision-making through the socialization of decisions.
b. The LSCU has a directory of honorable citizens from the municipality, who provide their services pro bono. These people can contribute their knowledge and experience in key areas that must be reviewed to ensure compliance with aspects concerning health, legal and client care. Directors do not receive fees, but they may incur costs for travel expenses and accommodation at events involving training and the exchange of experiences. Since the LSCU board consists entirely of citizens, it must have close links with the Municipal Commissioner, who is assigned similar general functions in the municipality.

c. The interrelationship between COMAS and LSCU states that COMAS is a body that serves the Municipal Government in an advisory capacity in regard to issues related to the policies, planning and coordination of activities related to the water and sanitation sector. It is tasked with compiling the register of governmental and non-governmental organizations that operate within the municipal sphere. Meanwhile, LSCU must maintain a close, continuing relationship with COMAS, since it is the body through which reports on the sectorial situation are submitted to the Municipal Corporation. This makes it an official, updated, permanent source of knowledge of the state of service delivery, the identification of problems that require preventive or corrective actions by the service provider, which COMAS must consider in the sectorial planning proposals it submits to the Municipal Corporation.

   Thus, the LSCU must identify situations where deviations occurring in a municipal provider's performance of functions warrant intervention to ensure that they are undertaken in accordance with the Framework Law, regulations, bylaws and statutes established in the legal status of the provider.

3.2 Service Coverage

Drinking water access is a crucial part of attempts to decrease the frequency and risk of diseases associated with fecal contamination. It also provides information on human development when associated with other indicators, particularly those of a socioeconomic nature. Its spatial analysis reveals the degree of equity of access to the service within a given territory.

Access to water in general and drinking water in particular has quite dramatic aspects in the Central District Metropolitan Area, with a distinction needing to be established between easy access and no access to water. Easy access to water means that a person has to walk a daily maximum distance of 200 m to fetch a basic amount of water, estimated at one barrel, equivalent to 40 gallons or 125 liters, regardless of whether it is potable; whereas in the case of no access to water, water may be available at larger or smaller distances, but the person does not have access to it for a variety of reasons.

Due to the varied biophysical, socio-economic and socio-cultural conditions, water service coverage scenarios in the Central District Metropolitan Area include the following systems.

3.2.1 Conventional systems

Conventional systems generally focus on domestic connections, through which the water supply to each house or apartment is allowed through an individual connection to the municipal network administered by SANAA. This type of access provides direct drinking water service for a person in the comfort of his own home. In other words, he will have sufficient quantity and quality of water for human consumption and for performing daily activities such as bathing and washing food and personal items.

3.2.2 Non conventional systems

Non-conventional systems include conditions of easy access to water, which occur in the following situations:

a. Tanker Trucks. SANAA provides water supply service to developing neighborhoods, which have a storage tank and network. Tanks are filled by the Water Board, and water is subsequently supplied by gravity to the dwellings connected to the network. It also supplies water to the homes of very poor people who have some type of container or basin where they can store at least a small amount of water.
b. Public key banks. Public key banks still exist in certain developing neighborhoods, providing service with water from the municipal network administered by SANAA, indicating that it is good water.

   Public key banks operate as collection centers, where there is a person who keeps the access key to the taps, opening at times agreed on by the community of residents.

   At times of crisis, the Fire Department, government trucks and CDMA provide support in distributing water to the poorest sector of the population. Since the water they supply is taken from the SANAA municipal network, the water supplied is considered to be of good quality.

In the case of the Central District Municipality, the systems are currently being transferred from SANAA to CDMA. This has been a slow process, due to the complexity of the systems, both administrative and operational, and the fact that the Administrative Division of Metropolitan Area comprises two major cities with their own characteristics. This includes the establishment of the administrative model, which has yet to be defined, the creation of COMAS and LSCU.

c. Free water sales. A fleet of trucks fitted out with makeshift tanks belonging to people who sell water, supplying water to all kinds of housing located in any neighborhood or district, although most clients are residents of developing neighborhoods on the periphery of the city, where there is no water supply network.

   Water is sold to slum inhabitants using the barrel as a unit of measure, while dwellings from a higher social stratum are sold the entire contents of the tank.

   The average cost of a barrel is US$ 2.14, while the average cost of a 400-600 gallon tank is US$ 35.71.

d. Lastly, there is a totally destitute sector of population, which has no form of access to water and so goes to rivers or streams, where it uses the water, regardless of the quality. In some cases, these people take advantage of the rains to collect rainwater in containers, which serves as a palliative during the rainy season.

The following table summarizes the water supply situation in terms of access to water by the population.

According to the table above, crossing information from INE and SANAA, both official information sources, showed that drinking water coverage totaled 53.2% of all the households registered on the basis of EPHPM in May 2013.

SANAA records state that the Metropolitan Area has 120,204 subscribers, in other words, households with individual household connections.

An analysis of the information from both institutions shows that the coverage reported by SANAA refers, in percentage terms, to the users within its service area. In other words, of the total number of subscribers, 80.9% have direct connections in their homes, while 19.1% are served by non-conventional systems. In fact, the issue of coverage has different interpretations, but a more accurate picture is provided when both INE census figures and SANAA records are taken into account.

On the other hand, nationwide coverage is more optimistic, since the city of San Pedro Sula, together with the city of Puerto Cortés, has high coverage rates that increase average figures to approximately 80%

3.3 Coverage Expenses

The per capita cost incurred by service delivery according to the degree of coverage does not establish a differential ratio depending on the economic level of the client. It only considers four categories based on water use and consumption, based on the simple rule, "Whoever uses more should pay more."

Consumption categories are as follows:

1. Domestic
2. Commercial
3. Industrial
4. Government
5. Boards of Trustees and Water Boards

The domestic category includes four segments based on residential level, as shown below:

a. Segment 1, which applies to the population of developing neighborhoods; the cost of the basic water quota for 20 m³ is the lowest and residents are exempted from paying the fixed cost for connection.
b. Segment 2 applies to the lower intermediate population; the cost of the basic water quota for 20 m³ is 106.2% higher than the cost for Segment 1, while the fixed cost per connection is US $ 1.19 per month.

c. Segment 3 applies to the upper intermediate population; the cost of the basic water quota for 20 m³ is 178% higher than the cost of Segment 1, while payment for the fixed cost per connection is US $ 3.33 per month.

d. Segment 4 applies to the population in the higher social sector; the cost of the basic water quota for 20 m³ is 345% higher than the cost for Segment 1, while the fixed cost per connection is US$ 7.14 per month.

Although the cost of producing good quality water does not differentiate or discriminate according to whether the centralized supply is intended for the upper class, middle class or the poor, for use in public sources or by traveling salesman that transport water in tanker trucks for sale even to the privileged class who suffer the same inconvenience of rationing and lack of water, this differentiation is considered in the tariff structure, as one can see in the SANAA Current Rates approved for 2010, shown in the following table.

Analyzing the examples of payment for one month's service included by SANAA in the rates table, and replicating this calculation for each segment, considering only the use of the basic amount of water, shows that the following amounts would be payable:

a. Segment 1 L. 41.25 (US$ 1.96)
b. Segment 2 L. 108.50 (US$ 5.16)
c. Segment 3 L. 182.00 (US$ 8.67)
d. Segment 4 L. 328.50 (US$ 15.65)

The Table 7 includes a summary of SANAA's commercial invoice, with the items comprising the commercial invoice for each of the four categories of use served by this institution. The Board of Trustees and Water Boards Categories are not included.

Taking into account the number of users by category, the cost of production per category ranges from US $14.57 for a domestic user to $1055.52 for a government user.

A comparison of the previous unit cost of US $14.57.98, with estimated costs for the consumption of the same amount of water in the four segments of domestic category shows that only clients in Segment 4 cover the cost of service of the commercial invoice. Rates are lower for the remaining clients, resulting in a deficit in the commercial invoice (SANAA, 2013).

Evaluating the cost for commercial, industrial and government categories, based on consumption of 20 m³, is that the values that should be paid are US$15.49, US$29.77 and US$25.05, respectively. A comparison of the latter values with those calculated in the table above reveals a disproportionate subsidy for consumers in these three categories.

Table 5. Access to Water in the Municipality of Distrito Central

Description of Provider	Subscribers		
	Partial	Amount	%
SANAA Municipal Service		120,204	
Direct connections (80.9 %)	97,263		38.9
Direct connections (19.1 %)	22,941		9.2
Tanker Trucks		7,687	3.1
Public key banks.		744	0.3
Other means		4,215	1.7
Total dwellings with access		132,850	53.2
Total dwellings in urban areas		249,946	

Source: Calculations based on SANAA, Sales Department, June 2014.

Table 6. Cost of Water Supply in the Municipality of Distrito Central

National Autonomous Service of Aqueducts and Sewers SANAA, Commercial Department, Approved rate, December 2007

Domestic Category Range	Range of m^3 / month	Minimum water consumption per segment Lps / month	2003 Rates Lps m^3 / month	2010 Rates Lps m^3 / month	Variation	Fixed cost per connection	Sample calculations Domestic Category per Segment
Segment 1	0-20	31.80	0.85	1.59	0.74	Exempt	**For a consumption of 20m³ Segment 1** Range of (0-20) Lps. 1.59 per m³ Potable water 20m³ = L 1.59=L 31.80 Sewerage L 31.80 x 25% = L 7.95 Meter maintenance = L 1.50 Fixed cost per connection (exempt) L 0.00 **Total amount due 41.25 L**
	21-30		1.70	3.17	1.47		
	31-40		5.20	5.23	0.03		
	41-50		6.80	9.10	2.30		
	51-55		8.50	12.92	4.42		
	56 and over		12.90	16.11	3.21		
Segment 2	0-20	65.60	0.85	3.28	2.43	25.00	**For consumption of 25m³ Segment 2** Range of (21-30) Lps. 4.05 per m³ Potable water 25m³ x L 4.05 = L 101.25 Sewerage L 101.25 x 25% = L 25.31 Meter maintenance = L 1.50 Fixed cost per connection L 25.00 **Total amount due L 153.06**
	21-30		1.70	4.05	2.35		
	31-40		5.20	6.18	0.98		
	41-50		6.80	10.54	3.74		
	51-55		8.50	13.12	4.62		
	56 and over		12.90	16.79	3.89		
Segment 3	0-20	88.40	0.85	4.42	3.57	70.00	**For consumption of 35m³ Segment 3** Range of (31-40) Lps. 7.37 per m³ Potable water 35m³ x L 7.37 = L 257.95 Sewerage L 257.95 x 25% = L 64.49 Meter maintenance = L 1.50 Fixed cost per connection L 70.00 **Total amount due L 393.94**
	21-30		1.70	5.23	3.53		
	31-40		5.20	7.37	2.17		
	41-50		6.80	11.40	4.60		
	51-55		8.50	14.42	5.92		
	56 and over		12.90	18.24	5.34		
Segment 4	0-20	141.60	0.85	7.08	6.23	150.00	**For consumption of 50m³ Segment 4** Range of (41-50) Lps. 13.58 per m³ Potable water 50m³ x L 13.58 = L 679.00 Sewerage L 679.00 x 25% = L 169.75 Meter maintenance = L 1.50 Fixed cost per connection L 150.00 **Total amount due L 1,000.25**
	21-30		1.70	8.90	7.20		
	31-40		5.20	10.93	5.73		
	41-50		6.80	13.58	6.78		
	51-55		8.50	16.86	8.36		
	56 and over		12.90	19.42	6.52		
Commercial category	0-20	119.00	5.50	5.95	0.45	175.00	
	21-30		6.00	7.96	1.96		
	31-40		8.00	12.17	4.17		
	41-50		9.00	16.03	7.03		
	51 and over		12.00	22.48	10.48		
Industrial Category	0-20	299.60	9.00	14.98	5.98	250.00	
	21-40		12.00	19.67	7.67		
	41 and over		16.00	29.12	13.12		
Government Category	0-20	299.60	9.00	14.98	5.98	150.00	
	21-40		12.00	19.67	7.67		
	41 and over		16.00	29.12	13.12		
Trustees and water boards category	0-40	116.00	1.00	2.90	1.90	Exempt	
	41 and over		1.40	2.90	1.50		

To calculate the value to be billed monthly, the following is added to the value of the water: 1) sewerage charges, equivalent to 25% of the invoice value of water, 2) meter maintenance, charged at Lps 1.50 per month when a meter exists; 3) Fixed connection cost, applicable to each segment, published in the Official Gazette on September 17, 2007.
Source: SANAA, Sales Department, June 2014.

3.4 Supply Typology

In the particular case of the Central District Metropolitan Area, the type of water supply system is influenced and determined by its geomorphology, as described above. Additionally, according to research conducted by SANAA, the existence of groundwater in sufficient quantities for commercial exploitation to provide water for the population is extremely low. Despite this constraint, there are water boards that have small decentralized systems, whose intake sources are groundwater through wells drilled and fitted with their respective pumps.

3.5 According to the law (Ley Marco, Honduras)[1]

According to the Framework Law, the time limit set for the transfer of services prompted the search and creation of new organizational models for service delivery, including municipalization, concession and water boards, mentioned earlier.

The prevailing model is the Water and Sanitation Service Provider Body (EPS-AS), a decentralized municipal unit with extensive outsourcing of administrative services such as surveillance, among others, and some operation and maintenance services (Secretariat of Finance, March 2011).

1. Ley Marco Sector Agua Potable y Saneamiento

In the case of the Central District, SANAA remains the provider agency services while the transfer process of the systems that it administers, the management is still in process.

3.6 Characteristics

The characteristics of services in terms of continuity, water quality, pressure, leakage from the drinking water network, among others, have been evaluated by the ERSAPS, whose model with certain values is shown in the following table.

For the purposes of partially illustrating the ERSAPS model, only six elementary indicators have been selected to support the assessment of service management (Secretariat of Finance, March 2011).

3.7 Water Use

Water use in the Metropolitan Area of the Central District comprises the categories described below:

a. Domestic use. Intended for residential use.
b. Commercial use. Intended for the use of malls, stores, hotels, restaurants, public offices, academic centers and business centers.
c. Industrial use. For the use of metalworking and non-metalworking industrial centers. The water required and provided for agroindustrial centers must meet the same water standards

Table 7. SANAA Commercial Invoice

Item	Consumer Billing by Category (US $)			
	Domestic	Commercial	Industrial	Government
1. Clients	41,777	4,633	319	578
2. Consumption (m³)	54,819.76	15,418.90	1,515.81	16,841.62
3. Water consumption (L.)	372,041.76	304,773.00	42,103.27	487,094.48
4. Sewerage	91,996.27	75,996.66	10,582.09	118,657.79
5. Meter Maintenance	1,983.29	296.93	15.14	41.29
6. Retiree's Discount	13,132.85	3.57		
7. Fixed Cost	96,914.76	38,608.33	3,797.62	4,128.57
8. Interest in the event of overdue payments	32,651.47	26,570.82	5,317.34	170.74
9. Invoice value	608,720.40	446,249.31	61,819.46	610,092.87
Cost per Client	**14.57**	**96.32**	**193.79**	**1,055.52**

Source: Calculations based on SANAA, Sales Department, June 2014.

as those for residential consumption. However, in some metalworking industrial centers, good quality water is used for the type of industry, but not necessarily with the same features as that for residential consumption, except for the water intended for personnel. There is no water recycling.

There is no recycling of water for industrial use, only a SANAA wastewater treatment plant that discharges a certain amount into the river, estimated at 30% of the wastewater of the population located in the southern area of the city.

d. Public use. Intended for the use of civic government centers, government offices, hospitals, penitentiary centers, military and police barracks. The water required is supplied through SANAA's municipal network, meaning that it is good water, in other words, it meets the same standards as water for residential consumption.

In Honduras there are no regulations concerning the use of water saving or low consumption devices. The Ministry of Health promotes the use of low-cost sanitation units, although they are not water-saving devices. In general, the Ministry of Health and SANAA only promote sporadic water saving campaigns.

SANAA establishes prohibitions on wasting water, imposing sanctions ranging from fines to the suspension of service for the user who violates these prohibitions, which include the following: not using a hosepipe to water green areas, washing the floors and walls of houses or washing vehicles.

3.8 Problems

The ongoing water supply problem, for the population connected to SANAA's municipal network, is related to the rationing of water supply, which is exacerbated in the summer. The situation is worse in periurban areas and high areas of the city, which water is unable to reach due to pressure problems in the network.

This is linked to the lack of water infrastructure, which makes it impossible to meet the water demand of the growing population of the city. There are proposals for new reservoirs at the sources that supply water to the capital, but some of them have yet to be built, mainly due to the large amounts of financing required for public works on this scale.

4. Water treatment in cities

The demand for good quality water in large cities with high population density raises the need for water treatment for use in human activities, especially those intended for domestic use, which may include residential and commercial use. Within this context, water purification entails a series of individual processes that should culminate in the final disinfection process to ensure that water is safe for human consumption.

4.1 Water Treatment Coverage for Water Purification

Treatment coverage for water purification from the municipal network administered by SANAA is 100%. The network comprises four subsystems, each equipped with its own water treatment plant (see Table 9).

Groundwater sources are chlorinated in pipes, and at the El Lindero Center, chlorination is applied in the tank, which functions as a contact tank.

In the colonies or neighborhoods that are not supplied by SANAA, there are individual solutions that can be from both surface and groundwater sources. Although water is mainly used for domestic purposes, residents resort to buying bottled water for human consumption in order to ensure they consume good water.

4.2 Treatment Coverage by Economic Level

In the municipal network managed by SANAA, treatment coverage for water purification is widespread and there is no difference by the economic status of the population to be served. In short, the costs for this item are automatically included in the rates.

Likewise, water distributed through the network does not distinguish between the economic status of users, who may belong to the residential

Table 8. Characterization of drinking water indicators

Description	Amount	Source
1. Water and wastewater quality. Monthly samples of.		
• Potable water analyzed	329	2013, water treatment plant
• Treated wastewater analyzed	154	2014, wastewater plant
• Treated water that meets the standard	328	271 physico-chemical analysis; 328 bacteriological analysis
• Treated wastewater that meets the standard	133	2014, wastewater plant
2. Quality of service. Monthly records.		
• Complaints about lack of water	340	2011,SANAA, Internal report
• Complaints about incorrect billing	1,300	2011,SANAA, Internal report
• Complaints about sewerage system failures	250	2011,SANAA, Internal report
3. Monthly billing, US$, billing and revenue		
• Income for drinking water	158,730.16	2013, SANAA, Internal report
• Income for water source conservation service	0.00	2013, SANAA, Internal report
• Income for sewerage service	808,333.30	2013, SANAA, Internal report
4. Personnel		
• Number of employees in drinking water	2,116	2014 Human Resources SANAA
• Number of employees in sewerage	634	2014 Human Resources SANAA
5. Incidence of faults		
• Number of faults in drinking water system/month	372	2013, Maintenance SANAA
• Corrective actions in drinking water/month	504	2013, Maintenance SANAA
• Length of drinking water pipe, Km	3,000	2013, Maintenance SANAA
• Number of faults in the sewerage system/month	511	2011, SANAA, Internal report
• Corrective Actions for sewerage/month	511	2011, SANAA, Internal report
• Length of sewer pipe, Km	486	2011, SANAA, Internal report

Source: Calculations based on MOF/BM/ERSAPS, Manual para la identificación e implementación de acciones de tercerización, marzo de 2011. Tegucigalpa.

or commercial, industrial or public and government sector, regardless of the inputs used in the processes to purify the water distributed.

4.3 Cost of Treatment Systems (Expenditure per capita)

As mentioned in previous chapters, SANAA administers the municipal drinking water and sewerage service systems of the Central District, which are larger in size and more complex, due to the city's geomorphology.

Both systems have treatment plants that involve operating and maintenance costs, meaning that each case must be analyzed separately.

4.3.1 Water Treatment

Treatment plants for water purification systems are conventional systems that include individual processes of coagulation, flocculation and disinfection, in which the use of chemical inputs is required.

According to the water quality, sources in the El Picacho Distribution Center are those that require the fewest inputs. However, SANAA declares that the average daily cost of treating water for purification is L.0.50 (US$0.024) per capita, representing a total average cost of L.258,439.00 (US$12.307) per day for the population connected to the system.

Table 9. Water treatment plants in the SANAA system

Sub-system	Plant Type	Capacity (LPS)	
		Minimum	Maximum
1. Concepción	Rapid filtration	1,100	1,500
2. El Picacho	Rapid filtration	350	910
3. Los Laureles	Rapid filtration	250	750
4. Miraflores	Rapid filtration	25	75

Source: Calculations based on SANAA, Metropolitan Division, June 2014.

4.3.2 Wastewater Treatment

Since the issue of wastewater treatment plants is explained in section 4.51., this section will focus on analyzing the cost of wastewater treatment by SANAA.

Treatment plants for purifying wastewater from a sector of the sewerage system in the capital city are aerobic, oxygen being the only input required for operation. The average daily cost estimated by SANAA, of wastewater treatment is L.0.37 (US$0.018) per capita, equivalent to an total average cost of L.92,500.00 (US$4.405) per day for the population connected to the system.

4.4 Water Reuse

Within the Central District Metropolitan Area, there is no reuse of wastewater by state institutions.

There are some isolated cases of factories with wastewater treatment plants, whose effluents are used for landscape irrigation.

4.5 Graywater Treatment

The problem of high water demand in a small space in cities with high population density can be solved by the high amounts of used water, which can either be treated for reuse or simply purified for their reintegration into the ecosystem.

4.5.1 Treatment Processes

Wastewater treatment may involve two stages: the first is a purification process, which is the most common; and, second, a treatment process, when the water is to be subsequently used for an activity involving humans.

a. **Wastewater treatment.** The treatment is intended to reduce pollutant values to the typical values found in fresh water in nature, for their reincorporation into the ecosystem with no danger of pollution. The plants are known as wastewater treatment plants (WTP). For example, typical values of DBO5 in the surface waters of rivers, lakes and ponds are usually 30 mg/l, and it has been proven that with values of up to 50 mg/l BOD5, the content of fats and oils in rivers and lakes is zero mg/l.

   Honduras has the "Technical Standards for Wastewater Discharges into Receiving Bodies and Sewerage," which have regulated the values of liquid effluents for WTP since 1997.

   The presence of nutrients such as organic and ammoniac nitrogen, sulfates and phosphates, among others, is desirable in natural waters, since they contribute to the growth of trees and flora in general. These nutrients are found in high concentrations in wastewater, and therefore, through the treatment process, are reduced to values that are not harmful to the environment but beneficial to flora. The Honduran Technical Standards for Wastewater Discharges into Receiving Bodies and Sewerage regulate the limits for discharges into receiving bodies (Ministry of Health, 1997).

   The treatment processes typically include pretreatment or preliminary treatment, primary and secondary treatment, this flowchart being the one most commonly used in the Central District Metropolitan Area.

b. **Wastewater treatment.** Is applied when a tertiary treatment process is introduced for the purpose of making the treated water a suitable source of water supply for domestic use.

   At this stage, it is possible to add a water treatment plant to produce water for human activities that include residential, commercial and industrial use. This type of treatment is not yet used in Honduras.

4.5.2 Central District Actions

The Tegucigalpa, D.C.Master Sewerage Plan (SANAA, November. 1980) envisages the construction of two wastewater treatment plants (WTP), with the capacity to handle 25% and 75%, known as WTP 1 and WTP 2, respectively.

WTP 1 was strategically planned to be built in the Las Vegas sector, where SANAA currently has two WTPs, in order to process the largest possible volume of wastewater generated by the population in the southern sector of the Central District Metropolitan Area, representing 30% of the total volume of the entire population of the urban area of the Central District, as shown in the accompanying figure (Villafranca et al., 2009).

SANAA currently operates two WTPs, which together handle a daily volume of wastewater estimated at 50,000 m³ produced by an estimated 250,000 inhabitants. The population in the catchment area is approximately 380,000 inhabitants, meaning that a significant amount of wastewater remains untreated.

In the private sector, there are several neighborhoods that have small sewerage purification plants but due to poor operation and maintenance, these plants have collapsed, becoming sources of environmental pollution.

4.6 Reintegration of Water Into the Environment or Ecosystems

The main use of effluents from the SANAA WTP installed in the La Vega sector is the reintegration of the volume indicated above into the Choluteca river, for the following purposes:

a. Establish an ecological baseflow in the Choluteca River to preserve the two main features of fresh water: colorless and odorless. The river flow has been reduced due to the reservoirs built upstream in the headwaters of the basin.
b. Reduce the degree of pollution by diluting the high content of wastewater, and facilitate the excellent self-purification capacity of the Choluteca River due to its steep slope, which has a sufficiently fast flow to achieve this.
c. Ensure public health in the capital, by eliminating the unpleasant odors that often emanate due to the condition of septicity that can reach the river water during the hottest days in summer.
d. Reduce the pollution that can spread through the streams and rivers crossing the city, whose waters are used by a sector of the population, especially the one located on the riverbanks.

5. Water and Health in Honduras

Water, vital for human health factor, is also a vehicle for illness and death. Both extremes occur in Honduras: on the one hand, there is a water shortage, in both the urban and rural zone and on the other, there are floods caused by hurricanes and tropical storms. Both scarcity and abundance affect the health of Hondurans.

This becomes more dramatic in large cities such as Tegucigalpa and San Pedro Sula, the former with 1.11 million inhabitants and the latter with 677,000 (INE, 2013). Both cities have experienced rapid population growth over the last 50 years due to migration from the countryside to the city in search of better living conditions.

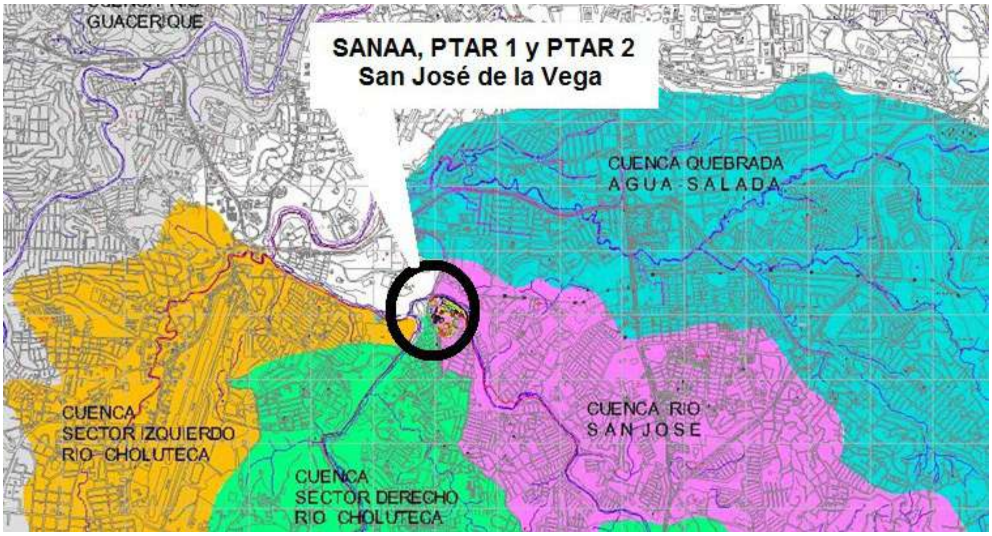
Tegucigalpa, located between hills in the interior of the country, is the more disorganized city and less prepared for this human wave, which requires water, food, health, housing, education, and transportation among other services. Each year, the city increases at a rate of 100,000 new inhabitants (Central District Mayor's Office, 2013), most without livelihoods, building homes classified as huts in hills where there is a lack of water, sanitation and roads. The city has nearly 900 neighborhoods and districts, of which over 400 are the result of urban encroachment (El Heraldo, May 14, 2014).

In the specific case of the Central District Metropolitan Area, two major rivers cross the urban area: the Grande or Choluteca River and the Chiquito River, and more than ten tributary streams that feed into it, flowing through numerous neighborhoods and districts located mainly in the upper parts of the city. In the headwaters of the Choluteca River, in the far south, two major rivers flow into the Choluteca River: the San Jose or Jacaleapa River and the Guacerique River.

Due to the growing demand for water, the population, especially those with the lowest income, often use the waters of these heavily polluted rivers.

The Choluteca River runs through the center of the city and serves as a dividing line between Tegucigalpa and Comayagüela. The river is heavily polluted due to the discharge of sewage it receives on its journey through the city, either directly or through leaks in the SANAA sewage sub-collectors, the majority of which have collapsed. The city's main markets are located near the edge of the left bank of the river. Due to the high pollution load of wastewater discharges it receives, the river become totally septic, in other words, the dissolved oxygen content is zero, meaning that it is devoid of aquatic life. During floods, the river has brought disease and death to thousands of residents (Rivera, 1967). For example, during Hurricane Mitch (1989), much of the commercial area of the city of Comayagüela, including markets, lay under three meters of water.

Figure 4. PTAR 1 and PTAR 2 Coverage Area



Additionally, the sewerage system in the lower areas of the city collapsed.

The city has two regulation dams: Concepción and Los Laureles, which store water from the Concepción and Guacerique rivers. Water from these dams is purified before being distributed in the city. Outside these reservoirs, there is another major source of water for the city, which comes from Mountain San Juancito, specifically La Tigra National Park. La Tigra National Park is a rainforest with significant biodiversity and through the El Picacho Distribution Center, supplies water to part of the Upper Network and the Higher Networks of the city.

5.1 Situation in Developing Neighborhoods

What do residents of neighborhoods set in the hills where there is no drinking water or sewerage do? For these people, water is a precious liquid for which they have to pay exorbitant prices to vendors driving around in tanker trucks. Although SANAA distributes water once a week in summer, it is impossible to cover all the neighborhoods. People must, in any case, reserve water for essentials: bathing at least once a week and washing one's hands before meals becomes a luxury. Since many homes lack sanitation or even latrines, sewage is washed away by rain to the neighborhoods below, polluting the streets before reaching the nearest creek.

5.1.1 Morbility

The health consequences are obvious. Childhood diarrhea is the leading cause of death in children under 5. Intestinal parasites, including amoebiasis, are common in children and even adults. The Hepatitis A virus, acquired in early childhood, goes unnoticed in most cases. Fortunately poliomyelitis has been controlled by vaccinating children, but before 1989, when the last case was reported, it was often transmitted by contaminated water (Rivera, 1967). The same happened with cholera during the period from 1991 to 1995 (Burdeth, 1995).

Several studies have been conducted at the National Autonomous University of Honduras on the causes of childhood diarrhea. Most point to the contamination of water and food, lack of hygiene when preparing infants' food and the lack of water for washing hands before eating, all strongly influenced by poverty, overcrowding and marginalization.

5.1.2 Mortality

The mortality rate in Honduras is 19.85 per thousand births (Secretariat of Health, 2013), water pollution undoubtedly being one of the main contributing factors.

Among the bacteria causing diarrhea, various studies mention Salmonella, Shigella and toxigenic strains of Escherichia coli (Figueroa, 1990). Late last century there was also an outbreak of Vibrio cholerae, which affected all of Central America, causing high mortality, primarily transmitted through contaminated water.

Waterborne parasites often include Giardia lamblia; while the Rotavirus virus is one of the leading causes of diarrhea in children under four.

In the city, people prefer to drink water sold in bottles or pouches and there are several companies selling purified water. The controls periodically carried out by the Ministry of Health's Contaminants Laboratory suggests that the quality of this water is acceptable. However, the outside of these bags is not clean and since the bags have to be opened with the teeth or nails, contamination may occur.

5.1.3 Floods and Storms

As a result of hurricanes and tropical storms, dengue and malaria thrive in flooded areas causing illness and death. Rains leave puddles and ponds where Aedes aegypti and Aedes albopictus mosquitoes, dengue-transmitting vectors, proliferate. In 2013, 29,500 cases of fever due to dengue were reported, together with 26 deaths from hemorrhagic dengue (Secretariat of Health, 2013). The most severely affected cities are obviously Tegucigalpa and San Pedro Sula, which have the highest population density. Cases of malaria, transmitted by mosquitoes of the genus Anopheles, also tend to increase in the wake of storms and hurricanes. Sporadic cases were registered of leptospirosis, an infectious disease affecting the liver, which is transmitted by water contaminated by rats' urine (Ministry of Health, 2010).

5.2 Other Pollutants

Chemical contaminants are unimportant in Tegucigalpa, since there are very few factories, and as in the agricultural field, these are small-scale operations. Pollution of the Choluteca River is mainly due to organic matter from the city sewers. Decomposition of organic matter by bacteria and algae causes loss of oxygen from the water and therefore the death of fish and other aquatic life.

In the 1940s and 1950s, DDT was widely used in the campaign to eradicate malaria, and undoubtedly contaminated the water. The campaign was successful across the country, but once the possibility of carcinogenic effects was realized, the program was discontinued. Other possible chemical contaminants that may enter the water include PCBs from hydraulic fluids, coolants, transformers and paint. More recently, lithium from discarded batteries and radioisotopes used in medicine have been known to make their way into water. Nevertheless, chemical pollution of the water in Tegucigalpa remains low.

The health impact of water pollution in urban areas of the two main cities of Honduras has been highlighted. The same problem probably occurs in other cities and towns in Honduras. Public health would improve by 50% if it were possible to improve the quantity and quality of water consumed by residents and to reduce flood damage. Improving water quality would significantly reduce spending on hospitals and medicines, and therefore improve the quality of life for residents.

The solution to the water problem in urban areas is closely linked to other social problems, such as the lack of sustainable economic development, uncontrolled population growth, -Honduras grows 2.1% annually, one of the highest rates of America- rapid deforestation, which causes the loss of water sources, climate change and a gradual increase in the average temperature caused by the development of northern countries, and lastly, the lack of planning by national and local governments, particularly in urban areas with high development rates.

6. Climate Variability and Change

Prior to the analysis of the impact of climate variability and change on water resources in cities, with particular reference to the Central District Metropolitan Area, the basic concepts of climate change and its associated features will be analyzed.

6.1 Climate change[2]

Climate change is the modification of the climate in relation to its history on a global or regional scale. These changes occur with different time scales and above all, climate parameters, and may in theory be due to natural (Croles and North, 1988) or anthropogenic causes (Oreskes1, 2001).

2. INE, December 2010.

Climate studies show that constant climate change has existed due to natural causes, known as natural climate variability, but that this change has been influenced by man -anthropogenic climate change.

The United Nations Framework Convention on Climate Change uses the term "climate change" to refer to change due to human causes, in other words, a change of climate directly or indirectly attributed to human activity that alters the composition of the world atmosphere and contributes to the natural variability of the climate observed during comparable periods.

The earlier reference to the United Nations shows that greater emphasis is placed on anthropogenic climate change, and that the terminology is often used inappropriately to refer to climate change as synonymous with global warming.

Climate change has increased and will continue to increase the vulnerability of cities, as demonstrated by the capital of Honduras. Special measures are required in urban areas for the efficient use of water resources, including: prevention of an impact on quality, wastewater treatment, introduction of more water reuse projects, and runoff use, among others.

6.2 Cities in Dry Areas and How to Organize Supply

Ecosystems in dry land or zones are characterized by the lack of water.[3] Water shortage limits the production of crops, forage, wood and other ecosystem services.

There are four commonly accepted subtypes of dry lands: dry sub-humid, semi-arid, arid and hyper-arid, with a growing degree of aridity or moisture deficit.

The Central District is located in central Honduras, at an average altitude of 1,100 meters, and according to the above definition, does not classify as a dry area.

3. http://www.greenfacts.org/es/glosario/tuv/tierras-secas.htm

Due to its spatial location and altitude, it has a Tropical Savanna climate.[4] This type of climate has two seasons: a dry season that begins in January and ends in April, February being the driest month, and a rainy season beginning in May and ending in October.

During the rainy season, there is a short period between the months of July and August, during which it stops raining and a dry period. This period usually lasts a month and is known as the "mid-summer drought." [5]

Due to this behavior, 69% of the Central District water supply system, planned, managed and operated by the water authority, SANAA, relies on two regulating reservoirs: Concepción and Los Laureles, currently in operation, and three to be built within an estimated period of 25 years, in other words, by 2040.

6.3 Storm Water and Flooding Problems

The rainfall pattern is one of climate factors that has been most severely altered by climate change, causing serious problems in major cities. Consequently, storm water drainage systems are the most heavily affected, due to the increased incidence and intensity of precipitation.

The rise in heavy rainfall and stronger, more frequent and severe hurricanes may cause river and coastal flooding, and overcome the defenses of the city, if they exist, or reveal the extreme vulnerability of cities. Although the link between these events and climate change has yet to be proved, the flooding and destruction caused by Hurricane Mitch in Tegucigalpa and Comayagüela in 1998 serve as a reminder of the catastrophic impact of extreme weather events on urban areas and society in general.

6.3.1 Floods in Cities

The increasing frequency and intensity of rainfall means that runoff levels may exceed the capacity of storm drains leading into the drainage system, or cause flooding in conjunction with sewerage systems. These overflows can cause street

4. http://www.xplorhonduras.com/clima-de-honduras/
5. *Ibidem*

flooding, with the attendant health hazards due to contamination, but can also increase the cost of complying with the related regulatory requirements.

The overflowing of sewers is a problem linked to cross-connections commonly maliciously performed by builders of housing sewage systems to the urban drainage system, and from the roof and courtyard drains of houses to the housing drainage system and thence to the municipal sewerage network maliciously performed by builders of housing sewage systems.

a. This illegal crossing over of connections, in addition to the practice of using storm drains as public landfills, severely affects the urban areas of the Central District, since the amount of rainwater flowing through both systems in addition to surface runoff in the streets causes flooding due to overflowing, which is more common now in the rainy season. Additionally, heavy rains carry an enormous amount of trash combined with raw sewage, which they eventually discharge into the rivers crossing the city.
b. The cost of this recurrent problem of urban flooding is estimated by the authorities in terms of the participation of emergency service agencies, care for the population affected, and repairs to damaged infrastructure.
c. The most immediate actions to prevent this systematic occurrence of flooding in the Central District may include:
    - Conduct an intensive program to clean out the drains, manholes and discharge heads of the storm water drainage system.
    - Ensure strict supervision of all urban constructions in order to control illegal and clandestine cross connections between the sewer system and storm drainage by builders.
    - Establish monitoring mechanisms and incentives or penalties, as appropriate, to prevent the use of storm drains as trash cans. A health education program at the primary and secondary school level would be useful for training future citizens in the new culture of the effects of climate change on water resources.

6.3.2 New solutions in cities

Given the high impact of climate change on flooding problems in urban areas, it is essential to focus strategies on storm water management as part of urban water management policy.

The current water management infrastructure requires immediate, practical solutions to address changing circumstances, since climate change projections show that variability can change capacity requirements by region or season. The choice of sustainable systems for water management in urban areas designed to address variable and unpredictable conditions seems to be the best answer for planning new urban solutions and achieving the implementation of flexible, often decentralized options and technologies that take a range of future scenarios into account.

A flexible system is characterized by its ability to adapt to changing requirements. For example, possible responses by a flexible system to changing conditions would include reducing runoff through the use of Sustainable Urban Drainage Systems options, including:

- Green roofs
- Porous pavements
- Grassy Channels
- Rainwater Harvesting
- Detention ponds
- Retaining troughs

The design of a flexible system and the choice of options and technologies can and should be provided through the strategic planning process.

6.3.3 Decentralization and centralization

The flexibility of unconventional urban water systems is often related to decentralized solutions. Decentralization reduces vulnerability by spreading risk. In fact, it is easy to understand the greater risk faced by a city that relies on one or more large wastewater treatment plants compared with a city that operates several natural treatment systems on a small-scale located in various areas.

Moreover, decentralized solutions are often quicker to install and more cost-effective to build and maintain. These considerations are particularly important in the face of changing conditions, which can either facilitate major investments in new treatment facilities or be redundant in water supply infrastructure.

The condominial systems for sewerage systems are the latest innovation in decentralized systems (Mendoza, 1999). These systems have introduced innovations into design criteria, eliminated the maximum distance between two manholes, implemented new devices for the construction of singularities in networks, including pipe inspection and cleaning, terminal boxes and cleaning terminals.

a. The main advantages of condominial sewage:
   - Lower cost of excavation, due to shallow depths of condominial sewers
   - Lower cost of material for condominial sewerage, which is less extensive
   - Lower cost per manhole, fewer conventional manholes required.
   - Increased number of pull boxes to replace traditional manholes
   - Lower cost of household connections because depths are shallower and the length of the connections is shorter.
   - Easier implementation of household connections, even for houses sharing common walls
   - Greater use of regional materials in the construction of condominial sewers and household connections
   - Greater use of unskilled labor
   - It is easier to unclog condominial sewerage and home connections through simple, easy to use equipment.

b. The main advantages of condominial sewage:
   - Greater demand for preliminary, permanent work, including the following: health education and social assistance to involve the community in the construction, operation and maintenance of its condominial sewerage system
   - Possibility that problems may arise over rights of way, expropriation and expansion of built areas.

6.3.4 Structural and nonstructural solutions

Impacts of climate change will be felt transversally in the various elements of the urban water cycle, as well as in all sectors of urban management. Current guidelines for urban water management are often fragmented in regard to the design, construction and operation of the various elements, which are implemented in isolation, with very little coordination with other urban management sectors and institutions.

This fragmented perspective often results in unsustainable practices, as when certain technical choices have unintentional impacts on other parts of the urban system. For example, the construction of reservoirs for the Central District water supply has reduced the baseline ecological flow of the Choluteca River.

A more sustainable approach to water management should include, in addition to the integrated management of the various aspects of the urban water cycle, the coordination of actions with other sectors of urban management, which can help identify synergies and address conflicts. Within the context of climate change, effects are likely to be felt across a variety of sectors and urban services, which is why the integrated approach is particularly valuable for adaptation planning. Moreover, flexible options and technologies may also benefit other urban sectors.

Integrated management can also be achieved through the development of a continuous process, regularly evaluated with current options and designed to meet changing circumstances, through strategic planning.

6.3.5 Solutions designed to achieve better management in the basin where the city is located

Any solution designed to improve water resource management in the basin must be accompanied by the participation of the inhabitants, who may become active members, as supervisors and caretakers of the basin, in exchange for being allowed to undertake normal farming or livestock raising activities within programs to control and manage their activities.

A watershed management plan can and must be developed to include the best practices of resource management, seeking the mutual benefit of both the inhabitants of the basin and the cities that use it, mainly in the form of water to supply the population.

The best actions could be developed and implemented through the Forest Conservation Institute (ICF) through Honduras Forest Management and Sustainable Development, posited since July 2010.

Solutions that may be envisaged within a watershed management plan include the following:

a. Fire control. Burning within the watershed may be permitted, but farmers must be taught control techniques, such as practicing shifts, and the removal and disposal of waste and ash after burning.
b. Tree felling Trees are often felled for firewood, fencing and the construction of rural housing. Since tree felling satisfies some of farmers' needs, there should be a Municipal Government policy to choose the areas where this is allowed and to select the particular trees that may be cut down. In return, farmers must be shown the need to plant three trees for every one cut down. The reason for planting three trees is that at least one of them will germinate.

   This policy should be still valid for operating licenses for timber businessmen, since the refusal of permits forces them to engage in illegal logging, causing enormous damage to the watershed.
c. Family orchards. Families should be allowed to have family orchards, and be trained to prepare composts for making organic mulch.
d. Erosion control and sediment transport. Programs should be developed to lessen deforestation as mechanisms for reducing erosion within the watershed. These programs should include the implementation of public works for the control and management of sediment from erosion.

   Changes in the characteristics of vegetation and soil, due to rising temperatures and high evapotranspiration rates, may change mitigation and infiltration rates, affecting the soil's retention capacity.

6.4 Other variability issues

Cities have populations that require infrastructure to engage in economic activity and create wealth, and are therefore disproportionately affected by the local impacts of climate change. Cities located in coastal areas and/or on the banks of the rivers are particularly vulnerable to rising sea levels and flooding. Cities are also characterized by the predominance of impermeable surfaces, which are less able to absorb increased precipitation and thus, increase the intensity of rainfall runoff (International Water Association, 2011).

As overwhelming population growth occurs in cities, managers of agencies responsible for urban water management face the growing challenge of maintaining a safe, adequate water supply and wastewater services for urban residents. In the case of the Central District, the urban population has a high growth rate, as in other developing countries, exacerbating the problems associated with urban poverty, increasing the size of the sectors of vulnerable population, and exerting additional pressure due to the dwindling supply of resources such as water.

The vulnerability of the urban supply of water, wastewater and storm water systems is strongly affected by the various manifestations of climate change, impacts mainly related to their physical infrastructure and functionality.

6.4.1 Water supply

The water supply has been affected by most of the predicted expressions of climate change, both in terms of water quantity and quality. Flows into rivers, lakes and reservoirs, as well as groundwater, are affected by:

a. The modification of precipitation patterns and rising temperatures, which increase evapotranspiration.
b. Security of supply is directly affected by drought, in a negative sense, as it reduces the flow of rivers and the amount entering reservoirs, lakes and groundwater, and indirectly, for example, by increasing the occurrence of forest fires that destroy the topsoil, thereby significantly reducing the yields of the basin.
c. The seasonality of water supply levels may change in any region and affect the main source of water. The decrease in winter rainfall affects the period for recharging groundwater, lakes and reservoirs.
d. Water quality is a key component of water supply, and adverse changes in this quality affects users, as well as increasing the cost of services. Water quality is affected by flooding,

erosion, which increases turbidity, rising nonpoint pollution, and faulty wastewater treatment plants, with the subsequent bacterial contamination of water. It is also affected by rising temperatures, which have an effect on the chemical and biological characteristics of water bodies, and decreased precipitation, which concentrates pollution. The consequences for certain sources of water have a knock-on effect on others. For example, decreased precipitation and its impact on surface water will result in increased extraction of groundwater and from sources with lower quality water (Bates, Kundzewicz, Wu and Palutikof, 2008).

e. The physical infrastructure of water supply is also adversely affected by floods, direct damage to pipelines and facilities, sedimentation of reservoirs and capacity overloading. Climate change may also reduce the functionality of water purification, for example, by reducing the effectiveness of treatment processes such as chlorination, or causing excess disinfection due to byproduct levels in distribution systems (Zwolsman et al., 2009).

f. Functionality is affected by rising temperatures that encourage the growth of algae that clog the equipment and result in higher spending on treatment to remove the taste and odor linked to the growth of bacterial and fungal growth. Moreover, certain management decisions made in response to climate change events may have consequences for water supply. For example, establishing the capacity of the reservoir as a buffer to absorb flooding may decrease the availability of drinking water.

g. Water supplies are also affected by climate change, altering water demand. Higher temperatures will increase water demand for all consumptive uses -restricting efficiency improvements- and may therefore lead to strong competition for water resources or require an alternative source of water supply. A related point is that in the context of reduced water availability, finding any minimum existing ecological flow requirement will become more challenging and could question the renewal of licenses for drinking water production (Zwolsman et al., 2009)

6.4.2 Wastewater Sewerage Systems

Like the water supply, the integrity and functionality of wastewater treatment infrastructure is affected by climate change. The physical infrastructure of the collection network and wastewater treatment plants, including drains, pipes and tanks, may be damaged by flooding caused by increased rainfall and overflowing rivers, as in the Central District.

Extreme events may challenge the functionality of wastewater treatment plants through the dilution or concentration of the inflow in the case of floods or droughts, respectively.

Functionality is also affected by higher temperatures, which may have positive or negative consequences for wastewater treatment (Bates, Kundzewicz, and Palutik and Wu, 2008). High temperatures with reduced precipitation may lead to more broken pipes due to the drying of the soil, as well as further deterioration of the pipes due to corrosion by hydrogen sulfide accumulation (Zwolsman et al., 2009; Howe, Jones, Maheepala and Rodas, 2005).

Wastewater management may also be indirectly influenced, for example, as happens when temperature increase affects oxygen levels in receiving water bodies, which in turn leads to stricter requirements wastewater treatment in order to stabilize these levels and not endanger ecosystems.

7. Conclusions

Honduras is a privileged country with abundance of water resources which means a good potential that can give relief to the growing demand for drinking water caused by the spread of urbanization.

The study case corresponding to the Capital of Honduras reflects the impact that the pressure of urban development exerts on the exploitation of natural resources, which is strong and relentless on the demand for water to meet this vital health need. The quality and quantity of water available is often exacerbated by the development of industrial and commercial activities that affect and degrade water resources in general, through deforestation, forest fires and wastewater discharges.

The lack of development of water infrastructure by the official provider of water supply in the capital of Honduras, oblige a rationed service with many interruptions by network failures and problems of pressure, being the most the severe the peri-urbans areas and the higher parts of the city where water does not reach due to insufficient of pressure. As a result, access to water service presents conventional solutions that are developing at a slow pace, and non conventional solutions that proliferate as relief measures to the despair of the population to meet their needs, among which are mentioned: tankers, bank public key, free sale "homemade tanks" capture or storage in improvised underground deposits denominated water harvesting, or on the surface of ground like water ponds

There is an enormous social debt to wastewater management, and the greater adverse impact of urbanization is the contamination of water sources due to the free discharge or improper disposal of urban and industrial wastewater, and lack of treatment thereof, contributing to the deterioration of water quality of the potential sources for drinking water

In relation to human health, as well as being a vital factor, water can also be a carrier of disease and death, and, in Honduras both extremes may occur, on one side there is shortage in water supply in urban and rural areas, and, on the other hand, there are floods caused by hurricanes and tropical storms. Both the scarcity and abundance affect the health of Hondurans. According to studies by the UNAH, the leading cause of childhood diarrhoea is the contamination of water and food washed with contaminated water. Due to the lack of potable water to meet the growing demand of the population, especially the lower-income people, water from polluted rivers is being used.

The effects of variability and climate change in Honduras can be observed at both extremes of the hydrological cycle: severe droughts and periods of heavy rain storms, and hurricanes that cause flooding. Its influence on the problems of water supply in the capital of Honduras is notorious, which added to the action of man with frequent burning of forest and deforestation has caused variability on natural resources as they are modified in rainfall patterns, extreme temperature changes, siltation of rivers due to effect of dragging erodible material, and frequent floods

8. Recommendations

In line with the conclusions, the main recommendations are given below:

1. The Honduran government must develop strategies and policies for sustainable development, maximizing its potential in its natural resources. It is necessary to establish policies and strategies oriented towards the rational and sustainable exploitation of its resources, taking into account three important characteristics: 1) It has a very young population (55% are under 25); 2) the population in rural areas is greater, and 3) the female population is larger.
2. The country's development strategy for the basins should be strengthened by allocating the necessary financial resources to promote progress by providing the required infrastructure.
3. SANAA, as the authority responsible for the water supply of the capital of Honduras, should undertake the necessary steps to harness the available supply of water resources, applying the well-known principle that the cheapest source is the nearest one.

4. The municipal authority must update the Land Use Plan of the capital to avoid urban sprawl to reserve areas and, as part of planning and governance, could typify urban developments, accompanying them with management plans for green environments. Thus, in the case of industrial development zones, the Taxation Plan must establish the need for wastewater treatment.
5. SANAA should expand water service coverage, particularly since the Honduran government is a signatory to the Millennium Development Goals, whose seventh goal is to: Guarantee the protection of the environment, by incorporating the principles of sustainable development into country policies and programs and reversing the loss of environmental resources; and halve the proportion of people without sustainable access to safe drinking water and basic sanitation by 2015.
6. SANAA must develop a strategic plan to build the new dams proposed, based on the Master Drinking Water Plan, whose construction has been delayed, mainly due to financial aspects, which in turn, are related to the scale of the public works.
7. SANAA must develop a strategic plan to build the extension of water infrastructure, based on the Master Drinking Water Plan. Expanding the water supply will require the construction of new water storage tanks and new water lines and distribution networks.
8. Greater support must be given to the Water Boards through technical assistance in administrative and technical fields, since they have endured for over 30 years. The fact that they have continued to grow since then has shown that they are in fact an excellent alternative, particularly for periurban areas and developing neighborhoods in inhospitable, scattered settings where the water authority has failed to deliver regular service.
9. The Framework Law on Water and Sanitation and its Regulations must be updated and fully enforced. Water supply systems have yet to be decentralized, including the one in the capital of Honduras. Likewise, COMAS and LSCUs must be set up in all municipalities of the country, particularly in the capital of Honduras, so that the law achieves its main objectives.
10. Emphasis must be placed on setting up COMAS and USCL in each community, since it is through these instances that the Framework Law on Water and Sanitation proposes transparency mechanisms and citizen participation.
11. The three models permitted by the Framework Law on Water and Sanitation must be established in order to determine which model has the best fit, adaptability and flexibility for communities, according to the geographical area of the basin to which they belong and considering socio-cultural aspects.
12. It is essential for all the actors involved in water system management, including SANAA, the Water Boards and private providers, to develop solidarity programs to promote access to safe drinking water, especially for people who live in scattered areas and those living in areas where water is available. And for residents for whom access to water is quite distant, they must seek viable options, including low-cost solutions, such as: harvesting rainwater and storing it in underground deposits and extraction by manual pumping or buckets.
13. Greater control must be exercised, particularly of the quality of the water distributed through private tankers, free water sales, bottled water and generally any type of supplier, to prevent the population's desperation to have access to water for their use and consumption from leading to extreme cases of epidemics of waterborne diseases by consuming water of dubious quality. This desperation also exacerbates extreme poverty, since the population purchases water at high prices.
14. The water authorities must adjust water sales prices, setting higher prices for consumption ranges above the base quota of 20 m^3, so that consumers upstream of the basic fee pay the actual cost of production. This cost should be such that it discourages large users from use treated water for washing vehicles, watering gardens or walls and so on.
15. Wastewater treatment plants must be built to eliminate environmental pollution through direct discharges of wastewater into rivers.

16. In the particular case of the capital of Honduras, in order to eliminate multiple discharges into the streams and rivers that cross the city, a program of sanitary additions to the general collection system should be developed for the safe handling of this wastewater and the elimination of the odors that pollute the air in the capital.
17. The case of the city of San Pedro Sula should be analyzed and its model replicated in the capital of Honduras, since the public health level in Tegucigalpa has the highest rates of morbidity and mortality from waterborne diseases, proving that “water is health” and “health is well-being.”
18. It is necessary to update the Master Sewer Plan for and the Project to Channel the Tegucigalpa and Comayagüela Rivers, since both projects provide solutions for developing sewer and storm drain systems until 2020. They should take advantage of the irregular geomorphology, which has created abundant micro-watersheds. A micro-drainage system integrated in a macro-system would be a viable and economical technical choice. This technical solution is fully compatible with the wastewater system and should be accompanied by wastewater treatment plants.
19. A supply of drinking water that is safe for human consumption must be ensured in order to maintain low morbidity rates from diarrhea, and if possible, reduce them further.
20. The recommendation for morbidity also applies to mortality rates from diarrhea, in other words, a drinking water supply that is completely safe for human consumption must be guaranteed.
21. It is essential to raise awareness of the variability and impact of climate change on water resources, by defining strategies and policies for the rational use of resources; adopting new technical criteria for adapting urban water systems, sewerage and storm sewers to climate change, and giving priority to water by declaring it a social good and an important factor in alleviating poverty.
22. The current water management infrastructure must be reviewed, since it requires immediate, practical solutions to address changing circumstances, since climate change projections show that variability may change capacity requirements by region or season. The choice of sustainable systems for water management in urban areas designed to address variable and unpredictable conditions would seem to be the best answer for planning new urban solutions and achieving the implementation of flexible, often decentralized options and technologies that take into account a range of future scenarios.

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10. Acronyms

AMDC:	Central District Mayor's Office
WB:	World Bank
COMAS:	Municipal Water Commission
CONASA:	National Water and Sanitation Council
BOD5:	Biological Oxygen Demand (after 5 days)
EPHPM:	Permanent Multi-Purpose Household Survey
EPS-APS:	Drinking Water and Sanitation Service Provider
ERSAPS:	Drinking Water and Sanitation Service Regulator
INE:	National Institute of Statistics
JAA:	Water Administration Board
Km:	Kilometer
KOICA:	Korea International Cooperation Agency
LPS:	Liters per second
WTP:	Wastewater Treatment Plant
SANAA:	National Autonomous Water and Sewerage Service
SEFIN:	Secretariat of Finance
LSCU:	Local Supervision and Control Unit