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**Sustainable Water Management in the City of the Future**

Integrated Project
Global Change and Ecosystems

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# INTEGRAL WATER MANAGEMENT IN THE MUNICIPALITIES OF SESQUILÉ, GUASCA AND GUATAVITA AN INTEGRAL VISION FROM THE BASIN OF THE TOMINÉ RESERVOIR

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**INTEGRAL WATER MANAGEMENT IN THE MUNICIPALITIES OF SESQUILÉ, GUASCA AND GUATAVITA:**

**AN INTEGRAL VISION FROM THE BASIN OF THE TOMINÉ RESERVOIR.**

## Audience

This document is of interest to medium level and higher management of municipal water departments and utilities, who are interested in including scientific assessment of urban water systems in strategic planning.
Also for all actors around the upper Bogota river basin that are working together for improve the conditions of the river.

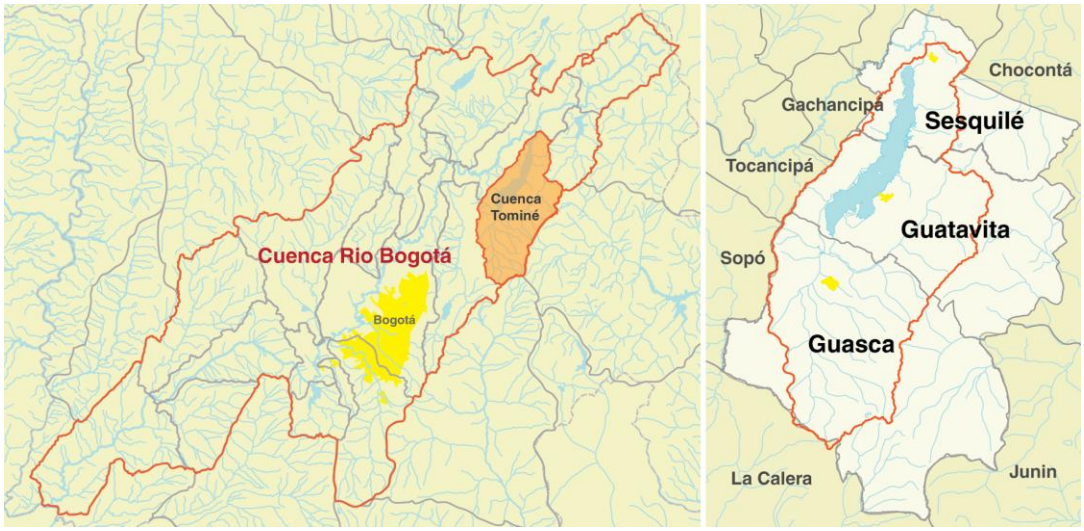
## Purpose

To improve the quantity, quality, equal access and permanent availability of water in the region of the Tominé Reservoir, through the participative proposal of the Integral Water Management IWM Plan in the municipalities of Guasca, Guatavita y Sesquilé.

## Background

At a province upstream Bogotá – Sesquilé, Guasca and Guatavita - an Integrated Water Management will be designed and proposed, inspired by the results from the SWITCH project - especially in terms of the decision making tools - and adapted to the local situation.

The municipalities of Sesquilé, Guasca and Guatavita are located at 60 km from the capital city of Colombia, Bogotá. These urban centres impact the Tominé reservoir (see figure below) which is part of the group of reservoirs associated with the Bogotá River which supply 4% of the potable water for Bogotá, 100% of the potable water for the surrounding municipalities and which generate the electricity for the area.



Therefore, the Tominé reservoir is rather important for various reasons. However, it is associated with a number of problems:

1. it receives the wastewater discharge from the two urban areas without any effective treatment (Guasca and Guatavita)
2. Sesquile uses the water from the reservoir for supply.
3. agrochemicals cause algae proliferation;
4. agricultural activities at more than 3000 meters above sea level and deforestation are related to desiccation and erosion. This affects the water flow into the reservoir (POMCA, 2004).
5. the sewerage system are combined system. In the rainy season, this system fills up with water resulting in floods.
1. according to previous analyses (PMSV, 2007) inferior public services are mainly due to a lack of planning and to not making sufficient infrastructure budget available.
2. the water shortage rate is considered high in the dry season and medium in the rainy season (POMCA, 2004).

This project proposes to evaluate the actual system for the management of water and to suggest improvements thereof on the basis of the lessons learned in the SWITCH project, using strategic planning.

**Potential Impact**

City managers that would adopt this approach would increase the involvement of the academic world in the planning of the cities water system. This would lead to more widespread and faster uptake of scientific innovations.

**Recommendations**

This report is the initial step for the adoption of Integral water management in the municipalities and reservoir. The entities related to the Reservoir must adopt and apply the Implementation Plan and continuously revise it in order to seek an Integral Water Management in the basin of the Tominé Reservoir.

The implementation of the pilot project proposed, are part of a second part of the project, funded by Governor and municipalities

**INTEGRAL WATER MANAGEMENT IN THE MUNICIPALITIES OF**

**SESQUILÉ, GUASCA AND GUATAVITA**

**AN INTEGRAL VISION FROM THE BASIN OF THE TOMINÉ RESERVOIR.**

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## INTRODUCTION

Traditional water management systems in cities have shown to be inefficient, with high environmental impacts and economic disadvantages (Butler and Maksimovic, 1999, Lawrence *et al.,* 1999, Bertrand-Krajewski *et. al.,* 2000, Mouritz 2000, Marsalek *et al* 2001, Vlachos and Braga 2001, Mitchell *et. al.,* 2003). Some of the associated problems are: increase of residues and their effect in water quality in rivers, the inadequate management of contaminants and nutrients, the high use of energy and chemicals for wastewater treatment, high costs for the rehabilitation and change of old infrastructure in areas of growth, increase in water demand (Mitchell, 2004).

The use of water in the city is not undertaken efficiently. Water treated for consumption is utilized for almost all uses, including the transport of liquid residues, industrial uses that do not require high water quality. The reuse is not common and rain water is mixed with wastewater for its subsequent treatment (Siebel & Gijzen, 2003).

With the limited water available (Cosgrove & Rijsberman, 2000) it is clear that this focus is not sustainable and the shortage of fresh water is increasingly more frequent (Siebel & Gijzen, 2003). As a result, the way water has traditionally been managed in cities requires revision.

Integrated water management in cities (IUWM) seeks to change the focus of the resource's management, whereby all water systems in the cities and their sources are analyzed in a comprehensive and holistic manner i.e., water provision, sanitation and drainage systems.

There are various successful experiences internationally regarding comprehensive water management in cities (SWITCH 2008 a; Mitchell, 2004), which have shown the need to integrate the concept to planning and development in the municipalities.

The approach proposed by SWITCH for water management in cities is the formulation of a strategic plan whereby in a participative manner with the different actors of the society, the vision of the city is defined in a timeframe of 30-40 years and possible strategies are studied in order to achieve the projected goal. The proposed strategies include actions that involve the social, economic, institutional and technical components (SWITCH, 2008a). The strategies involve technologies and methods in order to achieve a comprehensive water management where all parts of the water cycle in cities are taken into account, the water quality for its best use, water reuse and treatment seeking efficiency.

Integral water management -IWM- takes into account the cycle of water use and includes conventional and non-conventional ways in: a) water supply that seeks availability and quality, b) the efficient use for its best exploitation and c) the disposal of waste water.

The Integral water management project SWITCH - IUWM cities intends to change the focus of water use, where all the water supply, use and disposal systems are analyzed in a Integral and holistic manner, introducing technical, social, economic, institutional and water management elements.

The UNESCO - IHE Institute of Water Education, Delft, The Netherlands, and the Universidad Nacional, Bogotá, Colombia, have been working jointly in the framework of the SWITCH project in the Upper Basin of the Bogotá River. At this stage the formulation of the Integral water management plan in the municipalities of the basin of the Tominé reservoir is sought, which covers the municipalities of Sesquilé, Guasca and Guatavita, and in a next stage some pilot projects will be implemented. The reservoir is of special interest for the Upper Basin of the Bogotá River as it is employed to regulate the River's flow, and when necessary,

supplies the Tibitoc treatment plant, which is in charge of treating 30% of the drinking water for Colombia's apital city and five neighboring municipalities, approximately 4 million inhabitants (EAAB, 2009).

The three municipalities present diverse problems with respect to water use *i.e.,* shortage in dry seasons, discharges without treatment or with inefficient treatment, pressure over the water resource due to population growth, and the use of water in agriculture and inefficient urban use. The municipalities of Guasca and Guatavita discharge their wastewater onto the Tominé reservoir without treatment or with incomplete treatment and the Municipality of Sesquilé (downstream), uses water from the reservoir for human consumption. The region also depends on the reservoir to sustain the principal economic activities like agriculture and tourism.

This project seeks to formulate and implement a comprehensive water management plan of the municipalities of Sesquilé, Guasca and Guatavita taking the Tominé Reservoir, the main basin integrating the three municipalities as the unit of analysis.

The Integral water management plan is an opportunity to change the water management in the region of the Tominé Reservoir, with the participation of all actors involved and to open the possibility to replicate the experience in other municipalities and cities of Cundinamarca and the country.

## 1. GOAL OF THE RESEARCH

To improve the quantity, quality, equal access and permanent availability of water in the region of the Tominé Reservoir, through the participative proposal of the Integral Water Management IWM Plan in the municipalities of Guasca, Guatavita y Sesquilé.

## 2. OBJECTIVES

2.1. To identify the physical, social and economic dynamics that interact in the context of the Tominé Reservoir.

2.2. To project 30 years into the future, the optimal conditions for the Integral water management in the region.

2.3. To define, on the basis of mutual agreement, the strategies, alternatives, programs and projects leading to the achievement of the optimal conditions for the basin in the foreseen future.

2.4. To establish the action priorities in the short, medium and long term in order to gradually improve the conditions of quality, quantity, and availability of water in the municipalities.

## 3. BACKGROUND

In Colombia 68% of the energy is produced by hydroelectric plants (ISA 2010). This requires a network of reservoirs for its production. In the Department of Cundinamarca, in the Upper Basin of the Bogotá River lies the Tominé Reservoir (Figures 1 and 2), constructed in 1964 by the Bogotá Energy Company, which generates power for the electrical interconnection system of the country, and is administered by EMGESA S.A. ESP. (CAR, POMCA, 2008) To acquaint the reader with the region the principal physical, social, economic, legal, and technical aspects are described.


**Figure 1. Map of the region**

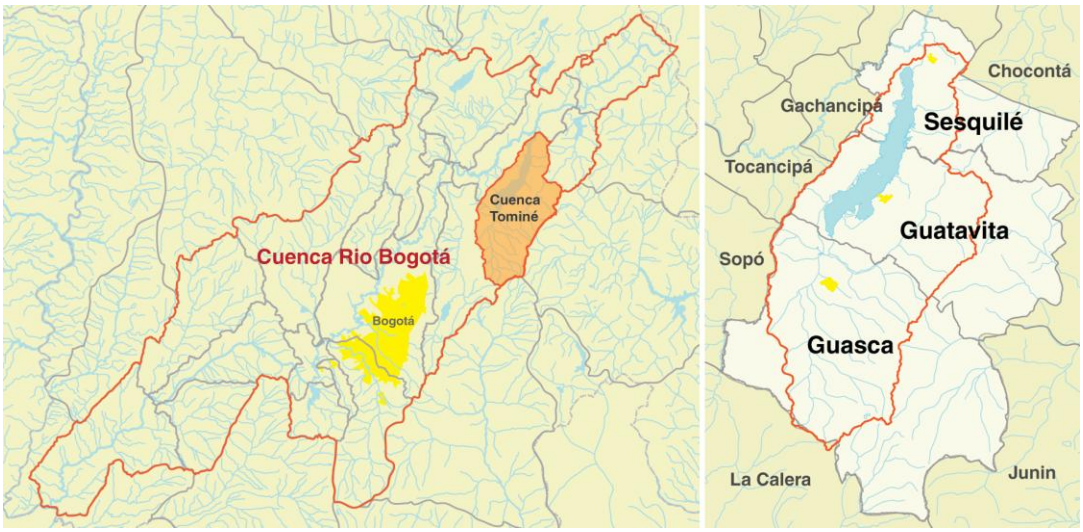



**Figure 2. Basins of the Bogotá River and the Tominé Reservoir**

### 3.1 Physical Aspects

Currently, the Tominé Reservoir serves to regulate the flow of the Bogotá River, avoiding floods in the rainy season, and shortages of water in the summer dry season, as this is the River that supplies water to the Tibitoc potable water treatment plant, which supplies 5 municipalities (Chía, Cajicá, Tocancipá, Gachancipá and Sopó) and treats 30% of the water destined for Bogotá. This represents drinking water for approximately 4 million persons (EAAB 2009). The Reservoir supplies water for the population and the agricultural activity of the Municipality of Sesquilé (EOT Sesquilé 2009); receives wastewater from the municipalities of Guasca and Guatavita, which generates pollution of the Reservoir. The latter municipality is constructing its wastewater treatment Plant.

Figure 3 presents a map of the water bodies that are part of the Tominé Reservoir's basin, Isohyets, topography, rural aqueducts, potable water treatment plants PWTP, wastewater treatment plants WWTP, and the location of the stations of the Institute of Hydrology, Meteorology and Environmental Studies IDEAM, and the Autonomous Corporation of Cundinamarca CAR from where the hydroclimatological information was obtained.

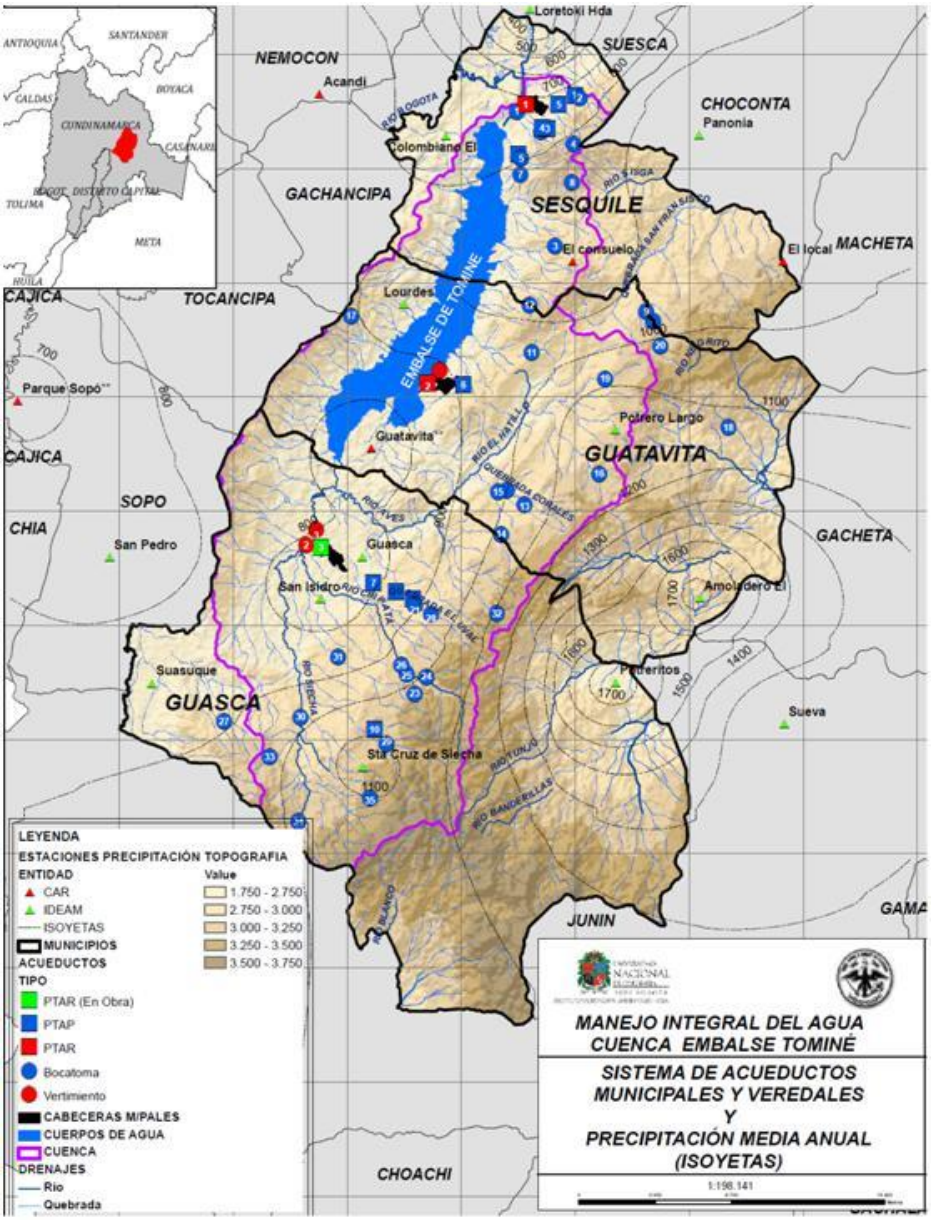



**Figure 3. Water bodies, rural water distribution systems and WWTP in the Tominé basin.**

From available hydro-meteorological information, there are two rainy seasons over the Tominé basin. The first begins in the month of March and lasts until the end of July, and the second corresponds to the months of October and November. The period of least precipitation goes from December to February. This bimodal behavior of the rain is typical in the majority of the national territory. Table 1 presents the data for precipitation, temperature, relative humidity and evaporation mediums of the zone´s seasons, calculated between the years 1982 and 2009. It can be observed that the lowest average temperature occurs towards

the month of July and the highest during January. Fluctuations in relative humidity and the changes in evaporation are small in comparison with the variation of the other parameters.

**Table 1: Monthly average values of the main climatological parameters. Tominé**

| Month | Average Precipitation (mm) | Temperature (°C) | | | Relative Humidity (%) | Evaporation (mm) |
|---|---|---|---|---|---|---|
| | | Maximum | Minimum | Mean | | |
| **January** | 35 | 10.5 | 15.2 | 14.4 | 82.8 | 88 |
| **February** | 47 | 10.1 | 15.7 | 13.6 | 82.4 | 80 |
| **March** | 70 | 10.4 | 14.5 | 13.3 | 84.4 | 82 |
| **April** | 86 | 10.9 | 14.8 | 13.4 | 84.5 | 78 |
| **May** | 111 | 10.9 | 14.8 | 13.3 | 85.4 | 83 |
| **June** | 86 | 11.1 | 14.3 | 12.5 | 84.1 | 73 |
| **July** | 102 | 10.8 | 14.6 | 12.2 | 85.8 | 86 |
| **August** | 83 | 10.9 | 14.2 | 12.4 | 86.1 | 89 |
| **September** | 66 | 11.0 | 14.0 | 12.7 | 84.8 | 83 |
| **October** | 95 | 11.1 | 14.5 | 12.9 | 84.7 | 87 |
| **November** | 82 | 11.4 | 14.9 | 12.7 | 85.6 | 79 |
| **December** | 43 | 10.5 | 15.3 | 12.9 | 84.6 | 83 |

In the basin there are a total of 10 parks declared as protected areas for water production.

### 3.2 Wastewater and sewerage system

**Urban Area**: Wastewater in the three urban areas are collected by the sewerage system in a mixed system: rain waters with sewage. Guasca has a Wastewater Treatment Plant (WWTP) in construction phase.

**Rural Zone**: In the rural districts all users utilize pre-fabricated septic tanks or ones that are constructed by them. The systems usually consist of a grease trap and a tank with two partitions that separate solids from liquids. In general the water that comes out of the septic tank is used for irrigation in the property. In the region the maintenance of the septic tanks is scarce.

### 3.3 Social Aspects

The Basin of the Tominé Reservoir currently has 32,000 inhabitants (DANE 2005), of which the Municipality of Guasca has 13,566 inhabitants (66% rural), Guatavita 6,789 inhabitants (73% rural) and Sesquilé 11,730 inhabitants (75% rural). In all the municipalities a high percentage of inhabitants live in the rural zone, most in agricultural occupations. The population of Sesquilé, both urban as well as rural is the most vulnerable to the shortage of water during the dry summer periods.

### 3.4 Economic Aspects

In Guatavita the main economic activity is agriculture; and the product most sown is potato (41%), in addition to corn, pea, blackberry and strawberry. There is also piscine activity, cattle ranching and mining of clay and construction materials. (Guatavita 2001)

Guasca also has agriculture as the principal activity, with potato, strawberry, pea, carrot crops and flowers. In second place is the dairy cattle activity. There is also piscine of trout and chickens for eggs. (Guasca 2001)

Sesquilé produces potato, corn, pea, flowers and transient crops. There is also cattle ranching and mining of construction materials. In the three municipalities surrounding the Tominé Reservoir there are activities related to aquatic sports like sailing and aquatic skiing, which attracts tourism primarily from Bogotá.

### 3.5 Institutional and Legal Aspects

**Institutional:** In Colombia the smallest territory is the municipality which has an urban and a rural area. It is administered by the Mayor, who is democratically elected for a period of three years. In this study three municipalities are included: Guasca, Guatavita and Sesquilé. The three belong to the Department of Cundinamarca, which has 106 municipalities and is administered by a Governor.

At the regional level, the environmental authorities are the Regional Autonomous Corporations -CAR, in charge of protecting the natural resources, monitor that the norms and laws in their jurisdiction are complied with, granting permits and fixing the rates envisaged in the law for the environment. In the Tominé Basin intervene the Regional Autonomous Corporation of Cundinamarca -CAR and the Regional Autonomous Corporation of Guavio -CORPOGUAVIO.

In the issue of Power Generation the Bogotá Power Company -EEB is involved and the EMGESA company, which administers the Reservoir, since the dam has been a power generating source since its construction.

The issue of water resource destined for human consumption and that is supplied by the PWTP, is the responsibility of the Bogotá Aqueduct and Sewer System Company -EAAB.

**Legal:** The country complies with international agreements for the protection of natural resources specially those related with biodiversity, the atmosphere, climate and water.

The country has 17 environmental policies formulated, it has developed the national hydric Policy (MAVDT 2010) oriented towards the efficient use and exploitation of water, the protection of spring heads and zones of aquifer recharge, prioritizing the use of the hydric resource for human consumption, the principle of precaution and the incorporation of environmental costs for the correction of environmental deterioration.

The provision of drinking water and basic sanitation public utility services is regulated by decentralized companies that work in the municipalities. Each municipality must have an aqueduct and sewer system Plan and a Plan for the management of wastewater. (MAVDT 2002)

Colombia has an ample environmental regulation, the most important relating to different issues with respect to water is summarized below:

Regulation about surface water, availability and use: There exists a Program for the efficient use and saving of water.

Regulation about drinking water, and sanitation: There is the Potable Water and Basic Sanitation Commission -CRA, and the Technical Norms for potable water quality.

Regulation about water bodies and hydrographic basins: The zoning arrangement and management of basins that supply water (POMCA, by its Spanish initials) on the part of the CAR regional environmental authorities. Decree 1900/06 determines the investment of 1% of the total investment for the recovery, conservation, preservation and surveillance of the hydrographic basin that feeds the respective hydric source.

Regulation about contamination and discharges related to the compensation rate for the direct utilization of water as receptor of punctual discharges, the installation of equipment, systems and implements of low water consumption; the Technical Regulation for the Potable Water and Basic Sanitation - RAS sector; the

rates for the utilization of waters and the issuance of minimum fees, (updated to 2010): US $ 0.056 per Kg of biochemical oxygen demand (BOD) and US $0.010 per kg of total suspended solids (TSS)

### 3.6 Innovative technological alternatives for effective water management.

The formulation of the strategies management plan that was defined by the actors in order to achieve the vision of the city, should be accompanied by innovative technological solutions, which provide the city with mechanisms to work with some or all of the components of the water management system with a comprehensive vision. The possible innovations are classified in 5 groups according to the developments that SWITCH has carried out (SWITCH, 2008a):

#### 3.6.1. Water Sensitive Urban Design (WSUD)

The objective of water sensitive urban design is directed towards the sustainable development of cities through cooperation between water management, urban design and land use planning. Coordinating all aspects of sustainability, i.e., ecological, economical, social and cultural demands, allows cities with local area attractions and identity, which foster an efficient and comprehensive water management (Langenbach, 2011)

Diverse study cases have shown the advantages of this approach towards a comprehensive water management, i.e., green roofs, wetlands or surface channels in cities in order to reduce floods stemming from rain water (Langenbach, 2011).

#### 3.6.2. Demand management and sustainable water supply

The institutions in charge of water management need to adopt a comprehensive planning of the resource, an approximation that jointly evaluates the provision and the demand, so that it tries to close the gap of the difference between the offer and the demand, that is, to minimize loses (SWITCH, 2008ª).

The provision planning encompasses a large number of possible sources such as surface, groundwater, desalination, as well as various options of location and size of conventional storage and treatment. (SWITCH, 2008ª). Some examples of alternative sources studied in SWITCH are storm water use and temporary aquifer storage, Rainwater harvesting, permeable pavement. (Hoang Duong *et al.*, 2011)

On the other hand, management of the demand is defined as the development and implementation of strategies, policies and diverse initiatives that influence water demand, in such a way that the efficient and sustainable management of the scarce resource is accomplished (Savenije and Van der Zaag, 2002). As a part of these initiatives, there are successful experiences with the management of the payment tariff of public utilities, environmental education, measurements of loses (WEDC,Loughborough University, 2011).

#### 3.6.3. Decentralized wastewater management.

The objective of this initiative is to develop the prevention of contamination through the separate collection of residues and their independent treatment. A large number of demonstration cases have proved that this approach is economically effective for the wastewater management, facilitating new local water sources and the use of nutrients in agriculture. The systems that separate gray water, wastewater and urine, offer new solutions with advantages such as the elimination of environmental contamination and the reuse of nutrients. Some examples studied in SWITCH are: Wastewater reuse at unit-block scale, wastewater reuse at cluster scale (Hoang Duong et. al., 2011),

### 3.6.4. Natural systems for water treatment and reuse of non-drinking water.

One of the technologies studied in SWITCH are aquatic ecosystems constructed for the treatment of residual and rain water. These systems are characterized by the use of energy occurring in nature, i.e, solar or wind energy, as opposed to conventional treatment technologies that depend on non- renewable sources of energy or by the addition of chemicals. These systems include artificial wetlands, stabilization lagoons, treatment with aquifers or soil (soil aquifer treatment SAT), filtration in the River bed, green roofs (Bates, 2006).

On the other hand the reuse of non-drinking water in other uses, for example in buildings the use of rain water as gray water, or in canopies for agriculture, show good results (Tettenborn . *al.*, 2009, Winker et al, 2009, Chong Qing University, 2010).

### 3.6.5. Water used in urban agriculture.

Due to population growth, the price of food items in cities is high and seeking the food security of the population, urban agricultural programs have been implemented in various cities, with great success (SWITCH, 2008a). The shortage of water in cities is becoming increasingly common, and to confront the problem the consumption of drinking water for these type of activities has been prohibited (Tettenborn *et al.*, 2009, Winker et al, 2009).

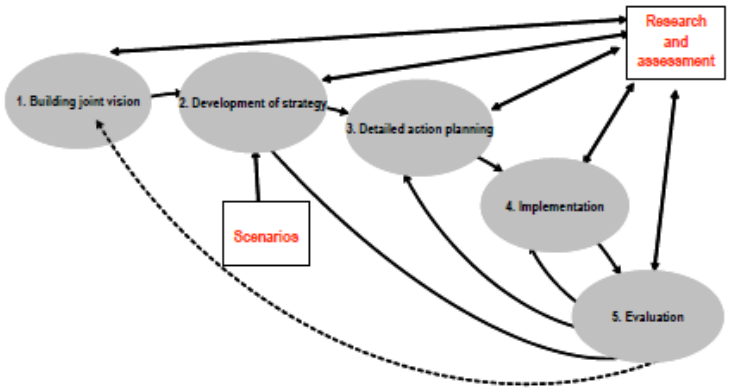
It is possible to use rain or wastewater for this purpose, aiding food security and the efficient management of water.

## 4. METHODOLOGY

The methodology utilized in the study on the basin of the Tominé Reservoir in order to define the comprehensive water management Plan, is a combination of Strategic Planning (SP) based on Learning Alliances (LA) (SWITCH 2008), including Negotiation Theory (SANZ 2010), alternated with the Analytic Hierarchy Process – AHP (SAATY 1980) for decision making with multiple criteria. The process integrates opinions and agreements of basin actors (social, economic and institutional actors), with the opinion of a group of technical experts in order to identify hierarchies of importance in the initiatives proposed by the actors.

The methodology adopted by SWITCH in the demonstration cities for the strategic planning, include the following activities (Figure 4.): 1. Building joint vision, 2. Development of strategy, 3. Detailed action planning, 4. Implementation and 5. Evaluation.

*SWITCH Approach to Strategic planning for Integrated Urban Water Management (IUWM)*




**Strategic Planning - SP supported by Learning Alliances –LA applied to the Tominé Reservoir.**

1. Initial Assessment. The background depicts the current state of water management in the municipalities, their potential and problematic, the social practices in receiving, using and disposing of water in urban and rural areas. Likewise, the economic activities that demand water and of quality, the institutionality and the biophysical and environmental conditions of the basin of the Tominé Reservoir. A "map of actors" social, economic and institutional is developed, with which the technical background is supplemented through interviews, with the administration of a social survey and with the participation in three stakeholders' workshop. See Figure 4.

2. Building joint future vision, objectives, strategies and action initiatives. Starting from the diagnosis, work was undertaken in three workshops (L.A. methodology and conflict resolution, SANZ 2010) with community leaders, plumbers, economic actors and community in general from the three municipalities. An additional workshop was carried out with the institutions involved in the project in order to define: 1. A future vision to the year 2040, where an efficient water management is carried out; the current local potential is maintained and the current problems and conflicts are solved; 2. Coherent with the vision of the future the general objective of the comprehensive water management Plan for the region was defined; 3. Likewise, three strategies were proposed with their objectives that facilitate the achievement of the agreed future scenario; and 4. a list of ideas or action initiatives was developed that could contribute towards the achievement of the proposed objective and that subsequently formed the basis for the definition of the projects.

3. Definition and hierarchy of criteria and initiatives. The methodology Analytic Hierarchy process AHP was utilized. See Figure 4.

> 3.1 The **Analytic Hierarchy Process** – AHP (SAATY 1980). Is a technique used in decision making with multiple criteria, which allows the incorporation of both qualitative as well as quantitative aspects of a problem in the evaluation process, by means of comparisons between pairs: Objective - Criterion and Criterion - Alternative, carried out in a matrix of comparisons, where the perception is sufficiently significant to make a distinction expressed in a number that stands for the importance of each criterion. The definition of IWMP was carried out by the multidisciplinary team of experts through the following steps: 1. Definition of six criteria to analyze the feasibility of the initiatives proposed by the actors in the workshops. 2. In a "Matrix of importance" where the criteria are located vertically and horizontally, each expert rates each criteria in relationship with the others

answering the following questions: "Which of the two is more important?", and "How much more important from 1 to 10?". 3. The average of the experts' answers is converted into a percentage in order to generate a hierarchy order or ranking of the six proposed criteria.

3.2 With the same procedure each one of the 24 ideas or alternatives the actors proposed in the workshop are rated. The experts answered the following questions: This criterion is important for the development of this alternative?, and From 1 to 10 how important is it? This generated a ranking of the alternatives, out of which those rated between 10 and 7 points are considered of a HIGH Importance, those rated between 7 and 5 points are considered of MEDIUM Importance, and those rated between 5 and 3 are classified as of LOW Importance. Alternatives that had a rating inferior to 3 were discarded.

4. Construction of the IWMP Integrated water management Plan. The three strategies proposed by the actors in order to accomplish the future vision, became the strategic actions of the IWMP, and their objectives contribute towards the realization of the overall IWMP objective. The hierarchy of importance of the initiatives proposed by the actors were analyzed by the group of experts who generated a first list of programs and projects, which will be reviewed again with the actors at a second stage of the project.

5. Proposal for the implementation Plan. This Plan orders the activities in stages in accordance with action priorities. Each one of the proposed initiatives was analyzed on the basis of the following criteria: Priority (High, Medium, or Low), Timeframe in which results will be observed (Short, Medium, Long Term), and the Execution suggested for each initiative (Occasional, Immediate, or Permanent).

The Implementation Plan is defined by the combination of the three above criteria, and in a first phase the projects presenting a HIGH Priority, Results in the SHORT term, and IMMEDIATE Execution will be implemented. For a subsequent stage of application will be left those projects rated with a LOW Priority and with results in the LONG term.

6. Evaluation of the comprehensive water management Plan and of the Implementation Plan with the stakeholders.

7. Feedback with stakeholders. An adjustment of the process is expected to take place with all the actors in order to choose and initiate the development of the demonstrative projects in the second stage of the IWM project of the Tominé Reservoir.

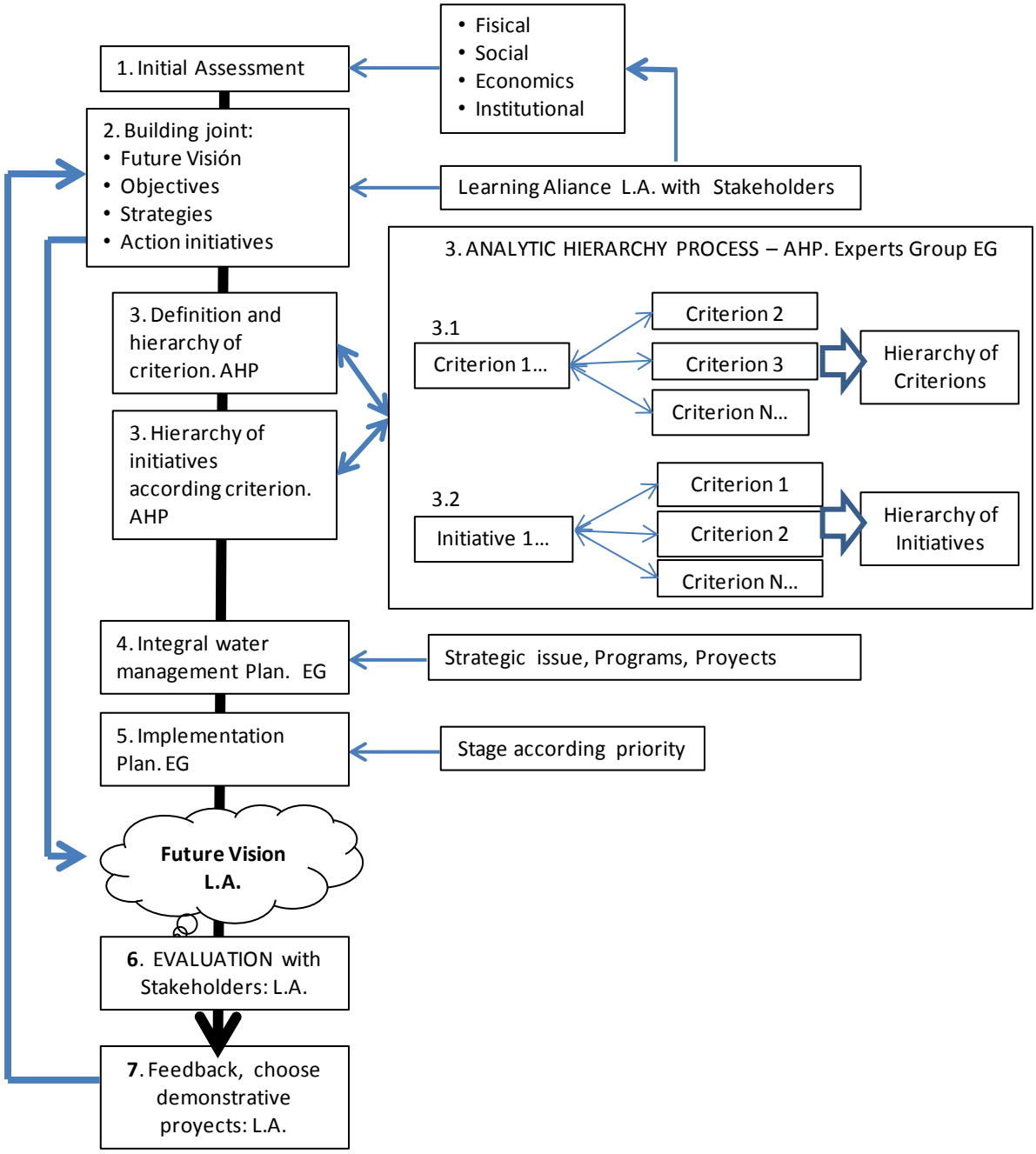



Figure 4. Scheme of the methodology applied in the IWMP in the basin of the Tominé Reservoir.

## 5. RESULTS

### 5.1 Diagnostic

The starting point for the formulation of the Integral Water Management Plan in the basin of the Tominé Reservoir are the findings gathered by the Technical Team in the different topics: technical, social and economic.

### 5.1.1 Technical Diagnostic.

#### 5.1.1.1. Water available.

Over the basin of the Tominé Reservoir falls rain water in quantities that can vary from one municipality to the other during the year. On average the municipalities of Guasca (1050 mm/year) and Guatavita (1100 mm/year) have a greater precipitation than the Municipality of Sesquilé (840 mm/year). Over the basin of the Tominé Reservoir 907 mm of rain precipitate annually.

The zone has a great potential of groundwater, for 2003, the groundwater was 40'200,000 $m^3$/year (JICA, 2003).

According to the census of users of groundwater for the Bogota Savannah registered by the CAR Cundinamarca (CAR 2008), in the districts of the municipalities of the study zone there are 153 points of exploitation of groundwater, nevertheless, only 61 of these are in use (Table 2).

**Table 2. Inventory of users of groundwater, Tominé. Source: CAR, "Reporte Censo de Usuarios de Aguas Subterráneas - Sabana de Bogotá" 2008**

| Municipality | Wells | Cistern | Springs | Total points | In use |
|---|---|---|---|---|---|
| **Sesquilé** | 22 | 16 | 10 | 48 | 20 |
| **Guatavita** | 3 | 0 | 1 | 4 | 0 |
| **Guasca** | 5 | 83 | 13 | 101 | 41 |
| **Total** | 30 | 99 | 24 | 153 | 61 |

The rain over the basin feeds the rivers that serve as source of groundwater for the three municipalities that make up the basin. Nevertheless, there is an external entrance to the basin, which comes from the San Francisco Ravine and with a small contribution of 0.29 $hm^3$/year serves to supply the urban zone of Guatavita and the districts of Upper Carbonera and Lower Carbonera.

Figure 5 is a schematic representation of the entrances and exits to the Tominé basin.

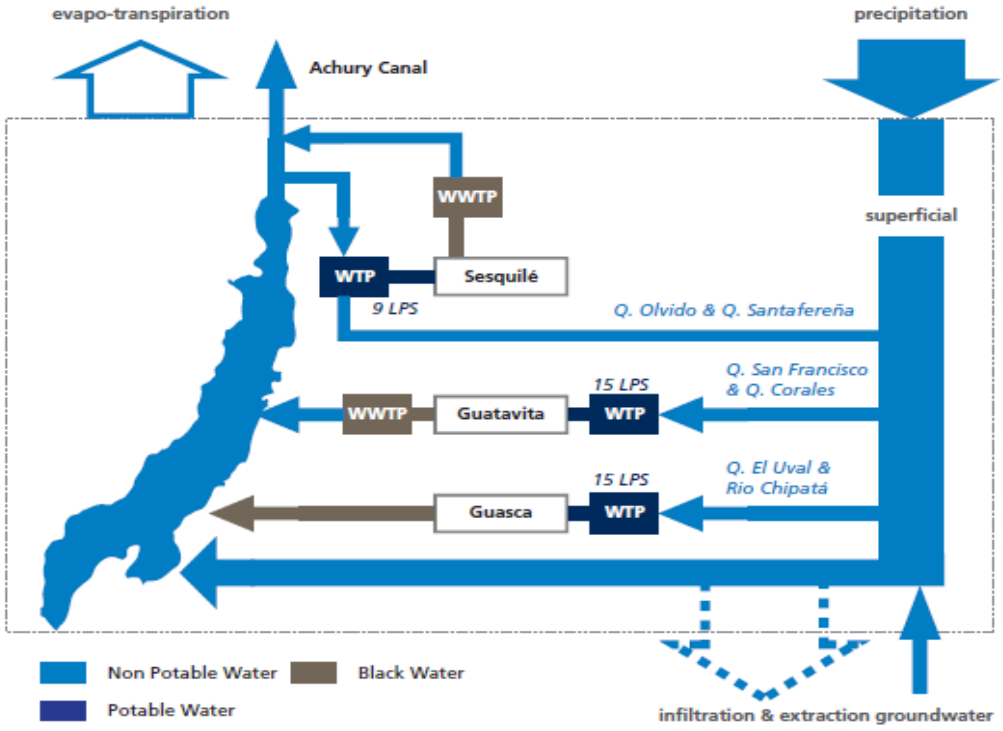



**Figure 5. Water management scheme in the Tominé basin.**

**Water provision for the municipalities**

Urban zone: The urban areas of the three municipalities receive potable water from their own treatment plant. Guasca has 1,251 subscribers, Guatavita has 730 and Sesquilé 1,002. The latter takes water from the Achury Channel which connects the basin with the Bogotá River. Of the 3 WWTP of the urban zones of the municipalities, the one at Guasca is in the construction phase, and it is expected to begin operating sometime in the year 2011 (Figure 3).

Rural zone: Guasca has 13 ravines with water inlets that supply water to 1,261 subscribers; Guatavita has 12 ravines with water inlets that supply water to 1,170 subscribers and Sesquilé has 8 ravines with water inlets for 219 subscribers (Figure 3). There are 11 PWTP, of which 3 are urban and 8 rural.

The water inlets that supply the urban areas are managed by the public utility offices of the mayors' Offices. The other water inlets are managed by the rural aqueduct boards. Only 7 of the 35 rural aqueducts included in this study have a potable water treatment plant.

Some factors may have an incidence in the reduction of the hydric offer in the region, for example: In Guasca there are processes of desertification in the surrounding areas to the reservoir in the middle basin of the Aves River due to the increase in crops and extensive livestock farming. The deforestation is observed to be accelerated in the districts of Hatillo, Lower Carbonera, Upper Carbonera, Corales, Potrerolargo and Guandita due to the introduction of the potato crop. In the districts of Monquentiva, Amoladero and Juiquín there is present the drying of the Martos Swamp with livestock farming purposes (Guasca 1999). Guatavita has lost 70% of the hydric sources due to mining exploitation and agricultural activities that degrade the soil, specially the potato crop in the following districts: Tominé de Indios, Chaleche, Montecillo, Santa María and el Choche (Guatavita 2001).

**Rainwater harvesting**

Rainwater harvesting was established in each municipality as the average precipitation (calculated from isohyets of hydrometeorological data) multiplied by the roof's area of each municipality. It's assumed that each cluster collects rainwater from the roofs and is used in garden irrigation, bathrooms, toilet flushing and laundry (Table 3).

**Table 3: Rainwater harvesting**

| | | Year 2010 |
|---|---|---|
| Sesquilé | Population | 2,884 |
| | Subscribers | 1,002 |
| | Consumption of drinking water (m3/year) | 286,296 |
| | Average rain urban area (mm) | 713 |
| | Exploitable rain water* (m3/year) | 71,443 |
| Guatavita | Population | 1,866 |
| | Subscribers | 1,251 |
| | Consumption of drinking water (m3/year) | 139,596 |
| | Average rain urban area (mm) | 893 |
| | Exploitable rain water* (m3/year) | 111,714 |
| Guasca | Population | 4,623 |
| | Subscribers | 717 |
| | Consumption of drinking water (m3/year) | 271,860 |
| | Average rain urban area (mm) | 786 |
| | Exploitable rain water* (m3/year) | 56,356 |

If the calculated exploitable rainwater is compared with the consumption, it is found that for Sesquilé the exploitable rainwater represents 25% of the consumption for the year 2010, for Guatavita it represents 80% and for Guasca 21%. It would entail that a large amount of urban water demand could be supplied by means of system to collect, make drinkable and store rain water through little networks on the cities.

#### 5.1.1.2. Water demand (estimate)

The IDEA Technical Team carried out an investigation (See Table 4) to estimate the **rural** and **urban** demand of each municipality for the year 2020. The exercise was undertaken in two scenarios. the first takes into consideration the expected population for the year 2020 (Projections DANE), maintaining the same current consumption habits; and the second scenario also takes into account the population projection but expects cultural and social habits to be modified with water savings practices, the recovery of rain water, the reuse and recycling of water, which will allow to adjust to the specifications of the Colombian norm that for municipalities of these characteristics establishes a demand of 120L/h/d.

**Table 4: Current demand and projected demand for the year 2020**

| | | Rural | | | Urban | | |
|---|---|---|---|---|---|---|---|
| | | **2010** | **2020-1** | **2020-2** | **2010** | **2020-1** | **2020-2** |
| **Sesquilé** | Population | 8,846 | 12,366 | 12,366 | 2,844 | 4,118 | 4,118 |
| | **Total drinking water demand (m3/year)** | **424,608** | **595,794** | **541,631** | **286,296** | **414,847** | **180,368** |
| | Demand per inhabitant (l/h/d) | 132 | 132 | 120 | 276 | 276 | 120 |
| **Guatavita** | Population | 4,923 | 4,957 | 4,957 | 1,866 | 2,025 | 2,025 |
| | **Total drinking water demand (m3/year)** | **413,532** | **416,140** | **217,117** | **139,596** | **151,521** | **88,695** |
| | Demand per inhabitant (l/h/d) | 230 | 230 | 120 | 205 | 205 | 120 |
| **Guasca** | Population | 8,943 | 10,220 | 10,220 | 4,623 | 5,747 | 5,747 |
| | **Total drinking water demand (m3/year)** | **429,264** | **492,400** | **447,636** | **438,480** | **545,390** | **251,719** |
| | Demand per inhabitant (l/h/d) | 132 | 132 | 120 | 260 | 260 | 120 |
| **Total drinking water demand** | | **1,267,404** | **1,504,334** | **1,206,383** | **864,372** | **1,111,758** | **520,782** |

The estimations for production and consumption are limited due to the lack of continuous periodic registries in the plants and in the distribution networks. The annual quantities are based on the estimated production reported as a specific data (production from 6 a.m. to 6 p.m. in l/s). The use per inhabitant was calculated dividing the consumption by the number of inhabitants.

According to the estimates presented in Table 4, with the introduction of new habits of savings, reuse, and recycling of water, and the implementation of the collection of rain water, the rural demand for water could be significantly reduced.

It is noticeable the high level of loss of potable water in the urban water distribution networks. The loss on the distribution network is computed as the difference between the amount of potable water (made drinkable by means of a WTP) and the amount of billed water. This difference is due to the loss of water through the distribution network owing to miss connections and non regular connections. Table 5 presents the calculation of the average loss of water up to the year 2010 in each municipality, and then an exercise is undertaken where water to be made drinkable and the water able to be billed are projected taking into account two scenarios for the year 2020: (i)in the first hand the same current level of loss is takink into account : and (ii) in the second hand presuming the control of those losses through optimization and regionalization of the networks and the control of the non-regular connections.

**Table 5: Water loss in urban distribution networks.**

| | | Urban | | |
|---|---|---|---|---|
| | | **2010** | **2020-1** | **2020-2** |
| **Sesquilé** | Population | 2,844 | 4,118 | 4,118 |
| | Water billed for (m3/year) | 286,296 | 418,978 | 1,015,704 |
| | Water made potable (m3/year) | 876,840 | 1,269,630 | 1,269,630 |
| | Distribution Network Loss | **67%** | **67%** | **20%** |
| **Guatavita** | Population | 1,866 | 2,025 | 2,025 |
| | Water billed for (m3/year) | 139,596 | 151,900 | 347,201 |
| | Water made potable (m3/year) | 399,924 | 434,001 | 434,001 |
| | Distribution Network Loss | **65%** | **65%** | **20%** |
| **Guasca** | Population | 4,623 | 5,747 | 5,747 |
| | Water billed for (m3/year) | 271,860 | 337,955 | 436,071 |
| | Water made potable (m3/year) | 438,480 | 545,089 | 545,089 |
| | Distribution Network Loss | **38%** | **38%** | **20%** |

**5.1.1.3. Water balance in the basin**

A monthly water balance was realized (Figure 6) on the basis of the basic hydroclimatic parameters of the basin, considering the potential evapotranspiration as 85% of the registered evaporation in the evaporation tray of the station closest to the reservoir (Guatavita Station). A field capacity of 80 mm (reserve) was considered.

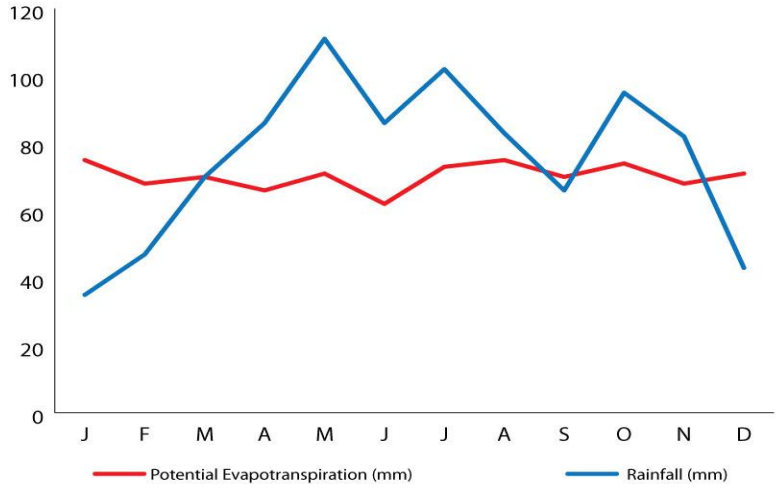



**Figure 6. Monthly water balance Tominé basin**

During the month of February there is a deficit of nearly 10 mm in the basin while during the more humid months (June, July, August, October, and November) there is an abundance of water with an average of approximately 15 mm.

Keeping in mind the inlets and outlets with annual resolution, the water balance of the basin is calculated (Table 6). The contribution of the San Francisco River results insignificant when compared to the precipitation.

**Table 6. Water balance annual data Tominé basin for the year 2010**

| Intake | hm3/year | Commentaries |
|---|---|---|
| Precipitation | 333.78 | Based on a precipitation of 907 mm |
| San Francisco R. | 0.29 | Urban Area of Guatavita and the district of Lower Carbonera introduces water from another basin. Data is based on an average flow of 12 L/s with a production from 6 AM to 6 PM. |
| **Exits** | | |
| Real Evapotranspiration | 171.86 | Based on an ETR of 467 mm (JICA Study - 2003) |
| Achury Channel | 109.30 | Based on a Runoff of 297 mm (JICA Study - 2003) |
| Groundwater | 52.91 | Recharge of groundwater. |

### Water quality

Samples were taken in some rural groundwater systems and analyzed in the Environmental Engineering Laboratory of the Universidad Nacional de Colombia

### Raw water

In some rural groundwater systems the water is collected directly from the source and is distributed without any treatment. This is water that could be made potable through a conventional treatment according to the physico-chemical values reported and one disinfection would be insufficient given the high values for total Coliforms and E.Coli. The Bicarbonate Alkalinity parameter lies between 4 and 12.5 mg/L $CaCO_3$, value that could be attributed to the photosynthetic activity of algae or to industrial discharges into the water bodies.

### Drinkable water

In the results no microbiological characteristics are reported but the values of Chloride in many cases exceed 2,0 mg/L $Cl^-$, indicating that in the water treatment there could be an excess of dosage of the disinfecting agent.

On the other hand, the values for Hardness are high in comparison with the norm, and therefore an evaluation of the discharges of wastewater of a domestic type into the surface water source surrounding edge zones would be required.

### Wastewater of the Municipality of Guasca

In general, it is observed that the difference in Dissolved Oxygen, which in turn determines the values of BOD and COD refers to the fact that Guasca does not have systems of wastewater treatment

### Water quality in the Tominé Reservoir

The Reservoir receives specific discharges from the WWTP of Guatavita and from the Siecha River onto which waste water from the urban area of the Municipality of Guasca, whose WWTP is in the construction phase, are directly discharged. These discharges deposit Fecal Coliforms, E.Coli and Suspended Solids, which has been confirmed in five observation zones of the Reservoir where these contaminants surpass permissible limits. The Reservoir also receives diffuse contamination by the runoff from the agricultural area of the basin, which contributes Total Phosphorus and Ammonia Nitrogen from the agrochemicals utilized, surpassing the maximum regulatory limits (0.3 mg N-NH4/L and 0.1 mg P/L). This contamination has produced an increase of the alkaline condition of the Reservoir's water, high reports of Hardness, and a large zone has been created with the aquatic plant Buchón (*Eichhornia crassipes)* in the river mouth of the Siecha River, which presents a process of eutrophication (EMGESA 2010).

The above mentioned factors generate an increase of lacustrine vegetation, which may be seen in the central island and to the south of the Tominé Reservoir in Figures 7 and 8.

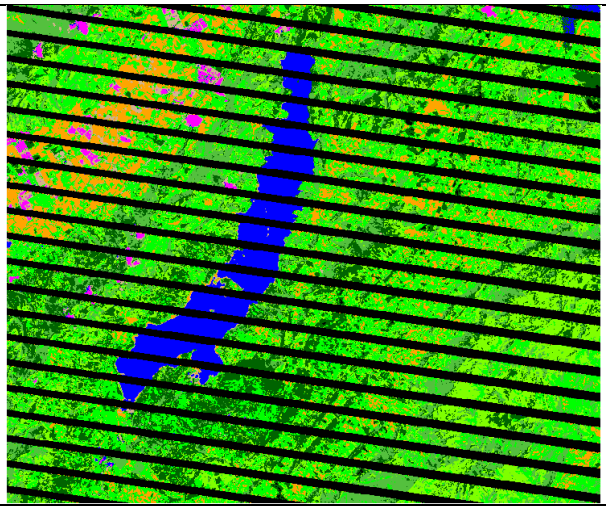


Figure 7. Image Landsat ETM+ 2004 (NE 8-57)

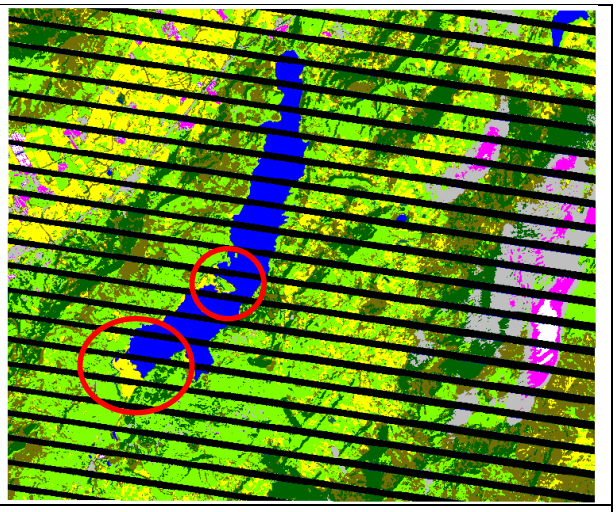


Figure 8. Image Landsat ETM+ 2009 (NE 8-57)

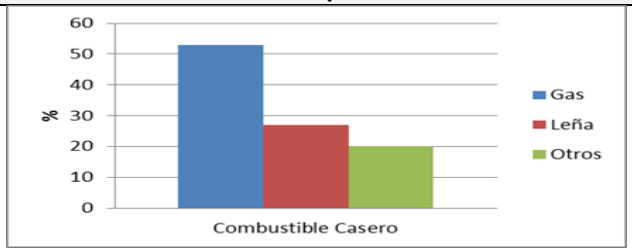
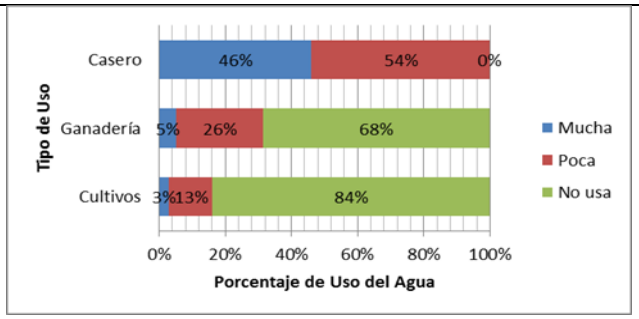
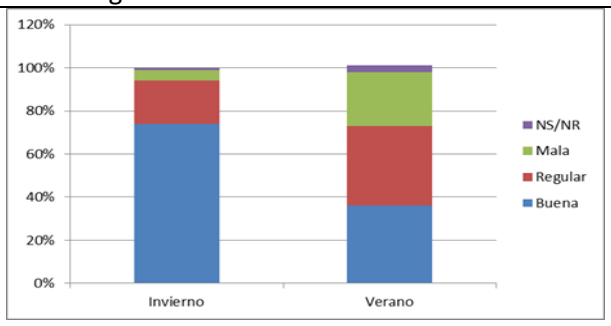
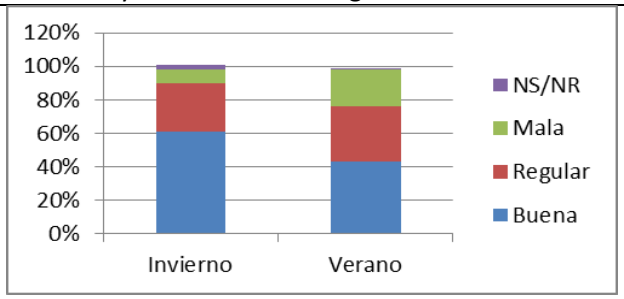
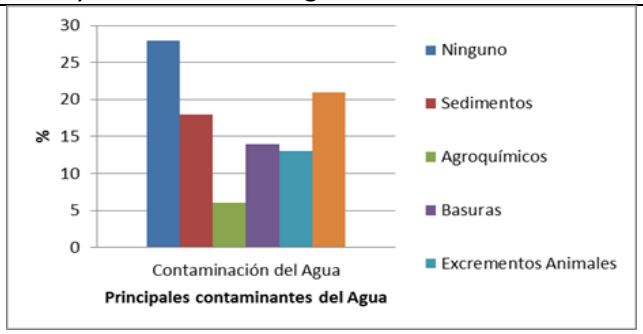
### 5.1.2 Social Diagnostic

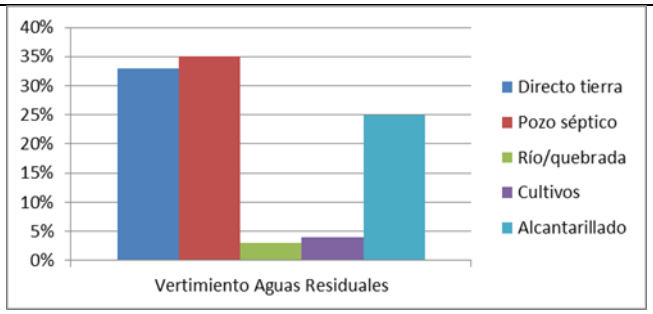
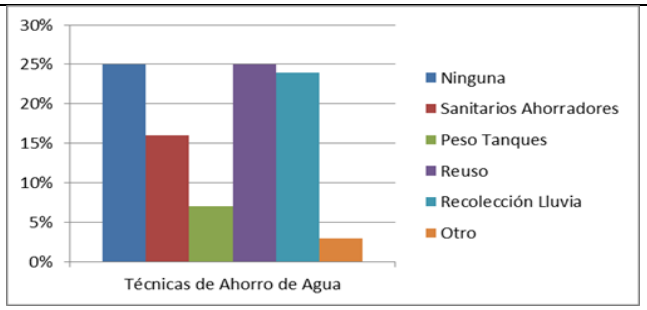
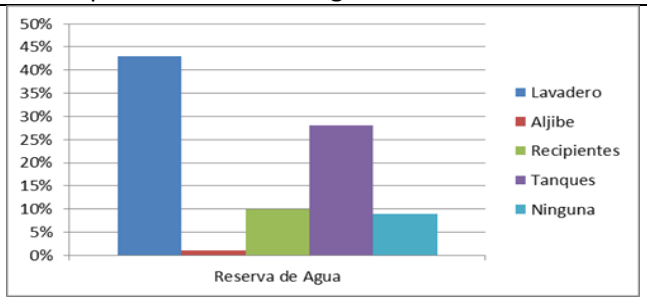
**Water use for social practices in the region**

Getting to know the cultural elements: customs, habits, priorities and how the inhabitants value and use the water are very important in order to define and agree on ways to make a more efficient use of the water and how to care for the water resource.

In order to get to know the cultural characteristics of the Tominé region related to water use, the technical team carried out a survey of 76 users composed of men and women, older than 18 years of age, rural and urban population of the municipalities of Guasca and Sesquilé (Table 7), on the following topics: domestic fuel, water uses, water quality, discharges onto water bodies, water savings and reserves of drinking water.

**Table 7: Cultural elements in water use in the Tominé region.**

| Graphs | Comments |
|---|---|
|  <br>Use of domestic Fuel | More than half of those surveyed cook only with Gas (propane); 29% with firewood and 20% with other fuels. The data reveal that the use of firewood is still high, which contributes towards the deforestation of the region and to a reduced production of water. |
|  <br>Percentage of water uses | With respect to the quantity of potable water that the homes receive, 46% use a great quantity of the water for domestic use, and 54% a little. Only 29% use potable water for livestock farming and 16% for crops. These figures show that for agricultural and livestock activities generally water without treatment is utilized. |
|  <br>Availability of water according to the climate | During winter (rainy season), 74% of those surveyed consider that the availability of water is sufficient for domestic use, 20% consider this to be fair and 5% insufficient.<br>In the summer or the dry season, the availability of drinking water is good for 36% of the homes, it is fair for 37%, and bad for 25%.<br>The availability of water for domestic use is reduced by 50% in the summer. |
|  <br>Quality of water according to the climate | With respect to the quality of water for domestic use, in the winter 61% of those surveyed consider it to be good; 29% fair, and 8% bad. In the summer season 43% of those surveyed consider the water quality to be good; 33% fair and 22% bad. Water quality in the summer is reduced by 18% |
|  <br>Principal contaminants of the Water | 27% of the inhabitants of the region have the opinion that the water used domestically is not contaminated; 21% think too many chemicals are used in making water potable, 18% think it contains sediments; 14% think the water is contaminated with trash; 14% think it is contaminated with animal excrements; and 6% think the water is contaminated with agrochemicals. From this it is deduced that 73% of those surveyed believes that the water for |

| | |
|---|---|
| | domestic use is contaminated. |
|  <br>Discharges of Wastewater | 35% of those surveyed state that in their home the greatest discharge goes to a septic tank, another 33% discharges wastewater onto the soil; and 25% has a connection to the sewerage system; 4% discharges wastewater onto the crops, and 3% does so directly onto a spring.<br>60% discharges wastewater onto the sewerage system or septic tank; and 40% do so with inadequate means. |
|  <br>Techniques for Water Saving | 25% of those surveyed state that they do not save water in any manner. 25% reuses the water discharged from the kitchen, shower or clothes wash sink; 24% practices the collection of rain water; 16% have toilets with water saving properties; 6% utilize objects (bricks or full bottles) that reduce the water discharged from the toilet.<br>Citizens are willing to utilize different water saving techniques. |
|  <br>Techniques for Water Reserves | 43% of those surveyed reserves water for dry seasons in the washing sink; 28% in reserve tanks (500 liters);<br>10% in home recipients; 9% do not carry out any type of reserve practice.<br>It is concluded that there already exists the custom of saving water (91% do so) through different means. |

**Actors linked to water management in the Tominé Reservoir**

The actors related to the environmental management of a territory are: Institutional, social and economic, which must interact in trying to balance the different public, community and private interests. (SIGAM 2006).

As actors involved in defining and applying the Integral Water Management Strategic Plan - PEIWM (by its Spanish initials) in the Tominé Reservoir region, the following stand out:

**Institutional:**

Of an international level: Academic institutions: UNESCO-IHE (Project SWITCH), International Water and Sanitation Centre –IRC (Project SWIRRL).

At the national level: Ministry of the Environment, Housing and Territorial Development and the Special Unit of National Natural Parks. The Superintendent's Office of Public Utility Services.

At the regional level: The Governorship's Office of Cundinamarca, Environmental authorities: Regional Autonomous Corporation of Cundinamarca –CAR, and the Regional Autonomous Corporation of Guavio – CORPOGUAVIO.

At the local level: Municipal Mayors' Offices of the municipalities of Guasca, Guatavita and Sesquilé; the municipal offices of Public Utility Services; the Offices of Municipal Planning; and the Offices of Social Development.

**Economic**:

1. At the regional level. The Bogota Power Company (Empresa de Energía de Bogotá –EEB), EMGESA, the Aqueduct and Sewerage System of Bogotá (Empresa de Acueducto y Alcantarillado de Bogotá -EAAB)
2. At the local level. Agroindustry companies (Potato, flowers, strawberries). Livestock and dairy farmers. Mining and construction material extraction companies. Organizations of small producers.

**Social**:

1. At the local level: Urban and rural Community Action Boards (Juntas de Acción comunal), rural Aqueduct Boards, Environmental NGOs, Foundations and community groups, Farmer associations.

The actors analyzed are set in three circles described from the outer towards the inner circles (Figure 9): a) Less influence, shows entities that control, coordinate and manage the Integral water management through plans and norms, b) Greater influence, institutions that impact the social territory according to the type of execution and participation in the decisions of the following sector; c) Influenced, are sectors, groups or organizations that are influenced by the decisions or proceedings of the previous groups.

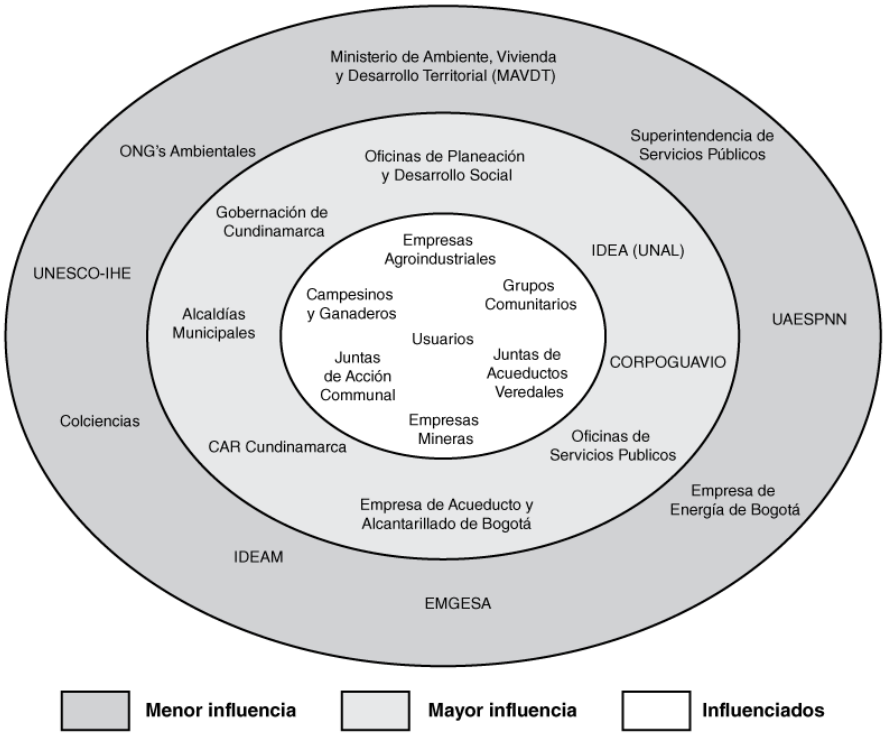



**Figure 9: Map of Actors**

### 5.1.3 Economic Diagnostic

**Costs of the of the water supply and sewage services**

On the basis of the quantification of the cost structure, the comparative cost relationship is presented for each of the municipalities for the urban aqueduct and sewerage systems (Table 8). The quantification of

costs and incomes for the aqueduct and sewerage systems, permits calculating the Net Real Value projected up to 10 years and a discount rate of 12%

**Table 8. Comparative Aqueduct and Sewerage System reference costs**

| Aqueduct reference costs | Guasca | Sesquile | Guatavita |
|---|---|---|---|
| Monthly average production (m3) | 36.540[1] | 73.070[2] | 33.327[3] |
| Monthly total average consumption (m3) | 22.655 | 23.858 | 11.633 |
| Subscribers | 1.251 | 1.002 | 717 |
| Average Administration Cost ($/ user/month) AAC | $ 4,992 | $ 2,512,11 | $ 2,881 |
| Average Operation Cost ($/ user/month) AOC and Average Investment Cost AIC | $ 326,14 | $ 877,97 | $ 804,12 |
| Average Cost of the rate per use ($/ user/month) ACR | $ 0.86 | $ 0.97 | $ 0.97 |
| Long term Average Cost ($/m3) LTAC – Treatment Cost m3 | $ 327 | $ 878,95 | $ 805 |
| **Sewerage System Reference Costs** | **Guasca** | **Sesquile** | **Guatavita** |
| Monthly average discharge (m3) | 21.574 | 20.418[4] | 11.633 |
| Subscribers | 1.168[5] | 818 | 536[6] |
| Average Administration Cost ($/ user/month) AAC | $ 1.996 | $ 1.440,05 | $ 1.152,4 |
| Average Operation Cost ($/ user/month) AOC and Average Investment Cost AIC | $ 100,85 | $275,55 | $ 322 |
| Average Cost of compensatory rate ($/ user/month) ACR | $ 32,15 | $ 3,45 | $ 15,85 |
| Long term Average Cost ($/m3) LTAC | $ 133 | $ 278,44 | $ 337,85 |

Likewise, the annual balances for the annual costs of potable water treatment with the PWTP and of waste water through the WWTP are carried out. Table 9.

**Table 9. Comparative of annual balances of urban water supply and sewerage systems.**

| Balance Aqueduct (in thousands of pesos) | Guasca | Sesquile | Guatavita |
|---|---|---|---|
| Number of Subscribers | 1,251 | 1,002 | 717 |
| Total Annual Revenues | $ 122,707 | $ 107,765 | $ 107,553 |
| Total Annual Treatment Costs | $ 218,383 | $ 281,844 | $ 347,726 |
| Deficit | -$ 95,676 | -$174,079 | -$ 239,173 |
| Net Real Value (thousands of pesos) 10 years | -540,591 | -867,569 | -1,351,383 |
| **Balance sewerage system (thousands of pesos)** | **Guasca** | **Sesquilé** | **Guatavita** |
| Number of Subscribers | 1,168 | 818 | 536 |
| Total annual revenues | $ 45,956 | $ 36,847 | $ 41,908 |
| Total annual treatment costs | $ 62,408 | $ 82,465 | $ 54,408 |
| Deficit | $ -16,451 | -$45,617 | $ -12,500 |
| Net Real Value (thousands of pesos) | -92,952 | -257,746 | -70,632 |

It can be observed that the three municipalities present budget deficits in the provision of aqueduct and sewerage services that are covered with their own budget. The budget is supplied by the Central Government of Colombia, of taxes.

[1] Office of Public Utility Services. Billing 2009
[2] Tariff Study. Office of Public Utility Services Sesquile, 2004
[3] Latin Consult (2009). Aqueduct and Sewerage System Master Plan, Guatavita
[4] Office of Public Utility Services Sesquile. Billing 2010
[5] Office of Public Utility Services Guasca. Billing 2009
[6] Users Sewerage System Guatavita. 2010

With respect to the rural aqueducts these evidence a diversity of costs, since they do not have a tariff study that establishes the costs of administration, operation, maintenance and environmental rates that allow setting tariffs. Nevertheless, no budgetary deficits are identified since the revenues per tariffs cover the costs incurred, and no type of subsidy is applied.

### 5.2 Vision, Alternatives and Strategies

**Vision of the future of the basin** within 30 years. Developed with elements that were contributed by the different actors in the workshops: community and institutional:

> *"For the year 2040 in the Tominé basin a **reduction of the demand** for water per person is achieved. The community has an **equal and permanent access to drinking water** and realizes an **efficient and sustainable use of the hydric resource.** The **water quality** in the reservoir has **improved** and is controlled. There is a **better communication between all actors** and they conserve the environment, based on the sense of belonging that they have developed."*

**Solution Alternatives**

In the workshops 20 solution alternatives were defined with 107 urban and rural persons in the three municipalities, the community for problems found in the basin.

In order to qualify the degree of importance and the priority of the initiatives, a Multiple Criteria methodology was applied with 6 criteria: Ease of application, Economic benefits; Low Cost; Governance (Political willingness, being part of the institutional functioning, and having the possibility of accessing resources); Community participation and positive environmental impact. These criteria were qualified by the technical team in order to find the percentile values and the order of each one (Table 10).

**Table 10: Matrix of the ranking of each criterium in order to qualify the proposed initiatives**

| Criteria | B | | | | | | Ranking of each one | |
|---|---|---|---|---|---|---|---|---|
| A | Ease of applica-tion | Econo-mic benefits | Low Cost | Gover-nance- | Community participa-tion | Positive environ-mental impact | Eigen Vector % | Order |
| Positive environmental impact | 7.00 | 5.26 | 5.00 | 2.86 | 2.63 | 1.00 | **43.71** | **1** |
| Governance | 4.55 | 1.32 | 2.00 | 1.00 | 4.21 | 0.35 | 20.04 | 2 |
| Economic benefits | 4.55 | 1.00 | 1.63 | 0.76 | 2.94 | 0.19 | 15.54 | 3 |
| Community participation | 1.14 | 0.34 | 0.94 | 0.24 | 1.00 | 0.38 | 7.44 | 4 |
| Low Cost | 0.67 | 0.61 | 1.00 | 0.50 | 1.06 | 0.20 | 7.40 | 5 |
| Ease of application | 1.00 | 0.22 | 1.50 | 0.22 | 0.88 | 0.14 | 5.86 | 6 |

This result indicates that the most important assessment criteria is the alternative Positive Environmental Impact, in a rate of 43.71%, followed by the criteria of Governance in a proportion of 20.04%, and in third place Economic benefits with 15.54%.

The initiatives are classified (in the first column) according to 3 predominant actions in the Tominé basin: Technical (T); Social (S); and Institutional (I). It is highlighted that the economic issue was included as a part of the institutional functions.

The Technical Team rated each one of the proposed initiatives according to the above criteria, taking into account the assigned values for each criteria, which generates a list of initiatives in the order of importance: HIGH, MEDIUM, or LOW. (Table 11)

**Table 11: Relative importance or ranking of the proposed from community initiatives.**

| Issue | INITIATIVES | Relative weight | IMPORTANCE |
|---|---|---|---|
| **T** | **Water recycling and reuse.** | **8.908** | **HIGH** |
| **T** | **Increase of ecologic and reforestation conservation areas.** | **7.5745** | **HIGH** |
| **T** | **Improvement of wastewater treatment technologies (artificial wetlands, biological treatment) and the separation of combined sewerage systems.** | **7.2045** | **HIGH** |
| **S** | **Environmental education on water management non-conventional solutions.** | **7.1215** | **HIGH** |
| **I** | Design and installation of an Information, communication and follow-up system to IWM. | **6.2264** | **MEDIUM** |
| **T** | Reduction of consumption through the implementation of water savings technologies. | **6.137** | **MEDIUM** |
| **S** | Training to reduce water contaminating elements. | **6.0448** | **MEDIUM** |
| **I** | Forming of the Tominé Integral Water Management Board. | **5.8254** | **MEDIUM** |
| **I** | Elimination of illegal connections and losses. (2 projects) | **5.5431** | **MEDIUM** |
| **I** | Integral management of solid residues. | **5.3741** | **MEDIUM** |
| **I** | Resolution of Institutional and social conflicts with regard to water. | **5.1465** | **MEDIUM** |
| **S** | Education about the adequate use of water according to its quality. | **5.1132** | **MEDIUM** |
| **I** | Greater control over current and future water concessions. | **4.4066** | **LOW** |
| **I** | Charge per consumption and per type of water use. | **4.2156** | **LOW** |
| **T** | Reduction of the dependency on only one source. | **4.0136** | **LOW** |
| **S** | Investment in prevention to reduce payments of compensatory rates. | **3.9887** | **LOW** |
| **I** | Generation and access to information: supply, demand, concessions according to usage | **3.8042** | **LOW** |
| **I** | Evaluation of the tariff system -fair prices, real costs. | **3.3523** | **LOW** |
| | | **100** | |

On the basis of a maximum of 10 points: the rated alternatives between 10 and 7 points are considered to be of HIGH importance; those rated between 7 and 5 points are considered to be of MEDIUM importance; and those rated between 5 and 3 are classified as LOW in importance. The alternatives that had a classification below 3 were rejected.

Table 8 shows that for the solution to the problems of the Tominé basin, three Technical and one Social alternatives were rated as being of HIGH importance. Of the eight alternatives rated as of MEDIUM importance, five are Institutional, two are Social, and one is Technical. Of the alternatives rated as being of LOW importance: four are Institutional, one is Social and one is Technical. This rating will contribute to

define which are the projects necessary in order that in 30 years time better conditions of the basin are accomplished.

**Strategies**

According to the rating of the alternatives of Table 8, it can be inferred that the strategies that must be implemented in order to reach the future Vision proposed by the actors, have to do with Technical, Social and Institutional issues. Analyzing the sense of each one of the alternatives, in conclusion the three **strategic actions** were choosing for the Tominé Integral Water Management Plan, thus:

1. Appropriate technologies
2. Social strengthening
3. Institutional management

### 5.3 The Integral Water Management Plan in the Tominé Reservoir region

The IWMP directly contributes towards achieving a future vision for the year 2040, agreed to in the community and institutional workshops, that is: to reduce the water demand; create a permanent and equal access to water for the urban and rural inhabitants; to achieve an efficient and sustainable use, to have water of good quality in accordance to the needed use and to generate a better communication between actors.

The IWMP is organized on the basis of the three proposed strategic actions in the previous numeral above. Each strategic issue groups two or three programs of a permanent nature. Each program in its turn groups a series of projects, which were proposed by the community, the institutions or the technical team.

**Objective of the Integral Water Management Plan:** Improve the quantity, quality, equal access and permanent availability of water in the region of the Tominé Reservoir, in the municipalities of Guasca, Guatavita and Sesquilé.

Consistent with the overall objective of the Plan, the strategic actions and Programs have the following objectives (Table 12).

**Table 12: Objectives of the strategic actions and Programs of the IWMP**

| Strategic Issue and Objectives | Programs | Program Objectives |
|---|---|---|
| **Appropriate Technologies** Objective: Improve the supply of water in terms of quantity, quality and availability. | **Improvement of water sources** | Assure a permanent flow of water of good quality for human consumption and for the agricultural and livestock sector. |
| | **Efficient water use technologies** | Increase the supply and facilitate the efficient use of potable and non-potable water for human and agricultural and livestock use. |
| | **Prevention of shortages** | Minimize the rationing of urban and rural drinking water in dry summer seasons. |
| **Social Management** Objective: Generate a more participative social base with a greater sense of responsibility regarding the use and discharges of the water resource. | **Environmental education and training** | Generate a culture of Integral Water Management in the Tominé region. |
| | **Learning alliances** | Maintain a social dynamic that solves its conflicts and learns from the exchange of personal hands on experience and that of others. |

| | | |
|---|---|---|
| **Institutional Strengthening** Objective: Achieve that institutions act efficiently with respect to their function with the water issue. | **Economic instruments** | Achieve a balance between costs and retribution for the provision of aqueduct and sewerage systems services. |
| | **Efficient Management** | Strengthen the institutions related to the IWM, in order that these may efficiently realize their functions with respect to the water issue. |

The IWMP for Tominé (Table 13) is made up of 3 Strategic Actions, 7 programs and 23 projects.

**Table 13: Integral Water Management Plan for Tominé.**

| Strategic Issue | Programs | Projects |
|---|---|---|
| ***1. APPRO-PRIATE TECHNO-LOGIES*** | **Improvement of water sources** | Increase of source conservation and protection areas. |
| | | Reforestation with native species in edge zone and land of the Bogotá Power Company, EEB. |
| | | Integral management of solid residues affecting water bodies. |
| | **Technologies of efficient water usage** | Installation of water low consumption technologies in regional institutional buildings. |
| | | Evaluation of potable water systems in rural zones. |
| | | Evaluation of a wastewater recovery system for agricultural use. |
| | **Prevention of shortages** | Diversification of water sources. |
| | | Rainwater harvesting in a local institution. |
| | | Collection of rain water in rural zones and use in agricultural and livestock activities |
| ***2. SOCIAL STRENG-THENING*** | **Environmental education and training** | Program of environmental education to promote saving and efficient use of water. |
| | | Training in water contamination processes and its prevention. |
| | | Training for officials of institutions in IWM and Environmental Management. |
| | | Training to PWTP, networks and WWTP operators. |
| | **Learning alliances** | Establishment of an Agenda for the management of conflicts between actors involved in the water issue. |
| | | Consolidation of the Integral Water Management Regional Board |
| | | Event for the exchange of successful experiences in IWM. |
| ***3. INSTITU-TIONAL MANAGE-MENT*** | **Economic Instruments** | Evaluation of losses and the design of the tariff system for the implementation of the Charge per consumption and per type of water usage. |
| | | Study of economic stimulus offers for the abandonment of agricultural and livestock activities in the páramo[7] |
| | **Efficient Management** | Inclusion of the issue of climate change in regional planning. |
| | | Elimination of illegal connections and discharges and potable water loss |

[7] (**Páramo** (from the Spanish word for "desolate territory") is a Neotropical ecosystem. It is located in the high elevations, between the upper forest line (about 3000 m altitude) and the permanent snow line (about 5000 m). In the páramo ecosystem bud the water and born the rivers.

| | | |
|---|---|---|
| | | Design and implementation of monitoring indicators and the installation of a follow-up Observatory for the IWM Plan. |
| | | Creation of a regional information System about the water issue. |

### 5.3.1 Implementation Plan

The implementation plan determines the projects with the greatest priority that must be initiated; and those that may be begun at a second stage. In order to define them, each project was rated on the basis of three criteria:

- **PRIORITY**: High, Medium, Low. To be developed in the Implementation Plan.
- **RESULTS**: Short, Medium or Long Term. Stands for the time in which the proposed results for each project may be witnessed. This is different from the duration of the IWM project.
- **EXECUTION**: Immediate, Permanent or Occasional. It means at what moment must the project be implemented. The conditions Immediate and Permanent may arise simultaneously, that is, it is initiated immediately and continues over the course of time. A project is Occasional when it is carried out only once.

The Implementation Plan has three stages (Table 14), the first is made up of 11 Projects considered of a High Priority, which should be initiated simultaneously. The second stage has 8 Medium Priority Projects and the third stage has 4 Low Priority Projects. An overall profile of the Projects is presented in Table 15, with their objective, project description, beneficiaries and participating entities.

**Table 14: Stages of the IWMP Implementation Plan**

| PROJECTS | PRIORITY | RESULTS | EXECUTION |
|---|---|---|---|
| | High, Medium, Low | Short, Medium, Long term | Immediate, Occasional, Permanent |
| **FIRST STAGE** | | | |
| Integral management of solid waste affecting water bodies. | H | S | I |
| Inclusion of the issue of climate change in regional planning. | H | S | I |
| Reforestation with native species in edge zone and land of the Bogotá Power Company, EEB. | H | M | I-P |
| Evaluation of potable water treatment systems in rural zones. | H | M | P |
| Evaluation of a system of wastewater recovery for agricultural use. | H | M | P |
| Rainwater harvesting in a local institution. | H | M | P |
| Collection of rain water in rural zones and use in agricultural and livestock activities. | H | M | P |
| Event for the exchange of successful experiences in IWM. | H | M | O |
| Program of environmental education to promote the saving and efficient use of water. | H | L | I-P |
| Increase of the areas of conservation and protection of water sources. | H | L | P |
| **SECOND STAGE** | **PRIORIDAD** | **RESULTADOS** | **EJECUCIÓN** |
| Training to operators of the WTP, networks and WWTP. | M | S | I |
| Establishment of an Agenda for the management of conflicts between water related actors. | M | S | I |
| Consolidation of the Regional Integral Water Management Board. | M | S | I |
| Installation of water low consumption technologies in institutional buildings in the region. | M | S | P |
| Training to officials of institutions in IWM and Environmental Management. | M | M | I-P |
| Design and implementation of monitoring indicators and the installation of a follow-up Observatory of the IWM Plan. | M | M | P |

| | | | |
|---|---|---|---|
| Training in water contamination and prevention processes. | M | L | I-P |
| Elimination of illegal connections and discharges and the loss of potable water | M | L | P |
| **THIRD STAGE** | **PRIORIDAD** | **RESULTADOS** | **EJECUCIÓN** |
| Study of the economic stimulus for the abandonment of agricultural and livestock activities in the “páramo” zone. | L | S | P |
| Creation of a regional information System dealing with the water issue. | L | M | P |
| Diversification of water sources. | L | M | O |
| Evaluation of losses and the design of a tariff system for the implementation of a fee per consumption and per type of water usage. | L | M | O |

**Table 15. General Profiles of projects of the Integral Water Management Plan in the Tominé Reservoir Region.**

| HIGH PRIORITY PROJECTS | | | | | |
|---|---|---|---|---|---|
| **PROJECT** | **OBJECTIVE** | **DESCRIPTION** | **BENEFICIARIES** | **PARTICIPATING ENTITIES** | **Budget Euros** |
| Integral management of solid waste affecting water bodies. | Eliminate the contamination of water sources, caused by the inadequate management of urban and rural solid waste on the edge zone. | Training in the adequate management of solid waste and the implementation of a model project in the edge zone of the reservoir, including existing social organizations. | Urban and rural community. Tominé Reservoir . | Mayors' Offices, PUPC, NGO, Nautical and recreational clubs | 13.600 |
| Inclusion of the issue of climate change in regional planning. | To begin climate change adaptation processes in the region of the Tominé basin. | To get to know possible effects of climate change in the region, develop the participative environmental agenda of each municipality, to include adaptation actions. | All the basin region | Mayors' Offices, CAR, IDEAM, community, University | 28.600 |
| Reforestation with native species in the edge zone and land of the Bogotá Power Company, EEB. | Increase the production of water and protect the edge zone of the water bodies. | Plant native species and replace the existing conifers. Reforestation in high Andean wooded zones and the recovery of land with conifers that are destined to lose agrologic quality. | Community at large | EEB, CAR, Mayors' Offices and community | 10.000 |
| Evaluation of water treatment systems in rural zones. | Improve the quality of water for rural domestic consumption. | Evaluate the costs of making water for domestic use potable; the development and follow-up of a demonstrative project; comparison with the costs of construction and maintenance of a collective rural potabilization plant. | Users of rural aqueducts | CAR, Mayors' Offices, Rural aqueducts, and rural community | 12.300 |
| Evaluation of a wastewater recovery system for agricultural use. | Improve the disposal of rural domestic discharges and increase the water supply for irrigation. | Design, construction and evaluation of a wastewater recovery system for agricultural use. | Community at large | CAR, Mayors' Offices, Governorship, rural community | 16.000 |
| Rainwater harvesting in a local institution. | Minimize the periods of rationing of water during the dry summer season. | Design, construction, exploitation and monitoring of a rainwater harvesting system in a educational institution or a mayor's Office. | Educational community or public officials community | Mayor's Office, educational institution, EAAB | 25.000 |
| Rainwater harvesting in rural zones and use in agricultural and livestock activities. | Rainwater harvesting in order to reduce the impacts of the dry summer season on flower growing activities. | Design and construction of a rainwater reservoir with biological treatment systems to assure the water quality required in the production process | Flower growing companies | CAR, business owners, University | 28.000 |
| Event for the exchange of successful experiences in IWM. | Apply the concept of Learning Alliances in order to learn from the community, academic, and institutional experiences | Event of a regional character with innovative traditional and non-conventional experiences regarding the management of urban and rural water. | Rural aqueducts, farmers, institutions | All regional actors | 3.500 |

| PROJECT | OBJECTIVE | DESCRIPTION | BENEFICIARIES | PARTICIPA-TING ENTITIES | Budget Euros |
|---|---|---|---|---|---|
| Environmental education program to promote the efficient use of water. | Promote the application of water saving systems. | Design and execution of an environmental education Program to promote the saving and efficient use of water. | Community, Municipal Mayor's Office. | JAC, Community, CAR, Public Utility Services Office of the Mayor's Office, Governorship, University. | 32.000 |
| Increase the areas of conservation and protection of water sources. | Increase the number of hectares in protected areas in order to guarantee the future availability of the hydric resource. | Acquisition of land terrains and the implementation of conservation programs in the zones of river and stream origin sources | EEB, EAAB, Community in general | EAAB, EEB, CAR, Municipal Mayors' Offices, Governorship | 50.000 |

| | MEDIUM PRIORITY PROJECTS | | | | |
|---|---|---|---|---|---|
| **PROJECT** | **OBJECTIVE** | **DESCRIPTION** | **BENEFI-CIARIES** | **PARTICIPATING ENTITIES** | **Budget Euros** |
| Training to operators of the WTP, networks and WWTP. | Develop training and education plans in accordance with the needs of each actor | Consult with training entities for the technical personnel and design environmental education programs | Community and operators of the PWTP, networks, and WWTP. | SENA, JAA, CAR, Community | 4.600 |
| Establishment of an Agenda for the management of conflicts between water issue related actors. | Resolve conflicts generated by the supply, use and availability of water, generating fairness, respect and social justice. | Bring about the establishment of spaces for the exchange of needs, solutions and agreements that allow solving conflicts in an environment of mutual respect. | Institutions, technical operators and Community | Municipal Mayor's Office, JAA, JAC, Community | 3.100 |
| Consolidation of the Regional Integral Water Management Board | Strengthen decision making for water management, in a coordinated and agreed upon manner on the basis of bona fide available information, and with all involved actors. | Generate a space for decision making at the institutional level, which allows the undertaking of coordinated and agreed upon actions. Detection and mitigation of conflicts between actors. | Community at large | EEB, Community, SSC, CAR, Municipal Mayors' Offices, JAA and SSP | 8.200 |
| Installation of water low consumption technologies in regional institutional buildings. | Installation and use of innovative water saving devices avoiding the waste of the water resource in daily activities. | Purchase, distribution and adequate use of water saving devices in the home and in every type of agricultural and livestock activities. | Community at large, WWTP Operators | Municipal Mayors' Offices, Governorship | 10.000 |
| Training to officials of institutions in IWM and Environmental Management | Jointly develop a regional vision and unify criteria of action regarding Integral water management. | Clarification of concepts, functions and institutional responsibilities. Exchange of regional information. Agreements to define joint and individual actions by participating institutions. | Regional and Local Institutions participating in the IWM Board | All participants in the Regional IWM Board | 15.400 |

| PROJECT | OBJECTIVE | DESCRIPTION | BENEFICIARIES | PARTICIPATING ENTITIES | Budget Euros |
|---|---|---|---|---|---|
| Design and implement monitoring indicators and the installation of a follow-up Observatory for the IWM Plan. | Carry out a participative follow-up to the implementation of the Integral Water Management Plan in the region of the Tominé reservoir. Socialization of regional information. | Concerted definition of follow-up indicators to the implementation of the IWMP; the creation of the on-line Observatory to consult information and follow-up to the IWMP. | Mayors' Offices, EAAB, EMGESA, CAR, CORPOGUAVIO, community. | All participants of the Regional IWM Board | 42.300 |
| Training in water contamination and prevention processes. | Training to the community in the prevention of water contamination. | Inform the community about aspects related to health and environmental risks due to the use and management of potentially toxic chemical substances. This requires to include GAP (Good Agricultural Practices) and the delimiting of safety strips. | Community, CAR. | JAA, Community, Municipal Mayor's Office, (UMATA or the entity acting as such), SENA, CAR, SSC, | 4.600 |
| Elimination of illegal connections and discharges and the loss of potable water | Reduce loss due to non-quantifiable consumption. | Identify and quantify the illegal connections, at the same time developing a legalization and control plan for them. | Community at large | Municipal Mayors' Offices, Public Utility Services Offices | 53.800 |

## 6. CONCLUSIONS

**Conclusions:**

6.1 The current water management in the region requires revision, because in dry season, the three municipalities have scarcity. The cost of treating drinking water and wastewater is higher than income, and the financial deficit is covering by each municipality. Both the institutions and citizens have willingness to change to achieve an efficient water management and have great interest in applying technologies such as those developed in SWITCH project.

6.2 A joint vision of the situation of the basin for the year 2040 was established with the basin actors, in which: the urban and rural water available per person will be increased; there will be an equal and permanent access to water, the quality of the water of the reservoir will improve, and the community will contribute with the efficient and sustainable use of the water resource.

6.3 The Integral Water Management Plan was developed in a participative manner. The three strategic actions are consolidated in it: 1) Utilize appropriate technologies for the Integral Water Management, which improve the water sources, offer technologies for the efficient use of water, and generate actions to prevent shortages; 2) Strengthen the social processes through Citizen Education and Training programs; and 3) Strengthen the institutions of the region so that these may improve their management of the water resource.

6.4. The implementation Plan defined three phases of implementation, in the short, medium and long term in accordance with the priorities of the proposed projects in order to accomplish the Integral Water Management in the basin of the Tominé Reservoir.

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**Abbreviations**

| | |
|---|---|
| MAVDT | Ministerio de Ambiente, Vivienda y Desarrollo Territorial, Colombia. (Ministry of the Environment, Housing and Territorial Development) |
| CAR | Corporación Ambiental Regional (regional autonomous corporation). Autoridad Ambiental regional (regional environmental authority) Cundinamarca. |
| CORPOGUAVIO | Autoridad Ambiental (environmental authority for the region) para la región del Guavio. |
| EPSP | Empresa Prestadora de Servicios Públicos. (public utility company) |
| EAAB | Empresa de Acueducto y Alcantarillado de Bogotá. (Bogotá aqueduct and sewerage system company) |
| EEB | Empresa de Energía de Bogotá. (Bogotá power company) |
| JICA | Japan International Cooperation Agency. |
| EMGESA | Empresa Generadora de Energía S.A. (power company) |
| IDEA | Instituto de Estudios Ambientales de la Universidad Nacional. (Institute of environmental studies) |
| IWM | Integral Water Management. |
| SENA | Servicio Nacional de Aprendizaje, institución de educación tecnológica del Estado. (National Learning Service, State institution of technical education) |
| SSC | Secretaría de Salud de Cundinamarca. (Health secretary office of Cundinamarca) |
| JAA | Juntas de Acción Comunal. (Community local action boards) |
| PWTP | Potable Water Treatment Plant |
| WWTP | Wastewater Treatment Olant |
| EOT | Esquema de Ordenamiento Territorial (Scheme Land use planning smaller municipality) |
| POT | Plan de Ordenamiento Territorial (Land use planning) |
| IDEAM | Instituto de Hidrología, Meteorología y Estudios Ambientales |
| DANE | Departamento Nacional de Estadística. |