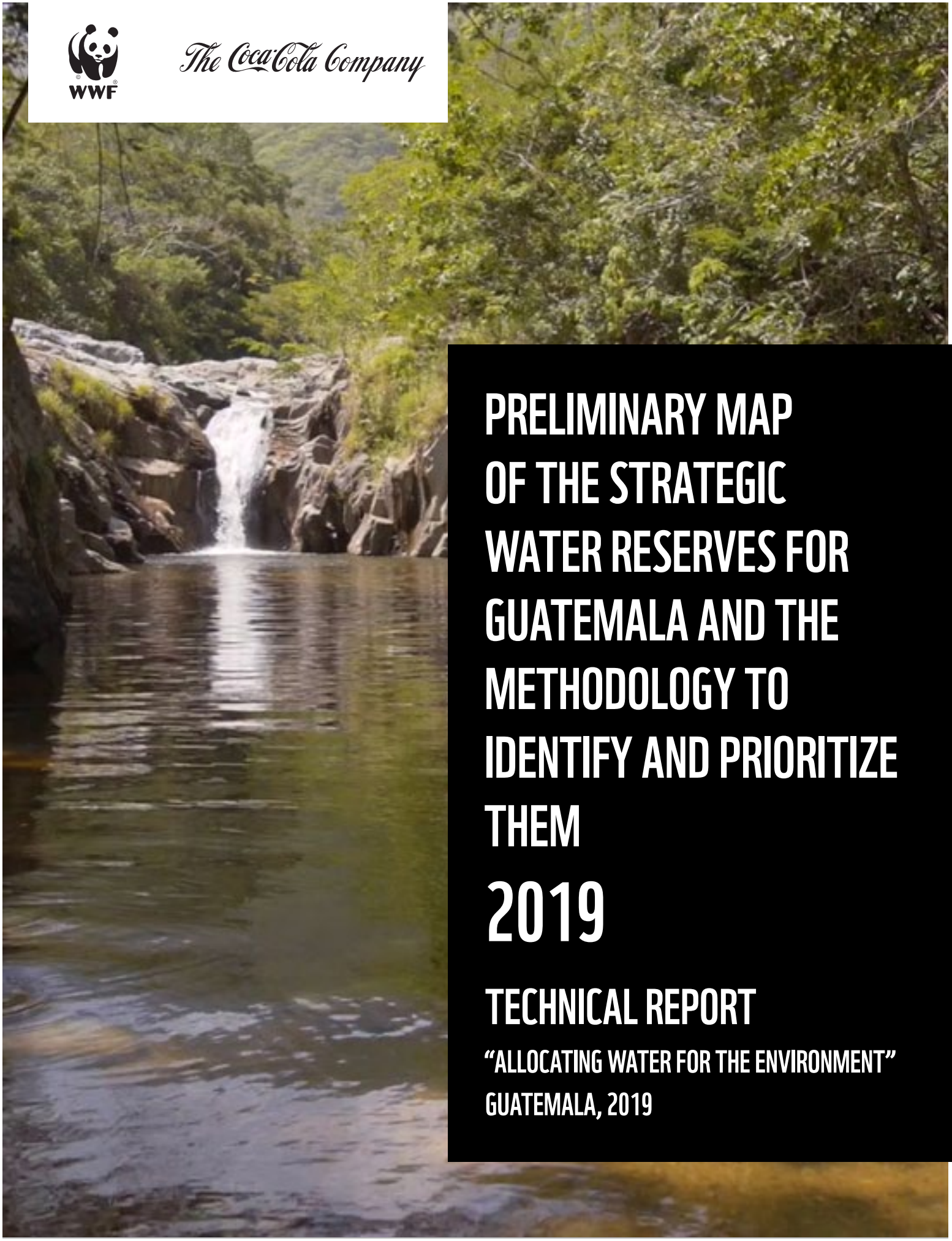

PRELIMINARY MAP OF THE STRATEGIC WATER RESERVES FOR GUATEMALA AND THE METHODOLOGY TO IDENTIFY AND PRIORITIZE THEM

2019

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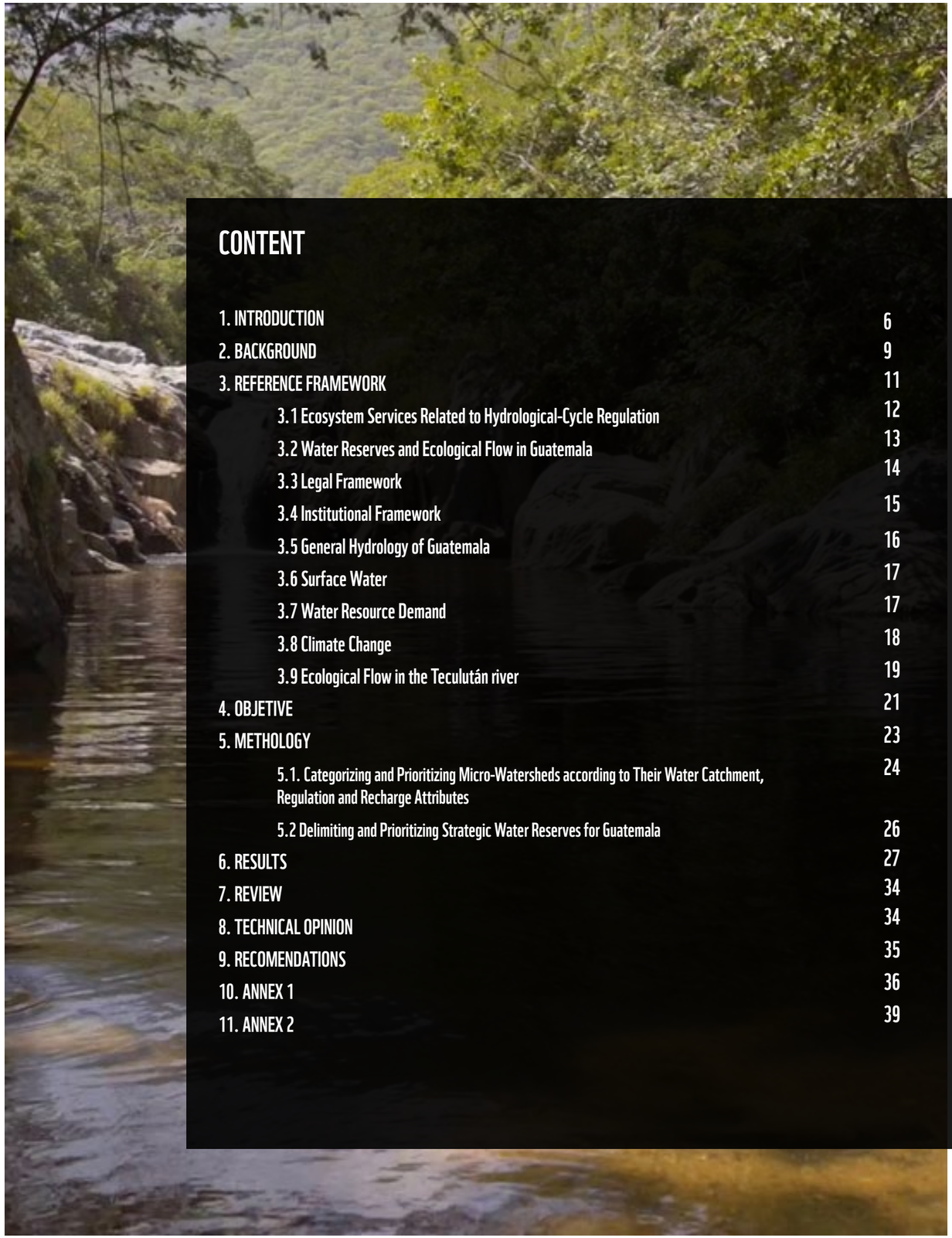

CONTENT

ACRONYMS

CONAP	National Protected Area Council
IGN	National Geographic Institute
INAB	National Institute of Forests
INSIVUMEH	National Institute of Seismology, Vulcanology and Hydrology
MAGA	Ministry of Agriculture, Livestock and Food
MARN	Ministry of the Environment and Natural Resources
SEGEPLAN	The Presidential Secretariat for Planning and Programming
SIG-MAGA	Geographic Information System of the Ministry of Agriculture, Livestock and Food
SIGAP	Guatemalan Protected Areas System
URL-IARNA	Guatemalan Institute of Agriculture, Natural Resources and Environment under the Rafael Landívar University
WMO	World Meteorological Organization
WWF	World Wildlife Fund

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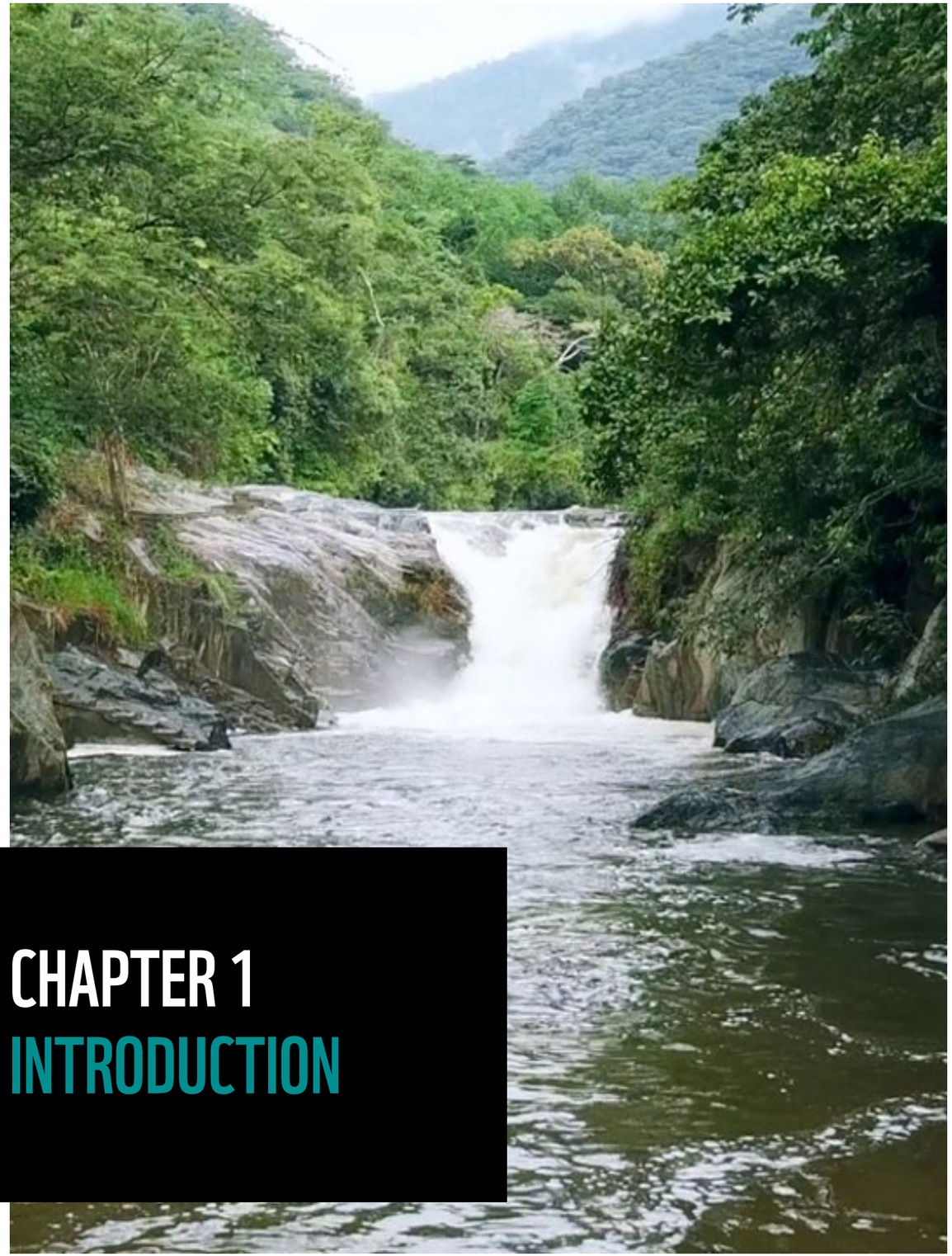


CHAPTER 1
INTRODUCTION

According to the World Meteorological Organization (WMO), the scarcity and excessive use of freshwater poses a growing and serious threat to sustainable development and environmental protection. Improving the management of water resources and soils, so that they are used more effectively, will contribute to the health and development of humankind and the ecosystems that depend on water.

Rainfall is the most important source of water in groundwater recharge areas (aquifers); however, there are many productive activities that hinder water infiltration and, as a result, aquifer levels are significantly reduced. Thus the importance of guaranteeing the hydrological cycle in strategic sites known as water reserves.

The traditional approach of any efforts related to water-resource management has focused on water quality and quantity. However, environmental connectivity and the natural regime of water resources, as a long-term vision, have never been discussed.

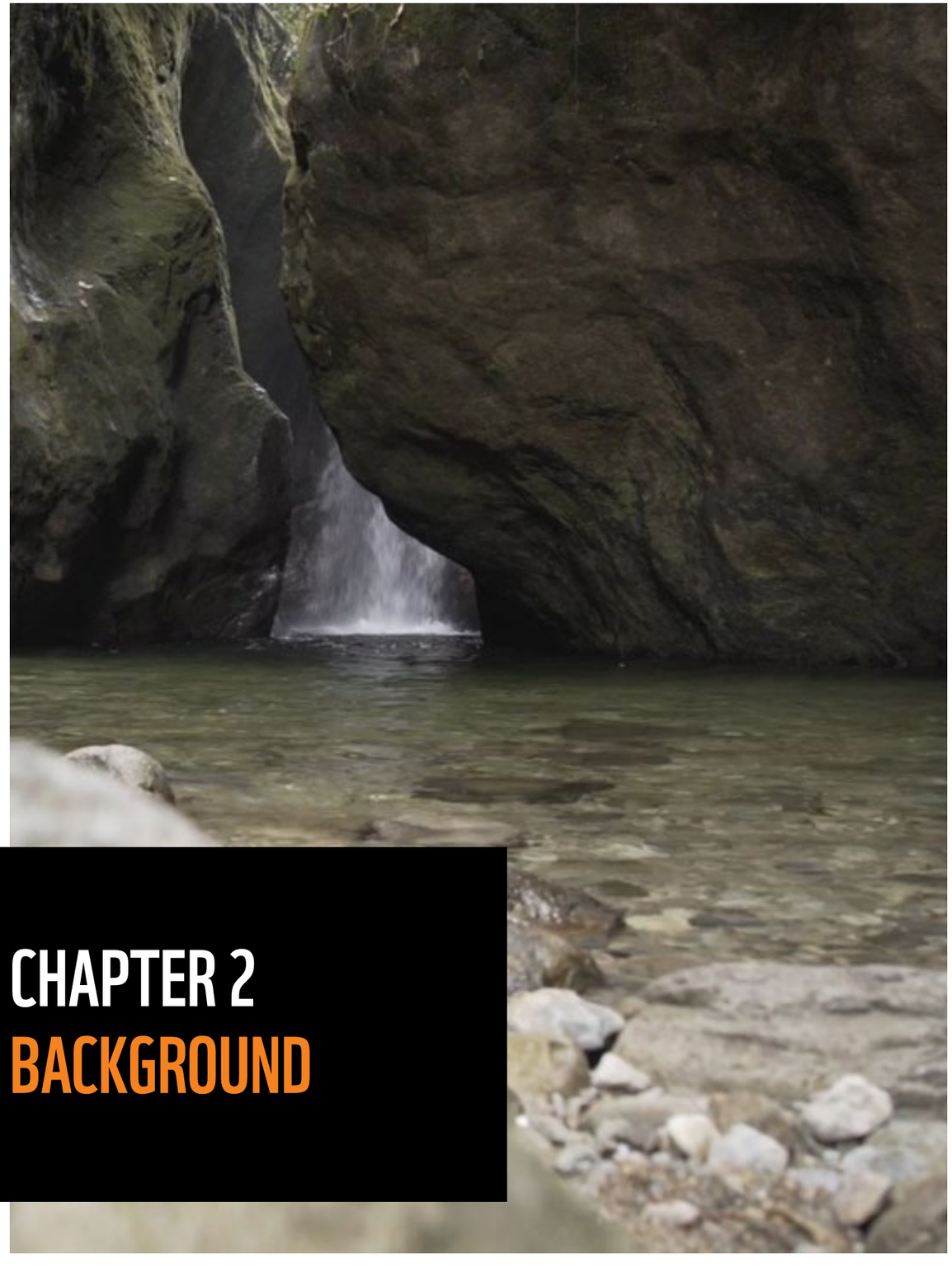
This is why it is so important to guarantee the hydrological cycle by allocating water to the environment in those sites that are essential for water catchment, regulation, and recharge, as well as for water connectivity in the Guatemalan territory. That is, to consider the ecosystem and its natural water flow regime as a user that requires a minimum amount of water flow to ensure continuity of its water ecosystem services that, in turn, are very important to biological diversity and wealth and also have considerable ecological value.

At present, Guatemala does not have a water-regulating law that ensures the availability of adequate quantity and quality of water or that mandates the protection of ecosystems and the natural resources associated with the natural regime of water resources. Consequently, there is an accelerated deterioration of the quality and the natural availability of this resource, as well as evident ungovernability and high levels of conflict linked to its access and use. Nevertheless, at the beginning of 2021, the Ministry of the Environment and Natural Resources published Government Agreement No. 18-2021 creating the Vice-Ministry of Water, and Government Agreement No. 19-2021 establishing the provisions to promote the protection and conservation of watersheds in the national territory. To this end,

WWF is providing support to the “Thematic Group to Support the Water Ecosystem Service in Guatemala Associated with Forests”.

To perform this study, a methodology that identifies water reserves by assessing hydrological attributes such as water catchment, regulation and recharge was used, in addition to conservation objects in order to prioritize strategic sites, with the aim of maintaining the hydrological cycle and ecosystem services by allocating water for the environment (ecological flow). These objects of conservation include Ramsar[1] sites. Protected areas are also considered objects of conservation, and they are those areas defined geographically and designated or regulated and managed to conserve them with the aim of achieving sustainable management options.

[1] Ramsar refers to the inter-governmental treaty that establishes the framework for the conservation and rational use of wetlands and their resources.



CHAPTER 2
BACKGROUND

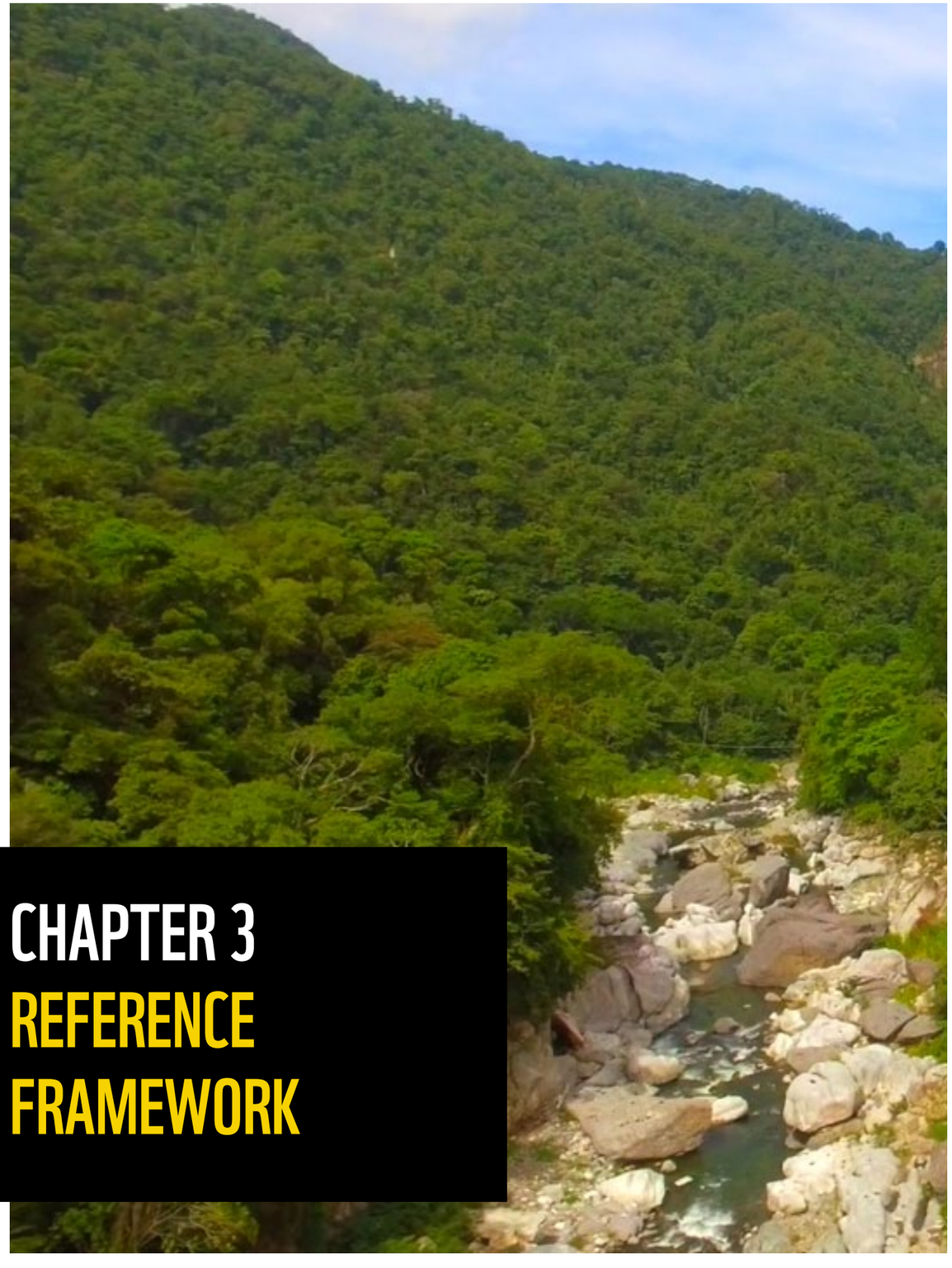
Climate variability has generated changes in river flows and in water availability. Due to the effects of climate change on water resources, it is extremely important to develop national strategies to ensure water availability through the continued functions of the hydrological cycle and the protection of the natural water-resource regime.

In Guatemala, there is scarce information on water flows. In 1998, the Presidential Secretariat for Planning and Programming (SEGEPLAN) quantified water resources, estimating an annual volume of 98,000 million cubic meters (m3), and in 2015, the Guatemalan Institute of Agriculture, Natural Resources and Environment of the Rafael Landivar University (URL – IARNA) estimated an annual water availability of 110,340 million cubic meters per year.

In 2016, World Wildlife Fund (WWF) Guatemala / Mesoamerica performed a reference study “Identifying and Prioritizing Strategic Water Reserves for Guatemala”, which assessed water catchment, regulation, and recharge attributes. 958 micro-watersheds that are the most important for the country were identified. They constitute 28% of the national territory. These hydrological units make significant contributions according to their biophysical characteristics, such as climate, soils, topography, erosion, etc. and foster availability of water resources, thus they are considered potential water reserves for Guatemala.

Based on the above, a comprehensive analysis was performed to prioritize strategic water reserves for Guatemala. The objects of conservation, which include biodiversity and ecosystem connectivity were incorporated into this analysis, based on hydrological functions (water catchment, regulation, and recharge).

The methodology and the “Preliminary Map of the Strategic Water Reserves for Guatemala” were validated at technical meetings with the following government institutions linked to the topics: The Ministry of the Environment and Natural Resources (MARN), the National Institute of Seismology, Vulcanology and Hydrology (INSIVUMEH), the National Institute of Forests (INAB), the National Protected Area Council (CONAP), and the National Geographic Institute (IGN).



CHAPTER 3
REFERENCE FRAMEWORK

3.1. Ecosystem Services Related to Hydrological-Cycle Regulation

The hydrological services from the watershed system, which includes natural and semi-natural ecosystems, stem from the main functions: water catchment, regulation, and recharge.

Catchment: The amount of rainfall that is available.

Regulation: The capacity of the micro-watershed system (land slope) to maintain balanced water flow. It is considered a variable to determine the land use capacity[2]. It depends on the forest cover resulting from appropriate land use.

Water recharge: The process deriving from infiltration as a result of regulation. It depends on forest cover and land slope.

Water recharge depends on catchment and hydrological regulation services, keeping in mind that they depend on the geological characteristics and land use. Thus, conserving soils through their adequate use, according to their capacity of use, ensures hydrological cycle processes, such as runoff (superficial water) and water recharge (groundwater). The factors that determine the capacity of the watershed system to buffer flow peaks are soil cover, topography, soils, and geology. Increasingly, however, the lack of capacity of the system is associated with poor land cover management and increasing climate variability.

In this regard, rainfall is considered an inflow into the system (country), and the main outflows of the water system are water regulation ecosystem services, such as flash floods and long-cycle water flow. Flashfloods refer to the rainfall occurring mainly during extreme events. This is high-intensity rainfall that runs off very fast (increase in the flow). Long-cycle rainfall, on the other hand, promotes water recharge because rains are less intense and they allow infiltration that saturates soils, thus resulting in water recharge.

[2] Land-use capacity: The determination, in physical terms, of how much a land unit can bear in terms of specific uses or coverages and/or treatments. Generally it is based on the principle of maximum intensity of bearable use without causing the physical deterioration of soils. (Klingebield and Montgomery, 1961).

The benefits of ecosystem water catchment and regulation services are that they diminish weather events resulting from global warming and local climate variability. Evidently, this should be analyzed in terms of specific watershed factors.

3.2. Water Reserves and Ecological Flow in Guatemala

Water reserves are critical sites for water catchment, regulation, and recharge, as well as for ecosystem connectivity. They are essential to social, economic, and environmental systems given the quantity and quality of water that they incorporate into local and regional hydrological systems (watersheds). They are crucial to supplying priority ecosystems, such as protected areas and Ramsar sites, populations, and economic activities, as well as diminishing the risks linked to extreme weather events derived from climate change.

Water reserves in Guatemala are strategic for national short-, medium-, and long-term water security, since they are based on water allocation (ecological flow) to ensure ecological services as well as water sources. Ecological flows are the water quality and quantity and the flow regimes, or the variations in the levels of water required for aquatic ecosystems to function. They are considered a water-management tool that seeks to establish a regime that will sustain ecosystems, water uses, and storage needs throughout the year. This means that, in addition to providing water for domestic, livestock, and agricultural uses, it is possible to maintain flows arising from runoff to conserve freshwater aquatic ecosystems.

3.3. Legal Framework

In Guatemala there have been isolated efforts aimed at sustainable management of the forests in areas that are important to hydrological regulation. These initiatives are mostly norms issued by environmental and natural-resource sectors. The Guatemalan legal framework pertaining to strategic water reserves for Guatemala is constituted by general norms linked directly or indirectly to the topic. These norms focus on the rational use of resources, conservation, ecological balance, protecting and improving biodiversity and natural systems, which are coherent with the water reserve initiative to ensure the essential ecological processes related to water recharge zones, critical wetlands, and ecological flows.

To date, MARN and SEGEPLAN are reviewing the Integrated Water Resource Management Policy, which will seek to ensure that water reserves gain importance in water security, forest cover conservation, and the efforts to continue with forest incentives in very high and high water recharge areas.

Within the international framework, Guatemala has ratified the Convention on Wetlands of International Importance (Ramsar) by means of which the State assumes an obligation to protect wetlands and to manage water aiming to maintain ecosystem balance. There are seven Ramsar sites in Guatemala: the Laguna del Tigre National Park, the Laguna Yaxhá Nakum Naranjo National Park, the Lachúa Ecoregion, Punta de Manabique, the Bocas del Polochic Wildlife Refuge, Manchón Guamuchal, and the Río Sarstún Multiple-Use Area. Guatemala has also ratified other agreements, such as the Convention on Biological Diversity and the Convention to Combat Desertification and Drought, in which the State acknowledges the need to protect and guarantee the conservation of ecosystems that are important for biodiversity and natural resources, as well as the ecosystem services for society and the environment.

Recently, the Ministry of the Environment and Natural Resources published Government Agreement No. 18-2021, which creates the Vice-Ministry of Water, within the framework of Article 97 o the Political Constitution, whose norms guarantee that “there is rational use and exploitation of fauna, flora, land and water, preventing their depredation” and the “Law on the Protection and Improvement of the Environment”, which establishes that “the Government of Guatemala will guarantee an amount of water for its use by people and for other activities in which its use is essential.”

In addition, Government Agreement 19-2021 was published, establishing provisions to promote protection and conservation of watersheds in the national territory. With this aim in mind, a watershed diagnosis has been planned, to be performed by means on a five-year inventory. The purpose of this effort is to implement strategic conservation and protection actions. In addition, it includes the creation of multi-sectoral technical groups to address the issue. These efforts represent an environmental and natural-resource conservation, protection, sustainability, and improvement commitment by the Ministry of the Environment, which are also its objectives. These legislative tools strengthen the institutional framework and prioritize the water issue by means of public-policy management.

For other references on the norms relating to natural-environment and natural-resource conservation and protection linked to water resources in Guatemala, see Annex 1, Legal Framework, at the end of this document.

3.4. Institutional Framework

The following government entities have competencies linked to strategic water reserves for Guatemala. The nature of their participation is detailed in Annex 2. Details of the Institutional Framework.

Ministry of the Environment and Natural Resources (MARN)	National Protected Area Council (CONAP)
National Institute of Seismology, Vulcanology and Hydrology (INSIVUMEH)	Ministry of Agriculture, Livestock and Food (MAGA)
National Institute of Forests (INAB)	National Geographic Institute (IGN)

3.5. General Hydrology of Guatemala

According to INSIVUMEH, the territory of the Republic of Guatemala is divided into three major river slopes. They are named according to the points where the rivers that cross or originate in the national territory finally flow: The Pacific river slope, the Caribbean river slope (Atlantic or Caribbean Sea) and the Gulf of Mexico river slope. They include 38 watersheds, 314 sub-watersheds, and 2,391 micro-watersheds (Table 1):

Table 1. General Data on the Micro-Watersheds of Guatemala.

River Slopes	Area (ha)	%	Number of micro-watersheds	Average Size (ha)	Maximum Area (ha)	Minimum Area (ha)
Caribbean	3,342,546	31	742	4,505	114,085	3.6
Gulf of Mexico	5,077,339	47	769	6,603	315,601	2.8
Pacific	2,407,687	22	880	2,736	124,341	2.5
Overall total	10,827,572	100	2,391	4,528	315,601	2.5

Even though there are considerable differences in the sizes of micro-watersheds, they can be considered as an adequate framework to prioritize water reserves and as territorial management units.

Water resources are abundant in Guatemala, but this varies according to the region of the country and the time of year (dry or rainy), so that water is not always available where it is most needed or when it is most required. Consequently, the crisis associated with its availability and access will increase in some of Guatemala's regions. Therefore, delimitation, management, and conservation of ecosystems that are important to hydrological functions (catchment, regulation, and recharge) are vital and should be promoted in institutional environmental agendas.

3.6. Natural Water Supply

3.6.1. Surface Water

Overall, Guatemala has from 1,769 to 3,190 cubic meters per second (m3/s) of surface runoff, which constitute from 55.6 to 100.6 billion m3/year. It is concentrated in the rainy season that lasts six or eight months, depending on the region.

3.6.1. Groundwater

According to the hydric balance developed by INSIVUMEH, it is estimated that the volume of groundwater in Guatemala is 33,699 million cubic meters. The floodplains, valleys and lowlands of Guatemala constitute 50% of the country, but they contain approximately 70% of the volume of available groundwater. However, groundwater availability is extremely variable.

3.7. Water Resource Demand

Table 2 shows the estimated water demand (in millions of cubic meters of water) in Guatemala, according to economic activities and consumption. Table 3 shows the national water balance by river slopes.

Table 2. Distribution of Water Use according to the Main Economic Activities and Consumption (2006-2010 period) in Guatemala, Expressed in Millions of Cubic Meters.

Economic Activities and Consumption	Year				
	2006	2007	2008	2009	2010
Agriculture, animal husbandry, hunting and forestry	5,042.00	5,490.10	6,003.62	6,252.08	6,496.56
Fishing	427.06	535.24	527.52	511.9	514.62
Mines and quarries	6.13	6.93	6.22	6.34	6.19
Manufacturing industries (includes agroindustries)	7,473.39	8,185.24	8,296.74	7,604.04	7,643.17
Electric power, gas, and water supply	4,765.13	5,184.56	5,516.04	5,110.16	5,057.33
Construction	93.17	104.36	102.94	87.29	76.26
Wholesale and retail business	51.33	44.36	44.94	47.27	48.22
Services	52.33	51.71	59.30	68.16	69.85
Households	422.93	433.51	444.35	455.45	461.68
Total	**18,333.48**	**20,036.00**	**21,001.66**	**20,142.69**	**20,373.88**

Source: Developed by the authors based on IARNA-URL (2011).

Table 3. National Water Balance by River Slope (IARNA-URL, 2015)

River Slope	Availability		Consumption		Balance		Consumption / Availability	
	Actual	2020	Actual	2020	Actual	2020	Actual	2020
Pacific	31,374	27,275	11,133	12,939	20,041	14,336	0.36	0.47
Gulf of Mexico	48,725	42,109	5,720	6,917	43,005	35,195	0.12	0.16
Caribbean	30,441	27,161	8,026	9,185	22,415	17,976	0.26	0.34
Total	110,340	96,545	24,879	29,041	85,461	67,504	0.22	0.30

3.8. Climate Change

It is expected that by 2025, the situation will give rise to conflicts during the low-water season[3], especially in the Pacific river slope, since there will be a water shortage reaching 301 to 490 million cubic meters in the driest month of the year. The Caribbean watershed will also go through a moderately difficult situation, since 88.2% of the water available in this watershed will be used for consumption and electric-power generation in the driest month of the year. The situation in the Gulf of Mexico river slope will be manageable, since the demands for various uses will constitute approximately 25% of the water supply.

[3] The low-water season is the period in which currents or flows are at their lowest level, in Guatemala this occurs specifically at the end of the dry season (March and April, and sometimes until May).

3.9. Ecological Flow in the Teculután river

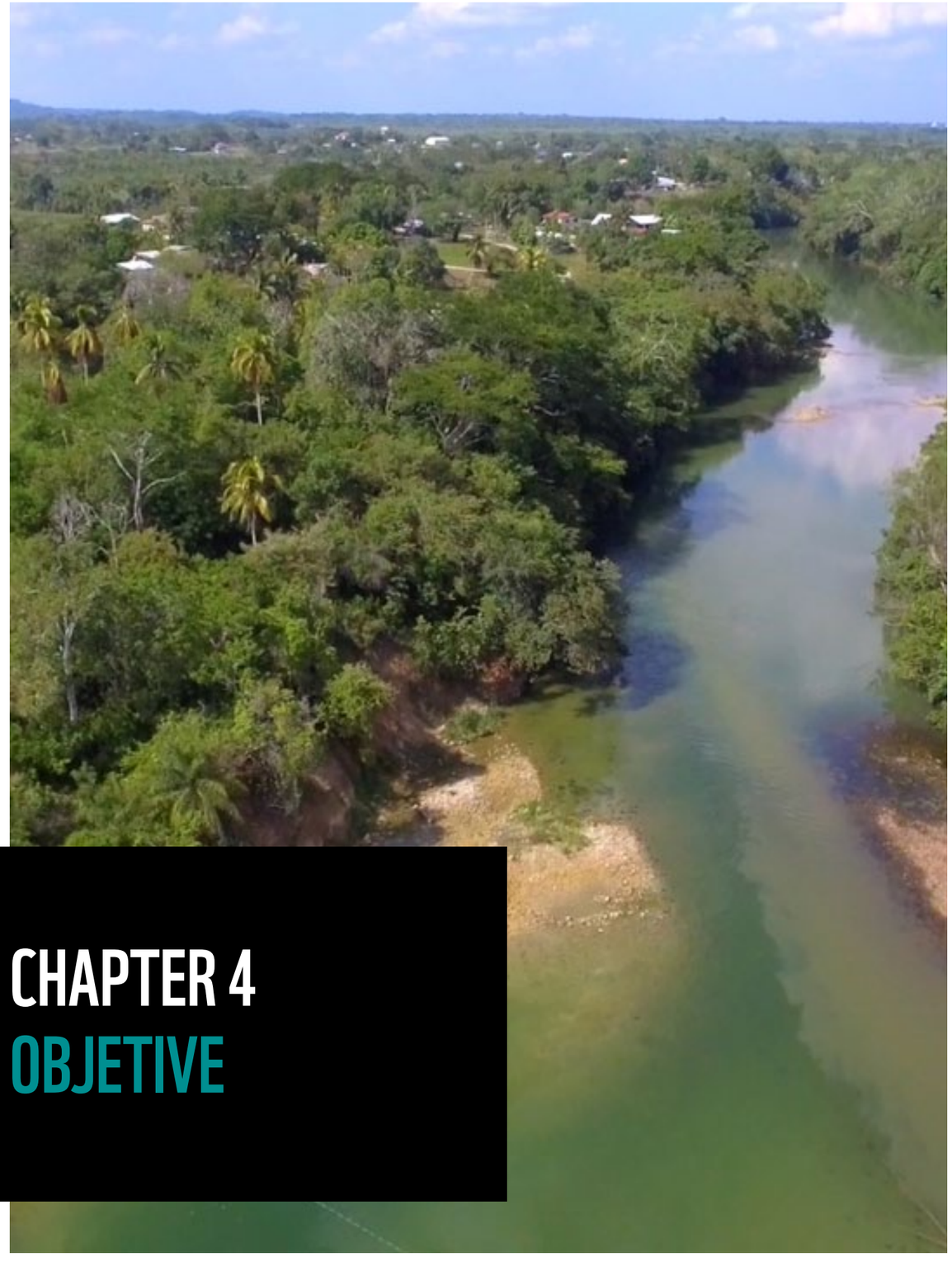
In 2017, WWF Guatemala/Mesoamerica, with support from WWF Mexico, performed a direct estimation of the ecological flow of the Teculután river. It estimated 1,872 liters per second (l/s) (environmental objective, with very high ecological importance and low pressure from use) as the maximum limit, and 603 l/s (environmental objective, with low ecological importance and very high pressure from use) as the minimum limit, according to the values in Tables 4 and 5. This 1,872 l/s ecological flow represents an annual volume of 55.8 million of cubic meters in an expanse of 20,033 hectares, which is essential to conserve biodiversity, the natural water resource regime, ecosystem connectivity, and associated ecosystems in the Teculután river watershed. The water in the Teculután river originates in the Reserva de Biósfera Sierra de las Minas protected area and it is used by people, agriculture, and livestock.

Table 4. Matrix of Environmental Objectives

ECOLOGICAL IMPORTANCE				
VERY HIGH	A	A	B	C
HIGH	A	B	C	D
MEDIUM	B	C	C	D
LOW	B	C	D	D
	LOW	MEDIUM	HIGH	VERY HIGH
	PRESSURE FROM USE			

Table 5. Ecological Flows according to the Environmental Objective

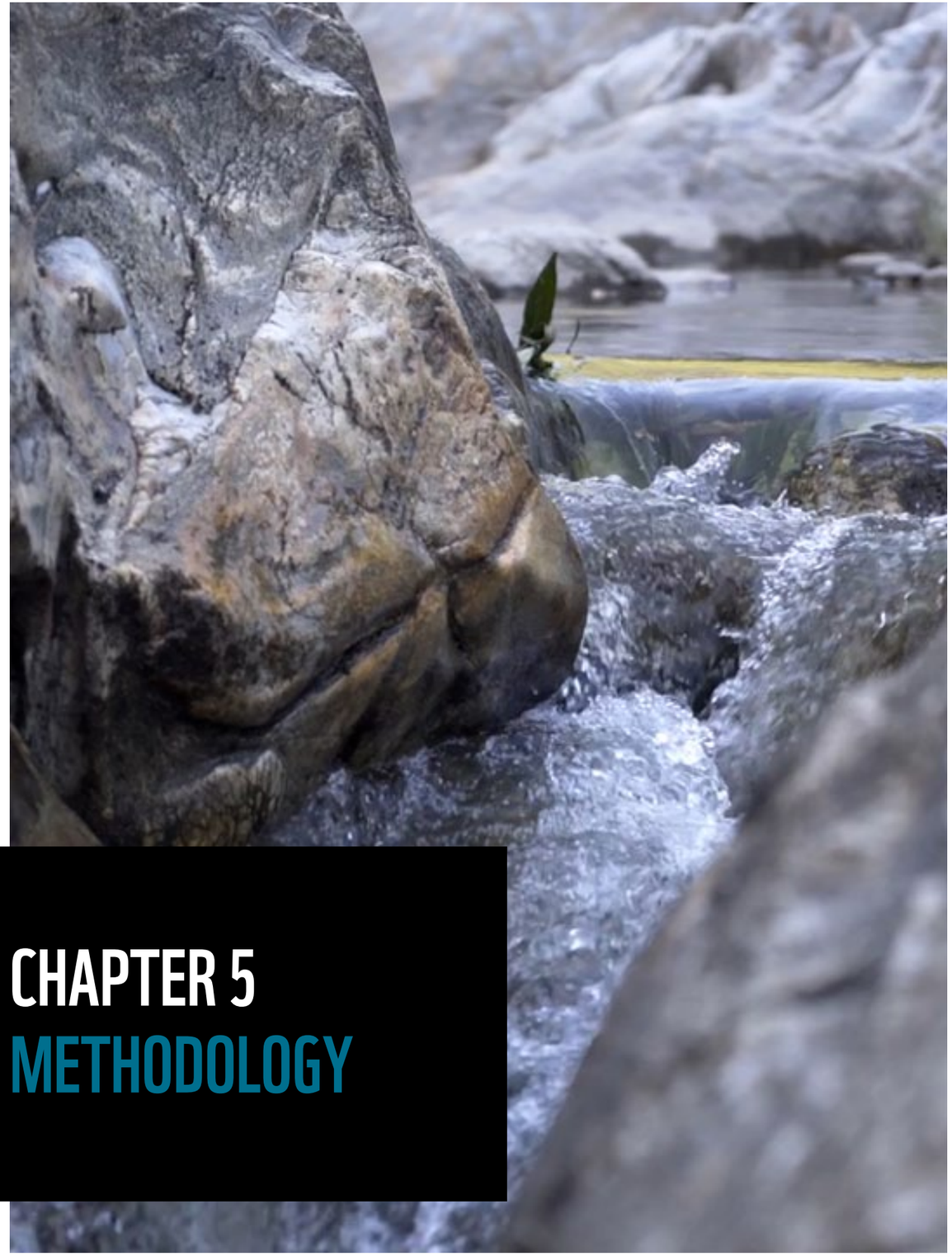
hm^3	ENVIRONMENTAL OBJECTIVE			
	A	B	C	D
TOTAL	105.8	81.0	69.9	60.0
% MAR Mean Annual Runoff	55.8	42.8	36.9	31.7
Flows m^3/s	1.872	1.099	0.818	0.603



CHAPTER 4
OBJETIVE

The general objective is to establish the methodology and the technical basis for strategic water reserves in Guatemala.

Additionally, consideration is being given to determining the attributes needed to identify and prioritize important territorial units for water catchment, regulation, and recharge; biodiversity, and ecosystem connectivity at the micro-watershed scale, all of which are basic for water management in Guatemala. In addition, the preliminary map of the strategic water reserves for Guatemala will be presented.



CHAPTER 5
METHODOLOGY

5.1. Categorizing and Prioritizing Micro-Watersheds according to Their Water Catchment, Regulation and Recharge Attributes.

Relevant information was gathered and updated to define the biophysical framework of water resources in Guatemala, based on secondary geographic information and basic official cartographic information, seeking to identify the important sites for water catchment, regulation, and recharge.

The main sources of information were publications by the Rafael Landívar and San Carlos de Guatemala universities, the national climate database of the National Institute for Seismology, Vulcanology, Meteorology and Hydrology (INSIVUMEH) and the database of the laboratory at the Geographic Information System of the Ministry of Agriculture, Livestock and Food (SIG-MAGA), and other institutional laboratories. Cartographic and thematic databases and the information analyses relevant to watershed delimitation in Guatemala were also consulted.

For the purpose of strategic water reserves in Guatemala, micro-watershed is defined as the smallest water unit, delimited by an imaginary dividing watershed line or watershed divide and a point of drainage. It is noted for the accumulation of temporary or permanent water currents. In the watershed map developed by SIG-MAGA, they are classified as Level 8.

The methodology to define strategic water reserves for Guatemala is based on analyzing three hydrological components, in addition to the conservation component. Other factors linked to each component are also included (Table 3):

1. CATCHMENT	
BASIS FOR ANALYSIS	It refers to average annual precipitation that is greater or equal to 1,500 mm at the micro-watershed level. It is important to consider that this inflow of rainfall is absorbed by the soil (infiltration) and the water table (water recharge) according to the use of the soils and the vegetable cover, which further this process. This constitutes the long-cycle water flow.
FACTOR 1.1.	Determining the main water catchment zones
	To delimit the main water catchment zones and the availability of natural water, the average annual rainfall (AAR) was obtained. Those areas where the average annual rainfall is greater than 1,500 mm are very important for water reserves.
2. POTENTIAL WATER RECHARGE	
BASIS FOR ANALYSIS	It refers to micro-watersheds in which 90% of the area has an annual water layer[4] that is equal to or greater than 300 mm of water recharge.
FACTOR 2.1.	Classification of the territory according to the water-recharge capacity of soils
	It is based on water recharge, which in turn depends on the texture of the soil and the average annual rainfall. High water recharge areas are those that favor infiltration in more than 90% of their extension and where the average annual water recharge values are greater than or equal to 300 mm/year.
3. FLASH FLOW REGULATION	
BASIS FOR ANALYSIS	Land slope was analyzed. To that end, it is important to consider territories with a slope equal to or greater than 32%, which should be used for forest cover (particularly forests)
FACTOR 3.1.	Delimiting critical zones to maintain water-regulation processes
	The main factor determining the physical capacity of the land for water regulation is superficial slope. Micro-watersheds with a slope greater than or equal to 32% and with 25% of their extension having these slope characteristics have been defined as critical for water regulation.

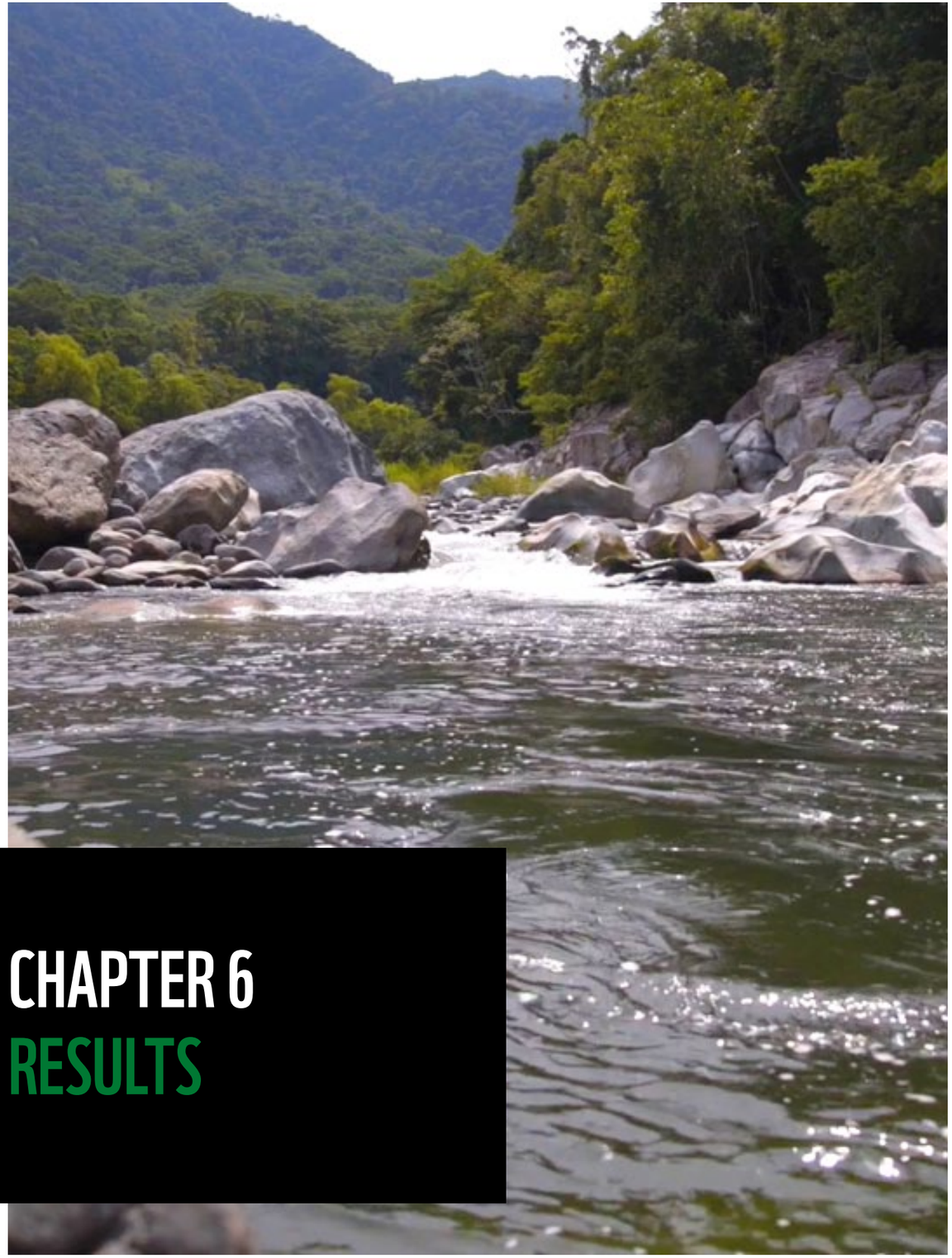
4. CONSERVATION AND CONNECTIVITY	
BASIS FOR ANALYSIS	It was based on the protected areas in the Guatemalan Protected Areas System (SIGAP) and Ramsar sites.
FACTOR 4.1.	Environmental management relating to conservation and natural water flow.
	These protected areas have the requirements needed to be considered as the main sites for water regulation due to their contribution to biodiversity and to conservation of Guatemala's national heritage and that of the region.

5.2. Delimiting and Prioritizing Strategic Water Reserves for Guatemala

To delimit water reserves in Guatemala, several aspects were considered: a) that they constitute water response territorial units, such as watersheds; b) that their field delimitation was feasible and that its size was considered as technically adequate for management, and c) that there was reliable –preferably official– information on it. Another attribute to establish a site as a priority 1 water reserve was that the site be classified as a protected area and Ramsar site.

Based on the above, the Guatemala's Watershed Map, developed and published by MAGA was used. Level 8 watersheds, commonly known as micro-watersheds, were defined as the unit for analysis. There are 2,391 of them and they measure an average of 4,600 hectares. It is important to mention that it was determined that potential water reserves for Guatemala are those micro-watersheds defined as medium or high priorities.

[4] Water layer: depth of the water whose volume covers a level surface, generally expressed in millimeters (mm). m).



CHAPTER 6
RESULTS

Figure 1 shows the "Intermediate Map of Potential Water Reserves", which is the result of overlaying factors 1.1, 2.1, and 3.1 and of the first analysis of micro-watershed (Level 8) attributes. The high-priority category includes those territories in blue that have the three attributes (water catchment, recharge, and regulation) and the medium-priority category includes micro-watersheds in light blue that only comply with two of the three attributes. These micro-watersheds are located in the western region (volcanic chain), the northwestern region (Sierra de los Cuchumatanes), the eastern region (Mataquescuintla mountain), the northern region (Sierra del Chuacús) and the northeastern region (the Sierra de las Minas and Sierra Yalijux system, as well as the lower portion of Izabal, corresponding to the Sarstún and Río Dulce rivers).

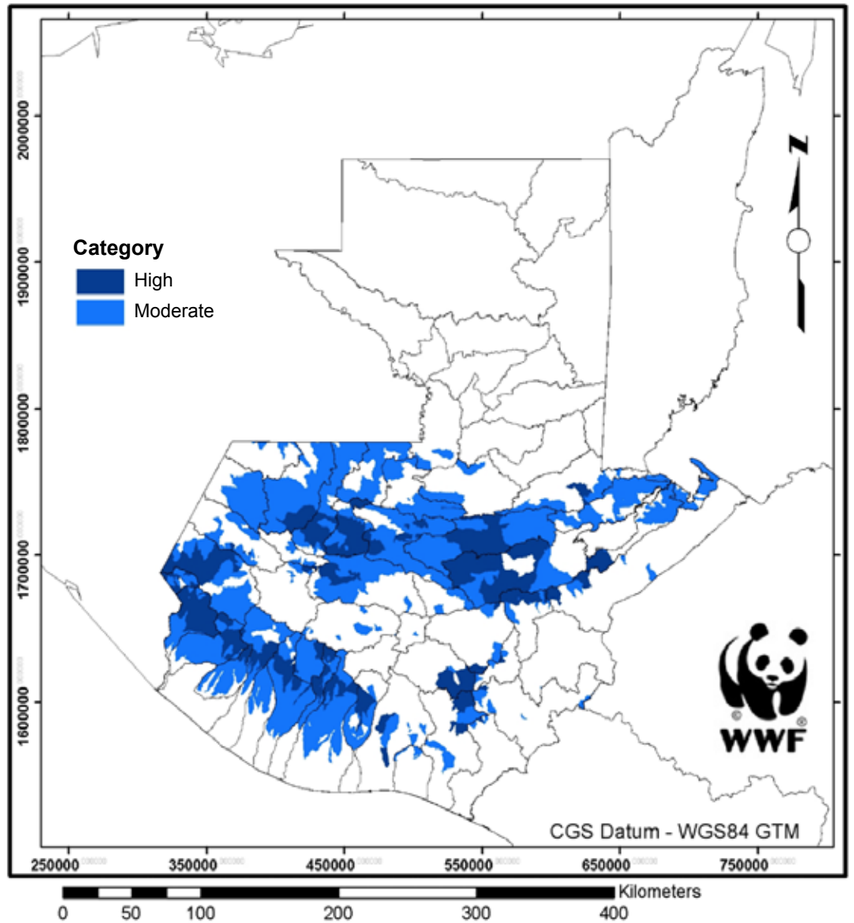


Figure 1. Intermediate Map Classifying High Water Catchment, Recharge and Regulation Areas.

Based on the "Intermediate Map of Potential Water Reserves (Level 8 Micro-Watersheds) for Guatemala", 958 micro-watersheds were prioritized. They constitute a territorial area measuring 3,083 million hectares, which make up 28% of the national territory.

In addition, it was estimated that if this territory is managed adequately, it will be possible to protect a volume of approximately 25% of the national water supply in the current climate conditions. This is equal to 23,000 million cubic meters of water.

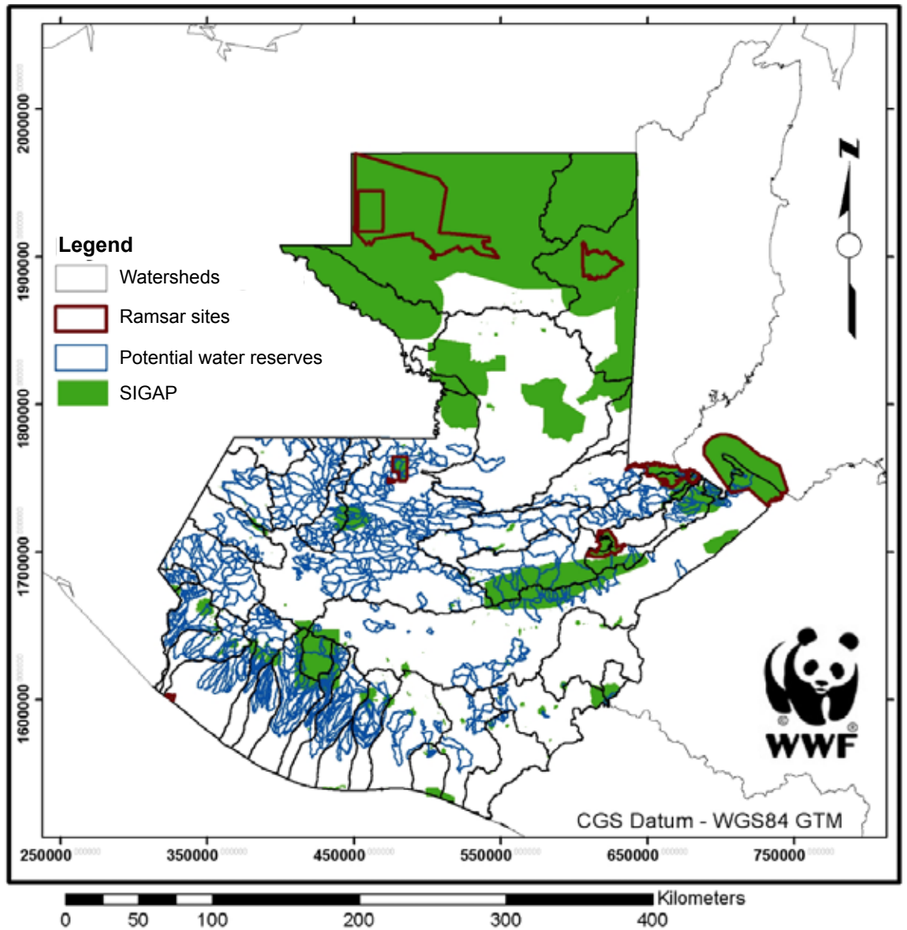


Figure 2. "Map of Potential Water Reserves for Guatemala", Based on Micro-Watersheds of the Guatemalan Protected Areas System (SIGAP) and Ramsar Sites.

By analyzing protected areas and Ramsar sites, the final prioritization for the "Map of Potential Water Reserves for Guatemala" (Figure 2) was performed. This analysis was made by overlaying the "Intermediate Map of Potential Water Reserves" (Figure 1) over the map of 336 protected areas of the Guatemalan Protected Areas System (SIGAP). It reduced micro-watersheds to 326, with 531,770 hectares in protected areas of various categories.

The analysis of Ramsar sites defined 32 additional micro-watersheds, with an area of 430,264 hectares, corresponding to 3.97% of the territory. Ramsar sites are protected areas, and four of these sites are notable as water reserves because they are important ecosystems due to their ecological connectivity and their biodiversity.

The adequate management of these 958 micro-watersheds is considered strategic to regulate short-cycle water flow and to keep up the productive capacity of soils, since it prevents the loss of 350 metric tons of soil per hectare per year (MT/ha/year).

Table 4 shows the number of micro-watersheds per river slope. The Pacific river slope is the one with the most water reserves, representing 41% of the river slope. Water reserves in this river slope are 43% of the total and they account for 31% of the extension of all reserves.

Table 4. Micro-Watersheds Prioritized as Potential Water Reserves

River Slope	No. of Micro-Watersheds	Area (ha)	% River slope Area	% Country
Caribbean	156	883,485.34	26.44	8.20
Gulfo of Mexico	392	1,235,448.33	24.37	11.47
Pacific	410	964,289.64	40.92	8.95
Total	958	3,083,223.31		28.63

In summary, the strategic water reserves for Guatemala (Figure 3) are the result of analyses that overlay the maps of water catchment, regulation, and recharge attributes, protected areas (SIGAP), and Ramsar sites. These analyses prioritized 358 micro-watersheds with an area of 959,856 hectares, which represent approximately 8.8% of the country. This means an estimated annual supply of 7,215 million cubic meters per year (groundwater and surface water).

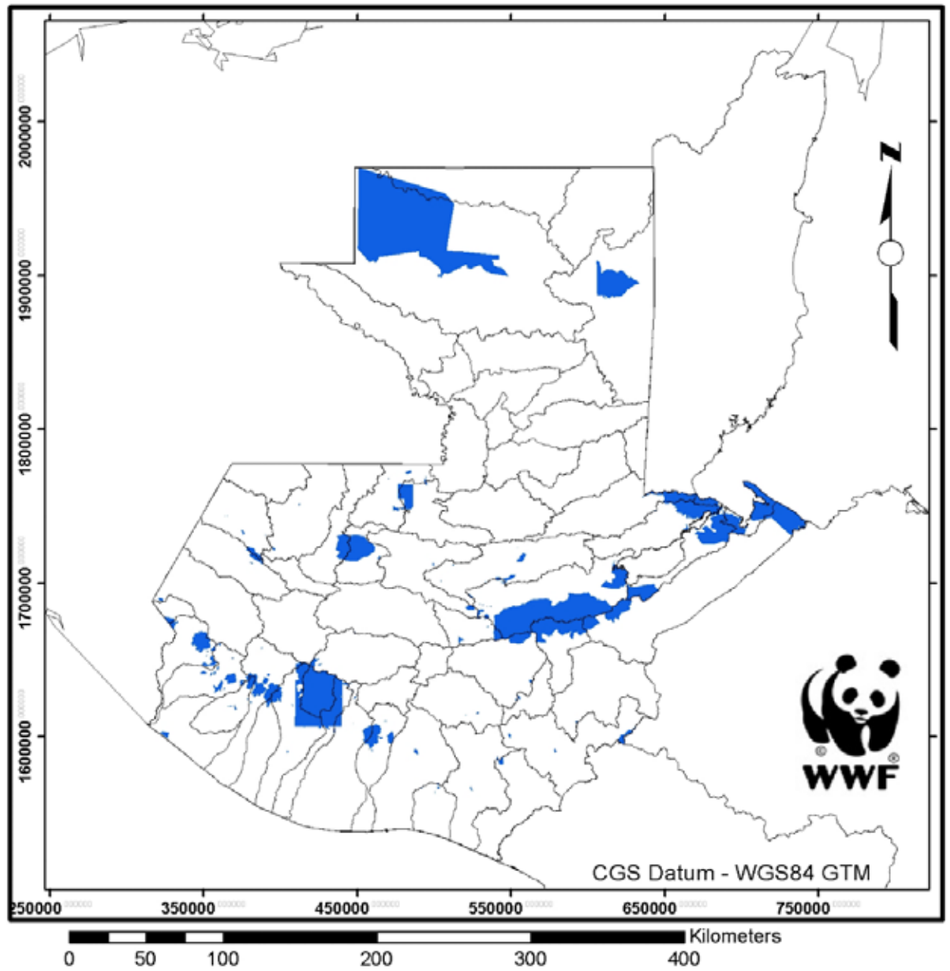


Figure 3. Map of the Strategic Reserves for Guatemala 2019.

The analyses performed on the three water attributes (water catchment, regulation, and recharge) and the importance of conservation and connectivity (protected areas and Ramsar sites) defined three priorities for Guatemala's water reserves. Priority 1 (strategic water reserves) includes micro-watersheds that have the three water attributes, protected areas, and Ramsar sites. Priority 2 includes micro-watersheds that only have the three water attributes. Priority 3, which represents micro-watersheds that have only two of the three water attributes.

Table 5. Prioritization Levels of Water Reserves for Guatemala

Category	Area (ha)	% Water Reserves Area	Micro-Watersheds	% Area of Country
Priority 1	959,856.07	27.44	358	8.86
Priority2	669,945.18	19.15	134	6.19
Priority 3	1,868,810.18	53.42	498	17.26
Total	3,498,611.44	100.00	990	32.31

The previously-described results were submitted to various government and non-government authorities for their validation in 2019.

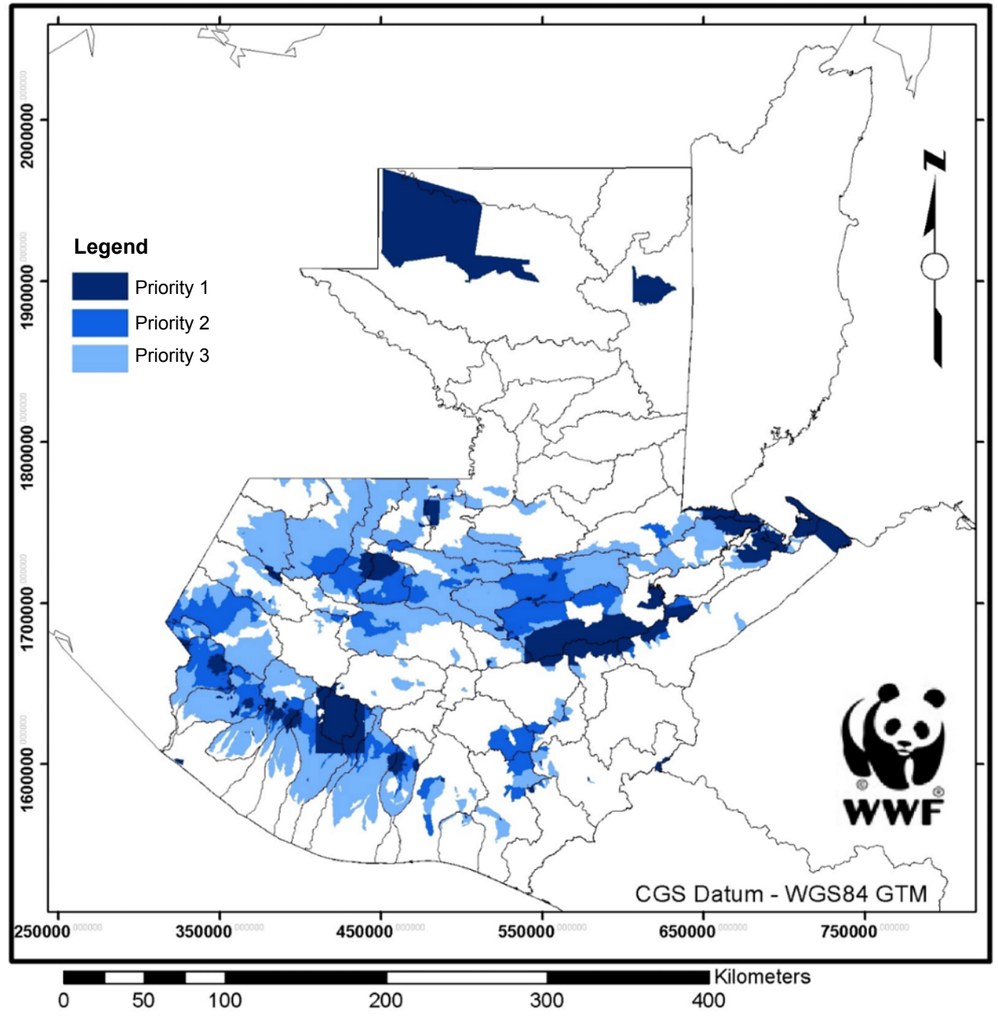


Figure 4. Map Prioritizing Water Reserves for Guatemala.

7. Review

Five workshops were held with MARN, INAB, IGN, INSIVUMEH, CONAP, and MAGA representatives. These workshops included presenting the objective, methodology attributes, variables, and other aspects to determine potential sites, prioritize water reserves and develop the first approach to the map. The various inputs from participants were incorporated into the methodology and the map.

Concurrently, high-level meetings were held with decision makers at MARN and other institutions linked to the water-reserves topic, aiming to discuss the importance of providing support and acknowledging WWF Guatemala/Mesoamerica's contribution to this water management tool for the country.

Lastly, WWF Guatemala/Mesoamerica held meetings with the technical teams from departments, directorates, or units of the Geographic Information Systems (GISs), watersheds, and other programs in the previously-mentioned institutions, aiming to seek their validation and obtaining technical inputs, which were incorporated into this technical report.

8. Technical Opinion

Given the importance of having science-based elements and information for decision-making purposes, the Ministry of the Environment and Natural Resources (MARN) will lead the process to generate an inter-institutional technical opinion by MARN, CONAP, INAB, INSIVUMEH and IGN on WWF Guatemala/ Mesoamerica's technical-scientific contribution. This is aimed at working jointly and starting the process to make the strategic reserves for Guatemala and their map official, in order to develop the technical and normative instruments for their implementation.

9. Recomendations

• It is important to continue with the institutional strengthening of entities linked to the conservation and restoration of critical water-regulation sites, especially INAB, CONAP, MARN, MAGA, IGN, and INSIVUMEH, so that they may jointly contribute information that supports the study and updates the "Map Prioritizing Water Reserves for Guatemala" in the near future.

• To organize and establish the responsibilities of the various institutions in conserving ecosystem services of the micro-watersheds that have been prioritized as strategic water reserves for Guatemala.

• To generate and apply the technical instruments and guidelines for an integrated management of the strategic water reserves for Guatemala. These instruments and guidelines must be coherent with the socio-economic reality of local populations.

• To promote the participation of the population and stakeholders linked to the strategic water reserves for Guatemala in order to make them aware of the lands with the greatest water catchment, recharge, and regulation attributes and to have them value their importance.

• To engage the academic and private sectors so that they become aware of the importance of water reserves and generate the essential data needed to update the "Map of the Strategic Water Reserves for Guatemala", as well as to promote their integrated management.

• To encourage the approval of the water law or a legal document that upholds the protection, conservation, and sustainable management of strategic water reserves for Guatemala.

• To develop an information system that integrates long-cycle regulation, short-cycle regulation, and water supply ecosystem services. To that end, it is necessary to develop one or several protocols that define information gathering with ecological, hydrological, hydro-geological, hydro-chemical (stable isotopes), climate, and integrated environmental and economic accounting variables. The latter should evaluate the water resources and water flows that the environment contributes to the economy, since the country's economic activities, both productive (agriculture, livestock, forestry) and service-oriented (ecological flow, water for human consumption, recreation, and hydropower) depend on water resources.

10. Annex 1

LEGAL FRAMEWORK

Guatemalan laws and articles pertaining to water resources

• Forestry Law of Guatemala (Decree 101-96)

• Law on Protected Areas (Decree 04-89).

• DECREE 02-2015. INAB–PROBOSQUE Law. Article 19. Compensation Mechanisms for Ecosystem and Environmental Services Associated with Forests.

• Law Establishing the Ministry of the Environment and Natural Resources

• National Institute of Forests: Managing incentives for the conservation of Water Catchment and Regulation Forest Lands, based on the 2005 map. This initiative contains incipient technical instruments, so that the map Water Catchment, Regulation, and Recharge Forest Lands (TFCRR in Spanish) was updated in 2017.

• Article 97: It establishes that "the State, municipal governments, and the inhabitants of the national territory are required to promote the social, economic and technological development that prevents environmental pollution and maintains the ecological balance, and thus, all necessary regulations will be issued to ensure that the use and exploitation of fauna, flora, land, and water are performed rationally, preventing their depredation."

• Constitutional Norm 64, which declares that the conservation, protection, and improvement of the natural heritage is of national interest and, to make it viable, it mandates creating national parks, reserves, and natural refuges, which are declared inalienable. The norm also dictates issuing a law to guarantee the protection of biodiversity and the protection of natural systems.

• Article 127: It defines water resources as public goods that are inalienable and imprescriptible and whose exploitation and use must be granted based on legal provisions and in accordance with the social interest. The law mandates the issuance of a law to regulate access to water resources.

• The Forestry Law, Decree 101-96 of the Congress of the Republic, defines the concept of water recharge zones as "surface areas, associated to a specific watershed that collect and allow the infiltration of water toward water tables and/or aquifers", "the strategic value of these areas depends on the saturation water that is extracted by human beings for their productive activities."

• Article 47 of the Forestry Law and Article 35 of the Set of Regulations for the Forestry Law foster protection for watershed and prohibit forest elimination in the upper watersheds, as well as the conservation and restoration of forests located in water recharge zones.

• The Law on Protected Areas (Legislative Decree 4-89 of the Congress of the Republic and its corresponding amendments) declared protected areas to safeguard watersheds, rivers, lakes, springs, and aquatic ecosystems in general. It generated the institutional framework for the administration of the Guatemalan Protected Areas System (SIGAP).

• Article 13: It creates a Rainy Forest Conservation Sub-System with the aim of ensuring a constant supply of quality water for the Guatemalan community.

• Article 97: The Environment and Ecological Balance: "The State, municipal governments, and the inhabitants of the national territory are required to promote the social, economic and technological development that prevents environmental pollution and maintains the ecological balance, and thus, all necessary norms will be issued to ensure that the use and exploitation of fauna, flora, land, and water are performed rationally, preventing their depredation."

• Law on Environmental Protection and Improvement (Decree 68-86), Article 11 mandates "To ensure the ecological balance and quality of the environment in order to improve the quality of life of the country's inhabitants."

• PROBOSQUE LAW

Article 10. Modes to be promoted (especially item e)
a. Establishing and maintaining forest plantations for industrial purposes. It includes managing voluntary forest plantations registered as seed sources.
b. Establishing and maintaining forest plantations for energy purposes.
c. Establishing and maintaining agroforestry systems.
d. Managing natural forests with production purposes. This includes national forests with the aim of producing forestry seeds.
e. Managing natural forests for protection and environmental-service provision purposes. This mode includes forest protection projects for water sources, conservation of biological diversity, ecotourism, germplasm conservation, sacred-site protection and other forests that are classified as protection forests by the Board of Directors of the National Institute of Forests (INAB).
f. Restoring degraded forestry lands.

The set of regulations for this Law will define the general characteristics of the projects that qualify for these modes, as well as the technical criteria and parameters for their approval and certification. Agroforestry plantations and systems that receive incentives according to this Law are deemed voluntary plantations, which must be registered in the National Forestry Registry.

Article 19. Compensation mechanisms for ecosystem and environmental services associated with forests. The National Institute of Forests (INAB), in coordination with beneficiaries and other stakeholders will promote the operation of compensation mechanisms aimed at owners of projects that generate ecosystem and environmental services associated with forests.

The issues related to planning, organization, management, and control of the different compensation mechanisms will be established in the set of regulations for this Law.

• PROBOSQUE Set of Regulations

CHAPTER X: ECOSYSTEM AND ENVIRONMENTAL SERVICES

ARTICLE 59. Promoting compensation mechanisms. INAB, through its specific department, in cooperation with beneficiaries and other stakeholders, shall promote the establishment of compensation mechanisms for ecosystem and environmental services associated with forests at the local and national levels, which

shall be governed by the Technical Guidelines Manual.

ARTICLE 60. Planning compensation mechanisms. Beneficiaries, in coordination with INAB, will design and develop plans to establish compensation mechanisms for ecosystem services in those areas with forest cover and/or restoration potential that meet the minimum technical, economic, social, and institutional conditions that ensure the continuous provision of such service, which must include the legal framework of the mechanism and the regulations to manage and execute the funds.

ARTICLE 61. Organizing compensation mechanisms. Beneficiaries, in coordination with INAB, shall establish the organizational structure and the roles of said actors in operating compensation mechanisms.

ARTICLE 62. Managing and controlling compensation mechanisms. INAB will provide accompaniment to establish and operate the monitoring, reporting, and verification systems in the compensation mechanisms that so require it, in order to ensure the execution of those activities stipulated in the agreements with stakeholders.

ARTICLE 63. Administrating compensation mechanisms. The financial income from administrating compensation mechanisms for ecosystem and environmental services associated with forests that so require or establish them, shall be paid to FONABOSQUE. For this purpose, INAB will sign a contract with the beneficiaries, seeking to define the administrative mechanisms that will provide the guidelines for channeling and using the financial income.

ARTICLE 64. Charging administrative expenses. INAB will establish a charge for the administrative expenses incurred while managing the funds from the compensation mechanisms for ecosystem and environmental services associated with forests that are received by FONABOSQUE, including monitoring, reporting and verification costs. For these purposes, the corresponding administrative document shall establish a cost related to the ecosystem service to which the compensation mechanism is applied.

ARTICLE 65. Thematic Support Groups. Ecosystem-service thematic lines must be addressed, discussed, and agreed upon with participation of the different stakeholders for each topic. INAB will be responsible for identifying and convening stakeholders to participate in each Thematic Support Group. The main functions of these Groups will be to manage the resources for economic compensation mechanisms, to generate strategic information, and to coordinate the activities that promote the establishment of compensation mechanisms.

11. Annex 2

DETAILS OF THE INSTITUTIONAL FRAMEWORK

• Ministry of the Environment and Natural Resources (MARN): Governing body of water resources as a natural good. It has a Watershed and Strategic Program Directorate, which is in charge of: a) promoting integrated water management, in coordination with the public and private sector, and b) issuing expert opinions and simple opinions within the Ministry pertaining to integral watershed management and strategic programs related to ecosystems, desertification and drought, as well as watersheds.

• Ministry of Agriculture, Livestock and Food (MAGA), By means of the Vice-Ministry of Rural Economic Development, it must ensure rural economic reactivation and development, by promoting strategies, programs, and productive projects, especially those pertaining to irrigation and watersheds.

• National Protected Area Council (CONAP): This is the entity in charge of encouraging and promoting conservation of protected areas, biological diversity, and special systems, such as wetlands. It contributes to the growth of the country's sustainable development by means of planning, coordination and implementation of the necessary policies and conservation models, working along other stakeholders.

• National Institute of Seismology, Vulcanology and Hydrology (INSIVUMEH): It is a technical-scientific institution that generates information and data related to atmospheric, geo-physical and hydrological sciences; coordinates services with the private sector and acts as technical advisor to the Government when natural disasters occur.

• National Geographic Institute (IGN): It is a technical-scientific agency under MAGA. It is in charge of establishing territorial boundaries and generating official national geographic information. It develops cartographic information for research, planning, and monitoring purposes related to the country's development.

• National Institute of Forests (INAB): This is a de-centralized institution under MAGA, in charge of the national forestry policy. It contributes to the sustainable development of the forestry sector in Guatemala, fosters improvement in the economy and the quality of life of its population, and helps to reduce climate-change vulnerability.